

Tropical Managed Ecosystems

Summer 1993



Study Sites

Palo Verde

Central Valley

La Selva

Boscosa

Las Cruces

Organization for
Tropical
Studies

EDITED BY UPTON HATCH

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Anthropological Entomology	Jeff Bentley
Soils of Costa Rica	F. Bertsch
Acid Rain	Dr. Bruck
Integrated Pest Managememnt	Hernàn Camacho
A Case Study of an IPM Project	Hernàn Camacho
Fundecor	Froylan Casteneda
Photosynthesis and Growth of Understory Plants in Response to Light Variation	Robin Chazdon
An Introduction to Aquaculture	Bill Deutsch
Water Quality	Bill Deutsch
Aquatic Ecology in the Context of Tropical Managed Ecosystems	Bill Deutsch
Organic Farming	Luis Eladio
The History of Agricultural Development	L. Fournier
Biotic Units	Luiz Diego Gomez
Production Economics	Upton Hatch
A Round Table Discussion on Sustainability	Upton Hatch
Resource and Environmental Economics	Upton Hatch
Introduction to Boscosa	Jose Joaquin Campos
Geography of Costa Rica	Oscar Lucke
Mammals of Palo Verde - Especially Opossum (<i>Didelphis Virginiana</i>)	Monica Marquez
Banana Plantations	Alex Martínez
Proyecto de Desarrollo Rural Integrado Osa-Golfito	Ana Mesa

History of Conservation in Costa Rica	Julian Monge
Fungi	Greg Mueller
Body Condition Score in Dairy Cows	Wayne Odegard
Sustainability of Dairy Farming in the Tropics	Wayne Odegard
An Introduction to Portico	Rudolfo Peralta
Water Quality/Drinking Water	Cathy Pringle
Functions of Biological Corridors	Jaime Rau
National Parks of Costa Rica	Jose Maria Rodriguez
Costa Rican National Parks	Jose Maria Rodriguez
Dairy Industry of Costa Rica	Augusto Rojas
Introduction to Coto Brus	Martha Rosemeyer
The Frijol Tapado System	Martha Rosemeyer, Darryl Cole, and Ken Slater
Inbio	Elvira Sancho
Organic Agriculture	Shogo Sasaki
Forest Growth Simulation	Lloyd Simpson
High Altitude Ecology	Carlos Valerio
Life Zones of Costa Rica	Carlos Valerio
Reproduction Strategies of Araceae	Carlos Valerio
Pasture Ecology and Management	Edzard Van Santen
Research Methods in Agronomy	Edzard Van Santen
Integrated Pest Management	Mike Williams

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**OTS SCHEDULE
SUMMER, 1993
COSTA RICA
Valerio, Hatch and Soto
July 20 - August 12, 1993**

Date	Place	Activity	Leader/Comment
6/20	USA - San Jose	Class participants arrive	
6/21	San Jose	6:45 bus leaves Galilea for OTS	
		7:00 Intro Meeting and Breakfast	
		7:30 Intro to Costa Rica (Valerio)	
		9:00 concurrent tasks	
		(1) Logistics for students (passports, tickets, money, etc. - Anna Carter)	
		(2) box assignment	
		(3) PC tutorial (small groups)	
		format for book, WP, HG, Lotus, MSTAT-C	
		12:00 lunch (across street from OTS)	
		1:00 PC tutorial	continue as needed
		1:30 leave OTS for UCR - CIA	Alvarado
		2:00 tour of UCR - Centro Investigaciones Agronomicos	
		3:00 soils of Costa Rica	Bertsch
		4:00 history of agricultural development in Costa Rica	Fournier
		5:30 leave for Hotel Galilea	
		7:30 Welcome dinner	Cuartel de la Boca del Monte
6/22	San Jose	7:30 leave hotel for CIA	Monge
		8:00 history of conservation	
		9:00 introduction to geography of Costa Rica	Luke
		10:00 Serpentarium	
		12:00 lunch	
		2:00 depart from hotel for Palo Verde	

MODULE 1

	Palo Verde	6:00	arrive in Palo Verde	
		8:00	introduction to Palo Verde	Rodriguez & Castro
		9:00	course objectives and expectations	Valerio, Soto, and Hatch
6/23	Palo Verde	7:00	park tour and interviews with park personnel Bagatzi, laguna, limestone hills	
		2:00	life zones of Costa Rica	Valerio
		3:00	Costa Rica National Parks	Rodriguez
		7:00	Overview of Aquatic Ecology	Deutsch
		8:00	chemistry involved in water quality testing	Deutsch
6/24	Palo Verde	7:00	river tour Barra Honda (small scale eco-tourism) Rookery (bird diversity)	
		2:00	return from boat tour	
		3:00	water chemical analysis	Deutsch
		7:00	ecotourism	Barboza
		8:00	area de Conservacion Tempisque	Castro
		9:00	explanation of field problems	
		(1)	ecotourism (Barra Honda - Arenal) (Barbosa - Valerio),	
		(2)	farming systems (Castro, Hatch, & Soto),	
		(3)	water quality (Deutsch)	
6/25	Palo Verde (Canas)	7:00	depart Palo Verde for Canas	
		9:00	visit SENARA overview of project (at office)	
		11:00	tour irrigation area, fish ponds, and IDA plots	
		12:00	lunch	
		3:00	return from SENARA	
		4:00	continue field problems	

		7:00	mammals of Palo Verde (especially Marquez possum)	
6/26	Palo Verde	7:00	continue field problem data collection	
		4:00	field problem analysis continued	
		7:00	student presentations (2)	
6/27	Palo Verde	7:00	depart Palo Verde	
		1:00	arrive Arenal observatory	
		3:00	introduction to Arenal	Valerio
		7:00	overview of aquaculture	Deutsch
6/28	Arenal	7:00	field problems	
		4:00	return to observatory	
		7:00	student presentations (2)	
6/29	Arenal	8:00	tour of volcano ecological succession in volcanic lava flows	Vanderlatt
		3:00	return to observatory	
		4:00	data analysis and report writing	
		7:00	student presentations (2)	
		8:00	complete field problem reports	
6/30	Arenal	8:00	field problem presentations	
		2:00	depart Arenal	
		3:00	geothermal bath (optional)	

MODULE 2

	Central Valley	7:00	arrive Central Valley (ICAES)	
7/1	Central Valley	7:00	IPM in the control of fruit flies	Camacho
		8:00	effect of fruit fly on food production in Costa Rica	

		9:00	Research results of IPM project in Costa Rica	
		1:00	visit to fruit fly control lab	Camacho
		3:00	visit Entomology Museum at UCR	
		5:00	return to ICAES	
		7:00	economic evaluation of alternative agricultural systems	Hatch
7/2	Central Valley	7:00	leave ICAES for Acosta for male sterile fruit fly release	Camacho and Williams
		5:30	return from field	
		7:00	insect bio-diversity in farming systems	Williams
		8:00	orientation to field problems	
7/3	Central Valley	7:00	visit to Zarcero	Williams
		(1)	compare organic to conventional vegetable farming systems	
		(2)	field technique demonstration - insect diversity and sampling techniques	
		5:00	energy budgeting for agricultural systems	Vasquez
		7:00	sustainability of dairy production in the tropics	Odegard
7/4	Central Valley		readings and discussion cook-out prepared by class	
		7:00	body scoring of dairy cows	Odegard
		8:00	orientation to field problem on sustainability	
7/5	Central Valley	7:00	tour of agricultural cropping systems (dairy station and coffee farms)	
		(1)	coffee (organic vs. conventional)	
		(2)	dairy (UCR dairy research station)	
		7:00	selection of field problem area (system and sustainability criteria)	
		(1)	criteria - insect diversity, economics, energy, and soils	
		(2)	system - coffee, vegetables, and dairy	
7/6	Central Valley	7:00	field data collection return to selected farms for more detailed data for field problem	

		1:00	visit National Biodiversity Institute (INBIO)	
		7:00	discussion: private vs. public control of bio-diversity - North South debate - Rio conference	Vasquez
7/7	Central Valley	7:00	field data collection and field problem write-up	
		7:00	student presentations (2)	
7/8	Central Valley	7:00	visit CATIE	
		7:00	biological corridors	Barbarak
7/9	Central Valley	7:00	complete field problems	
		7:00	field problem presentations - round table on sustainability	Hatch
7/10	Central Valley - Jaco	8:00	travel to Jaco	
		10:00	arrive Jaco - beach R & R	
7/11		1:00	depart Jaco	

MODULE 3

7/11		5:00	arrive La Selva	
		7:00	introduction to station	Deborah Clark
	La Selva	8:00	mixer with researchers at La Selva	
7/12	La Selva	7:00	orientation walks forest native species trails project agro-ecosystems experiment	
		1:00	group 1: ALAS group 2: GIS demonstration	Godoy Castro
		3:00	reforestation (La Guaria)	Gonzalez
		7:00	student presentation (1)	
7/13	La Selva	6:30	Portico visit	Simpson and Peralta
		7:00	overview of forest growth simulation model	Simpson

7/14	La Selva	8:00	water quality and local drinking water	Pringle
		8:00	model demonstration	Simpson
		10:00	group exercises - model simulations	
		2:00	free time to explore library, La Selva trails and contact researchers	
		4:00	pasture management and ecology	van Santen
		5:00	aroids	Valerio
		7:00	student presentations (2)	
		8:00	orientation to field problem	
7/15	La Selva	8:30	acid rain and forest degradation (optional)	Bruck
		7:00	field trips banana plantation and La Flaminea peasant settlement	Gonzalez
		12:00	lunch at La Selva	
		1:30	MUSA medicinal herbs, Pejibaye plantation, La Rambla forage parcel	Gonzalez
		7:00	video and lecture on conservation impacts of banana plantation expansion	Martinez
7/16	La Selva	8:00	field problem planning	
		7:00	field problems water quality (Pringle and R. Vargas), alternative forages (van Santen), environmental awareness survey (Bentley), arthropod populations (Valerio), use of native plants (O. Vargas)	
		7:00	FUNDECOR	Castaneda
		8:00	anthropological entomology	Bentley
		8:00	complete field problem analysis (from previous day)	
7/17	La Selva	3:00	field problem reports	
		7:00	feeding habits and population ecology of the Collared Peccary (optional)	Torrealba
7/18	La Selva	7:00	independent field problem	
		7:00	research methods in agronomy	van Santen

7/19	La Selva	7:00	independent field problem	Chazdon
		5:00	plant response to light (optional)	
		7:00	student presentations (2)	
7/20	La Selva	8:00	complete field reports	Schubert
		5:00	genetic defensive mechanisms in plants (optional)	
		7:00	forest ecology	
7/21	La Selva - San Jose	7:00	presentation of independent field problem	David Clark
		1:00	depart for San Jose	
		2:30	OTS - Anna Carter	
		4:00	check in at Galilea Hotel	
7/22	San Jose - Cerro de la Muerte	7:00	depart San Jose	Valverde
		8:00	blackberry plantation	
		11:00	blackberry cooperative	
		2:00	arrive Cuerici (late lunch) conservation and reforestation orientation talks	
		7:00	high altitude ecology	
		8:00	student presentations (2)	
7/23	Cerro de la Muerte	7:00	visit to CATIE forest management research and demonstration project	Campos
		1:00	introduction to Boscosa	
		2:00	field exercise	
		7:00	student presentations (2)	
7/24		8:00	field exercise presentations	Don Quincho
		7:00	depart Cerro de la Muerte	
		10:00	walk in Paramo	
		12:00	lunch at PINDECO	
		1:00	PINDECO tour	
		4:00	alternative land uses	
		6:00	arrive Boscosa	

MODULE 4

7/24		7:00	arrive Boscosa	
	Boscosa	8:00	introductory talk on Boscosa project	Jimenez
7/25	Boscosa	7:00	Corcovado National Park orientation walks	
		7:00	pollination	Valerio
		8:00	orientation to field problems	
		(1)	ADESCAB (Soto)	
		(2)	forest regeneration	
		(3)	alternative crops - Guanabana (Hatch)	
		(4)	insect-plant-fungi mutualism (Valerio)	
		(5)	tree identification key (Aguilar)	
7/26	Boscosa	7:00	field problems	
		12:00	lunch at Boscosa	
		7:00	Boscosa biodiversity	Aguilar
		8:00	student presentations (2)	
7/27	Boscosa	7:00	field problems	
		5:00	environmental education	Martinez
		7:00	mixer with Boscosa staff	
7/28		6:00	depart Boscosa	
		8:30	Palma Tica plantation tour pollination, bio- control, bio-technology	
	Golfito	5:00	arrive Golfito	
		7:00	field problem presentations	
7/29	Golfito	7:00	tour of mangrove	
		5:00	student presentation	
		7:00	integrated rural development	Mesa
7/30	Golfito	7:00	tour of Cooperative	
		1:00	depart Golfito	

MODULE 5

		3:00	arrive Las Cruces	
		7:00	introduction to Coto Brus	Rosemeyer
7/31	Golfito - Las Cruces	7:00	local tour agroecology and conservation biology	Gomez and Rosemeyer
		7:00	biotic units	Gomez
8/1	Las Cruces	7:00	local tour conservation biology Botanical garden Agroecology	Rosemeyer Gomez
		5:00	biological corridors in Costa Rica	Rao
		7:00	orientation to field problems	
8/2	Las Cruces	7:00	directed field problems (1) agro-forestry (Rosemeyer), (2) participatory rural appraisal (Villalobos) (3) fungi-beetle mutualism (Gomez) (4) home gardens (Hatch and Soto)	
		7:00	organic farming	Sasaki
8/3	Las Cruces	7:00	complete directed field problem	
		8:00	organic farming workshop (optional)	Sasaki
		4:00	buffer zone management of Parque Amistad	Gamboa
		7:00	field problem presentations	
8/4	Las Cruces	8:00	independent field problem	
		7:00	introduction to Cycads and Wilson Gardens (optional)	Hewson
8/5	Las Cruces		independent field problems	
		5:00	student presentations (2)	
		7:00	soil chemistry and Frijol Tapado	Rosemeyer and Schlather
8/6	Las Cruces		independent field problems	
		5:00	natural resource and environmental economics	Hatch
		7:00	student presentations (2)	

8/7	Las Cruces		independent field problems	
8/8	Las Cruces		independent field problems	
8/9	Las Cruces		write-up of independent study	
		7:00	independent field problem presentations	
8/10	Las Cruces	8:00	independent field problem presentations	
		5:00	OTS program	Bennett
		7:00	effect of plant neighborhood on pollination, herbivory and reproduction of Costa Rican native epiphytes	Carpenter
8/11	Las Cruces		write-up	
8/12	Las Cruces - San Jose		travel to San Jose	
		7:00	farewell dinner	
8/13	San Jose - U. S.		travel to U. S.	

COURSE OVERVIEW

The goal of the course is to assist the participant's ability to identify problems, to appreciate the underlying relationships between natural and agroecosystems, to learn new research techniques, and to synthesize disparate information and potential methods into viable research questions. Complex interactions of humans within the natural system often require multidisciplinary approaches. The backgrounds of course participants and faculty are diverse and should lead to multidisciplinary insights that would not be evident without such interdisciplinary interaction.

Course material is organized into modules around themes with educational objectives. However, logistical constraints sometimes means that course material will not always fit into neat, logical steps. We must operate within the realities of the available funds, sites and personnel. Nonetheless, lectures and field problems are targeted toward the focus of the module. At the end of each module, time for synthesis of lectures, field problems, presentations, and discussions will be provided.

Module 1 - CONFLICT OVER RESOURCE USE - HUMAN NEEDS vs. ENVIRONMENTAL CONSTRAINTS Palo Verde and Arenal, June 22 - 30

At our first two sites - Palo Verde Biological Station and Lake Arenal, the course will commence by identifying the problems associated with natural resource use in a Guanacaste watershed. The Arenal water, originally flowing to the rainy Atlantic lowlands, has been diverted to the dry Pacific. The SENARA project has dammed the Arenal River, producing a lake which provides hydroelectric power, irrigation water and tourism. What are the environmental and social costs of the project? For example, water quality may be degraded by various agricultural and other human activities. How is this public resource affected? How will potential land use changes (expanding farming systems, ecotourism, and aquaculture) affect water quality?

Module 2 - DEFINITION AND MEASUREMENT OF "SUSTAINABILITY" Central Valley, June 30 - July 10 Cerro del Muerte, July 22 - 24

Sustainability has been defined in various ways with correspondingly different measures. During our time in the Central Valley, we will measure indicators of sustainability in conventional and alternative agricultural systems. Of particular importance will be the comparisons of various conventional (high external input) and organic systems in terms of energy use, economic viability, affect on biodiversity, and soil factors. What are the economic incentives affecting farmer decisions in system selection? What is the impact of the systems on biological diversity, e.g., as measured by insect populations? How sustainable are the systems in terms of maintaining the soil fertility

and dependence on imported inputs, such as energy? We will also visit various projects demonstrating alternative production methods in the Central Valley and CATIE.

The environmental constraints of high elevation areas and how these affect economically and environmentally sound development will be the focus at Cerro del Muerte. High altitude restoration of animal and plant populations will also be examined, e.g., quetzales and oaks.

Module 3 - RESEARCH METHODS IN AGROECOLOGY AND CONSERVATION BIOLOGY La Selva, July 11 - 21

At the OTS La Selva Biological Research Station, improvement in participant's awareness of research techniques will be the focus. An unique opportunity to interact with tropical researchers will be provided. Social science survey techniques, agronomic and ecological research methods, and economic evaluation techniques will be complemented by the diverse array of research projects underway at the station. Specifically we will work with tropical tree growth modeling and natural forest regeneration as well as agroecosystem design. The sustainable management of tropical forests by the private sector will be compared with management by a non-governmental organization (NGO) in the next module.

Module 4 - INSTITUTIONAL ROLE IN SUSTAINABLE DEVELOPMENT AND CONSERVATION Boscosa and Golfito, July 24 - 30

The role of the multinational company in development will be examined through visits to Palma Tica (African oil palm for edible oil), Ston Forestal (Stone Container Corp., Gmelina wood for exported chips) and PINDECO (pineapple for export) in the south zone. A visit to BOSCOA will focus on the NGO community-based alternative to sustainable forest management. An integrated rural development project will also be visited. Discussion will focus on which method(s) provides a more viable sustainable development alternative.

Module 5 - INDEPENDENT RESEARCH SURROUNDING THE CASE STUDY OF A BIOLOGICAL CORRIDOR San Vito, July 30 - August 12

A proposed biological corridor links the forest reserve of Las Cruces Biological Station (Wilson Botanical Garden) with larger tracts of land such as the Guaymi Indian Reserve and Corcovado National Park of the Osa Peninsula. Students can develop research projects to address questions in corridor biology as preliminary studies required for the initiation of the project. We will visit research projects in the San Vito area which may provide potential solutions for degraded areas within the corridor or buffer zone areas, e.g., the slash mulch system and reforestation of pastures with native tree species.

**PALO VERDE -
ARENAL**

COSTA RICA

Guided Field Problem

WATER QUALITY ASSESSMENT IN PALO VERDE-ARENAL WATERSHEDS, COSTA RICA

Authors: Ellen Pedersen, Jagdish Krishnaswamy, Lucy Buchan, Nabiha Megateli,
Laura Howard, Jeff Zimpfer, Pantaleo Munishi, and Pamela Stedman
Faculty: Bill Deutsch

Resumen

Se realizaron análisis de agua en dos sitios de la provincia de Guanacaste, Costa Rica. El primer sitio comprende los humedales de Palo Verde y ríos y arroyos adyacentes. El segundo sitio comprende la cuenca del Arenal Norte. Los parámetros evaluados: oxígeno disuelto, pH, alcalinidad, dureza y turbidez fueron medidos utilizando el analizador portátil LaMotte Chemical Company. Los indicadores biológicos fueron clasificados de acuerdo al método de Deutsch y Hilsenhoff. Los humedales de Palo Verde mostraron variaciones diurnas en las concentraciones de oxígeno disuelto y pH. La cuenca del Arenal mostró aumentos en el pH, alcalinidad y dureza, correlacionados con una disminución en altitud.

Abstract

Water quality analysis was conducted at two sites in the Guanacaste Province of Costa Rica. The first site included the Palo Verde marsh and surrounding streams. The second site focused on the Arenal North watershed. The water quality parameters of dissolved oxygen, pH, alkalinity, hardness, and turbidity were measured according to the LaMotte Chemical Company kit. The biological indicators were classified according to the Deutsch and Hilsenhoff protocols. The Palo Verde marsh exhibited a diel fluctuation of dissolved oxygen and pH. The Arenal North watershed showed an increase in pH, alkalinity, and hardness correlated with a decline in elevation of the watershed.

Introduction

This field study, conducted at Palo Verde and Arenal, measured various water quality parameters. In general, water quality trends are critical to understanding the characteristics and the dynamics of any watershed. In order to understand the importance and applicability of various water quality tests, two distinctive water systems were studied. First, a marsh in a relatively dry region of Costa Rica and second, the upper end of a watershed originating in an area of volcanic activity. Two major factors affecting water quality were explored. At Palo Verde we focused on diel patterns influenced by photosynthetic macrophytes and at Arenal the focus was on patterns due to geological, atmospheric, and organic influences. Our report summarizes our initial findings and lists recommendations for future water quality testing projects.

Palo Verde

Site Description

Palo Verde National Park is located in northwestern Costa Rica, province of Guanacaste, approximately 20 kilometers south of Abangares, between the Bebedero and Tempisque rivers, near the area where the Tempisque river flows into the Gulf of Nicoya. The Park covers 20,000 hectares, and comprises 60% of the Tempisque Conservation Area. The annual temperature averages above 24°C and the annual precipitation is estimated between 1,000 and 1,500 mm. Tropical dry forest is characteristic of this area.

This site was chosen for a water quality field project due to the potential impacts of the Arenal-Tempisque irrigation project on the Park lowlands, especially its wetlands. The zone of influence of the irrigation project is approximately 140,000 ha, with potential direct impact on hydrology and water quality in the Park.

Both soil and its parent material significantly influence surface and groundwater quality, especially in young geological systems as in the area of concern. The two geological formations represented in the park are: 1) recent alluvial and marine sediments, and 2) mesozoic volcanic and sedimentary rocks that include poorly weathered siliceous limestone. These latter formations are represented mainly in the limestone hills that drain into the marsh.

The main soil types that have evolved in the park area are: 1) the udolls, ustolls and tropepts, which are well drained, deep, dark, friable soils with medium texture, and 2) aquents, which are very poorly drained, dark-colored, heavy textured and hydromorphic soils. The water table reaches the surface seasonally.

The colluvial mosaic of alluvial outwashes from the volcanos to the east, basic runoff from the limestone ridges, silt and salts from tidal floods influences the chemistry of soil water and soils. These soils are generally rich in cations and the pH is slightly acidic to neutral. Since most of the soils are young and weakly developed, they experience constant deposition and weathering of soil material.

Water Quality

Surface and groundwater quality in Palo Verde are influenced by parent geologic material and soils, as well the inputs from tidal floods and the natural vegetation. The gradual weathering of parent rock material directly contributes elements to the runoff and sub-surface water flow. Relative to hard, igneous rock, lacustrine, sedimentary rock is easily weathered and more soluble. Weathering produces leachate that is high in dissolved ions, and frequently hard, rich in calcium and magnesium salts.

Rainwater is the predominant weathering agent at Palo Verde. It is naturally acidic, mainly due to dissolved gases, but it also contains ions carried from sea-spray. Root respiration of vegetation on the limestone ridges also contributes to the weathering process by creating carbonic acids that release basic cations from the parent material.

Hypothesis and Methods

The first area in which we carried out water quality testing was the Palo Verde Marsh. Water from the marsh was tested at intervals over a 48-hour period to examine patterns in the parameters tested. Our hypothesis was that the parameters would follow the pattern frequently found in water bodies, which includes increases in dissolved oxygen and pH during the day, and decreases during the night.

During the day, photosynthesis is at its highest rate. Photosynthesis releases oxygen, thus increasing the amount of oxygen in the marsh. During the night, respiration releases carbon dioxide gas, which combines with water, forming weak carbonic acid. This acid lowers the pH of the marsh during the night. The opposite is the case during the day, causing an increase in pH.

Results and Interpretation

The data collected support our hypothesis, as can be seen from the figures at the end of this chapter. Dissolved oxygen and pH increase during the day and then decrease during the night. Both the amount of oxygen and pH dropped during night time (1600 - 0700 hrs) for the whole period of assessment (24 - 26 June 1993), while there was an increase during the day. Dissolved oxygen reached a low of less than 1 in the very early morning, and a high of more than 7 in the late afternoon. pH reached a low of 7 in the early morning and a high of 8.5 in the afternoon. (The daily cycle can be clearly seen in Figure 1.) This is explained by oxygen consumption through respiration and absence of photosynthesis to release oxygen during the night. Heavy concentrations of plants in the marsh contribute to the steepness of the increases and decreases.

The percent of oxygen saturation in the marsh follows the same trend as dissolved oxygen, with decreases and increases during the night and day, respectively (Figure 2).

The photosynthetic activity influences the diurnal variation in pH (Figure 3). When plants are consuming the dissolved carbon dioxide as photosynthetic activity increases with increasing availability of sunlight, the pH increases since the concentration of carbonic acid decreases in the marsh water. The net consumption of carbon dioxide is due to the higher rate of photosynthesis over respiration during periods of light availability. This is reversed in the night when only plant respiration is taking place and carbon dioxide is added to the water.

Figure 4 shows the results of pH and the hardness of the marsh water in Palo Verde. The pH varied from 6.5 to 8.5 throughout the day. It started out with a pH of 8.5 at 4:00 p.m. and declined to 6.5 pH at 7:00 a.m. Then it increased slightly and ended with 7.0 pH at 9:00 p.m. The hardness of the marsh water can also be seen increasing throughout the day.

Arenal

Site Description

The second area of water quality testing was also located in the Guanacaste province. Surface waters were sampled at various positions in a subwatershed of the Arenal watershed, Arenal North. Sample points within this subwatershed included a crater lake at Cerro Chato, groundwater inlets, streams above and below Arenal Volcano, and Lake Arenal, see Map 1.

The natural vegetation in the area is a mixture of primary and secondary forest. The forests were disturbed by natural influences such as volcanic eruptions and human influences, including the construction of dams and reservoirs, and the subsequent flooding of vegetated areas.

The geology in the area of Arenal sampled is primarily composed of volcanic basalt and conglomerates with high silica content. A general chemical description of the bedrock can be found in Table 1.

Soils derived from the volcanic bedrock are classified as typic hydrandepts. These soils, predominantly composed of allophane clays, have a high capacity to retain soil moisture without creating waterlogged conditions. They contain high levels of organic matter (>5%) in the surface horizons, which decreases with depth in the profile as pH increases. pH fluctuates between 4.5 and 6.6, depending on the chemical content of the precipitation. Both the surface and subsoils have low cation exchange capacity. Base saturation is moderate, and the amount of available phosphorous and potassium are relatively low.

We believed that the volcanic activity in Arenal North would strongly influence watershed characteristics. Specifically, we hypothesized that pH, alkalinity, and hardness would progressively increase as water moved further down the watershed.

Methods

The water quality testing utilized six parameters: dissolved oxygen, total alkalinity, pH, total hardness, and temperature. These physical and chemical properties were measured as per the instructions of the LaMotte Chemical Company water quality test kit.

Water sampling points included rain water (at Arenal Observatory), a crater lake (Cerro Chato), three groundwater inlets, a stream at the foot of Arenal Volcano and several streams located below the Observatory but above Lake Arenal. A depth profile was compiled for Lake Arenal, however, only the surface sample was used for water quality analysis in the subwatershed (See Map 1 for a spatial site description).

Rock and soil analysis involved collecting rock and soil above the upper stream. The rock was crushed and mixed with stream water in a two to one solution. The same process was followed for the soil sample analysis. Subsequent tests analyzed pH, alkalinity, and hardness according to the LaMott Chemical Company water quality test kit.

Results

In general, the pH trend followed an increasing gradient down the watershed. Figure 7 illustrates the increasing pH trend. The lowest pH sample was found in rainwater (pH 4), whereas the highest pH was found in Lake Arenal (pH 8.2). The water sources successively lower in the watershed generally increased in pH. The Cerro Chato water was pH 6.3, the groundwater inlets were between pH 7 - 7.2, and the streams lower in the watershed were between pH 7.3 - 7.8.

Figure 5 shows alkalinity (ppm CaCO_3) increasing down the Arenal Watershed. Highest in the watershed, rainwater and Cerro Chato exhibited the lowest alkalinities of 5 and 10, respectively. The groundwater inlets measured between 35 - 40, whereas the stream systems ranged from 25 at the waterfall, to 50 at the foot of Arenal Volcano. At the bottom of the watershed, the lake measured 40.

Figure 6 shows hardness (ppm CaCO_3) increased progressively down the watershed, although the trend remains unclear. Starting with rainwater and Cerro Chato, hardness was 0, however, the groundwater inlets showed a high degree of hardness of 50. The streams located progressively further down the watershed fluctuated between 30 and 50 until reaching the lake where hardness measured 50.

The results of the rock analysis indicated that volcanic bedrock was extremely acidic, having a pH of 3 and no measurable alkalinity. The soil had a pH of 7.3 and the alkalinity measured 35 ppm CaCO_3 (Table 2).

Discussion

The fact that our results corroborated with our hypothesis can be explained by several factors related to local geology, soils, climate, and volcanic activity. The volcanic gases emitted at Arenal included sulphur dioxide, sulphur monoxide, hydrochloric acid and several others that can be expected to contribute to the acidity of water in the area.

The analyses of pH, alkalinity, and hardness, of soil bedrock and rainwater suggest that acidity from both rainwater, airborne volcanic material, and bedrock are responsible for leaching ions from soils. The following discussion of this dynamic provides a model to explain the results of stream analyses in the subwatershed that illustrated successively increasing levels of pH, alkalinity, and hardness at lower sample points.

pH

Volcanic gases are acidic, containing sulfur oxides and hydrogen sulfide, which caused the pH of rainwater to drop below its normal of between pH 5-6. As the rain water falls on the watershed and passes through it, it gets neutralized by the base cations in the soil, parent rock and volcanic ash, reaching a pH slightly above 7. The pH increases further as more base cations dissolve. The trend observed may also reflect the decreasing effect of volcanic outfall as the water moves through the watershed and into the lake.

The isolated Cerro Chato volcanic lake has a slightly acidic pH (6.3), indicating that it is probably rain fed or has a very small watershed. These factors limit the amount of interaction of precipitation with any base rich material.

The processes influencing water quality in the Arenal North subwatershed are similar to those discussed for the Palo Verde site. Rainwater is the predominant weathering agent, leaching parent geologic material, and soils, but in addition, particulate and gaseous matter are produced by volcanic eruptions. Root respiration also contributes to the weathering process through the creation of carbonic acids.

Alkalinity

Alkalinity measured in the Arenal watershed is described by a gradient that increases from the top end of the watershed to Lake Arenal. As rainwater is converted to streamwater, alkalinity increases. The water in Lake Arenal seems to concentrate alkalinity from its watershed further. This increase in alkalinity may be attributed to the addition of bicarbonate ions to the rain water as it infiltrates into the soil and percolates. The bicarbonate owes its origin to the carbon dioxide that dissolves in the water in the soil. This carbon dioxide is released by respiring roots of the forest vegetation and the decomposition of the soil organic matter. At the pH levels found in the soil water (between 7 and 8), the dissolved carbon dioxide is converted mostly into bicarbonate ions.

The low alkalinity of Cerro Chato lake water is probably due to the predominant influence of rain water that is acidic and maintains low levels of alkalinity more than any interaction with soil components or geo-thermal springs that may transport Calcium rich waters from rock material deep below the surface.

Hardness

The level of hardness found in rain water and the volcanic lake water is virtually zero. There is a very significant increase in hardness as rain water is converted to stream water. However, there is no significant increase in hardness as the stream water flows down to the reservoir. The release of calcium and magnesium ions from the soil, and weathering lava and ash, contribute to the hardness.

The soil in this area is rich in clay and organic matter. As a result, its CEC is high, although in general the soil types which are present in this area usually do not have high base saturation or CEC. This means that for every two hydrogen ions in the percolating acidic rain water that interact with the clay and organic matter, one Mg or Ca ion is released to the water. This is because Mg and Ca are divalent ions, while hydrogen is monovalent. These freed ions are the cause of the hardness of the stream and lake water. The cations from the parent rock would get leached by percolating acidic water (acidic rain water and carbonic acid from root respiration), temporarily get locked up in the clay and organic matter and flow out of the system in sub-surface flows and enter streams.

However, the sample of hot spring water at Tabacon gave us clues to the major contributor to the hardness, alkalinity, and pH of the stream and reservoir water. This spring has a geo-thermal origin before emerging as a surface stream. The high alkalinity, pH, and very high value of hardness indicate that even though parts of the original limestone parent rock is buried under volcanic ash, it contributes significantly to the chemical composition of the water in the streams and the reservoir.

Depth profile

Bodies of water, such as lakes, generally have different water quality characteristics at different depths, including a decrease in dissolved oxygen at lower depths, with a sharp slope at some point in the curve. To see if this pattern existed at Lake Arenal, samples were taken at one meter intervals to a depth of 6 meters. No trends were found in any of the parameters measured. Only dissolved oxygen seemed to show a steady decrease, however, even for dissolved oxygen the changes were slight.

Despite the fact that one might expect to see a change in depth profile, the absence of this trend does not invalidate our data, rather it supports previous research conducted in 1980. Several possible explanations exist, and could be tested in further experiments. First, the low dissolved oxygen levels in the samples is consistent with the profile for bodies of water with light plankton blooms. The low levels of plankton may be due to a shortage of nutrients, particularly phosphorous, which is limited in the local lava rocks. Second, the lack of a clear cline may be due to the fact that the sample was taken in a small inlet where the water may be frequently destratified by boats and winds.

Conclusion

Our hope was to establish a baseline data set which future researchers might find helpful. Data from Palo Verde depicts a pre-irrigation profile for the marsh, most likely to be affected by irrigation runoff. The Arenal data describes a general trend in volcanic watersheds which might be monitored in conjunction with volcanic activity. We have compiled a list of recommendations to future researchers in order to facilitate project planning, and to encourage the pursuit of various aspects of watershed dynamics.

COROBICI STREAM BIOASSESSMENT

Bioassessment involves the use of living organisms as indicators of aspects of the environment. All terrestrial and aquatic organisms have tolerance ranges to chemical, physical, and biological conditions. When environmental quality declines, sensitive and intolerant species disappear first. Tolerant organisms then increase in abundance, while biodiversity typically declines (Deutsche 1993).

We used bioassessment around Palo Verde and Arenal in order to assess stream water quality using aquatic macroinvertebrates. Desirable characteristics of macroinvertebrates are their abundance, diversity, and relatively sedentary behavior.

Methods

For our purposes, we used two rapid bioassessment protocols. One of the bioassessment techniques was the Beginners Protocol used by Save Our Streams of the Isaac Walton League (Deutsche 1993). The other was the Intermediate Family Level Protocol developed by Hilsenhoff (Hilsenhoff 1988).

Both protocols employed random sampling of a minimum of 100 to 200 specimens by an aquatic net in riffles or shallow runs where currents exceeded 0.3 m/s. Also, rocks and organic matter were examined and pooled with net contents for the presence of desired macroinvertebrates, which were then put in water or ethanol filled containers. Sampled macroinvertebrates were then sorted in plastic trays and indexes of water quality were computed according to the protocol.

Beginner's Protocol

In the Beginner's Protocol (Table 3), we sorted the taxa into three tolerance groups, with the assistance of a key, to stream dwelling macroinvertebrates (Deutsche 1993, pgs. 38-45). Group number one included predator taxa that need high levels of dissolved oxygen and are generally sensitive to pollution. Good water quality is indicated by the presence of group one taxa such as dobsonfly larvae, caddisfly larvae, beetle larvae, stonefly nymphs, mayfly nymphs, rifle beetle adults and non-pouch snails. At the other extreme, group number three taxa can survive at high levels of decaying organic

matter with accompanied condition of low dissolved oxygen and often feed on detritus. Group three pollution tolerant taxa include black fly larvae, midge larvae, leeches, aquatic worms and pouch snails. Group number two taxa lie inbetween these tolerance characteristics and include crane fly larvae, beetle larvae, damselfly nymphs, dragonfly nymphs, scuds, sowbugs, crayfish and clams.

The number of taxa in groups one, two and three were summed for the sample (N), summed by group (N_j). The total number of taxa per group were then multiplied by a group water quality rating (R_j) of 3, 2 and 1 respectively to come up with group indices (I_j= N_jXR_j). The cumulative index (CI) for stream quality was then computed by summing group indices (CI=I₁+I₂+I₃). A stream could then be classified by its cumulative index. A rating of excellent stream quality is given for a cumulative index greater than 22, a rating of good for an index between 17 and 22, fair for those between 11 and 16, and poor stream quality for a cumulative index less than 11.

Hilsenhoff Intermediate Family Level Protocol

In the Hilsenhoff Family Level Protocol (Table 4), the sampled aquatic macroinvertebrates were sorted by arthropod families, excluding Hemiptera (true bugs), (beetles), aquatic worms and snails. We computed the family level biotic index (FBI) by multiplying the number of specimen in each family (N_j) by the appropriate Hilsenhoff tolerance to organic pollution for that family (T_j), summing these products and finally dividing by the total number (N) of arthropods in the sample (FBI=sum(N_jxT_j)/N). The stream water quality could then be evaluated using this family level biotic index, if between 0 and 3.8 a rating of excellent, if between 3.9 and 5 a rating of good, if between 5 and 5.8 a rating of fair, between 5.8 and 7.2 a rating of poor, and if between 7.3 and 10 a rating of very poor.

Results and Interpretation

On June 26, 1993, we collected a sample of 108 aquatic macroinvertebrates in a stream connected to Rio Corobici, just behind the Corobici Restaurant. The Beginners protocol indicated good stream quality based on a cumulative index of 22 with a total of 10 taxa (Table 2). The family level biotic index of 4.0 gave a similar rating of good stream water quality of good with a total of 10 families (Table 3). While the family level index did remove five specimen in the snail, shrimp and aquatic worm taxa that were accounted for in the beginners protocol, the index resulted in a similar assessment of stream quality. Furthermore, the family level protocol had the advantage of providing a better idea of macroinvertebrate biodiversity and the distribution of family abundances.

We found the rapid bioassessment methodology to be relatively simple, efficient and the protocols consistent. We thus highly recommend using both of the protocols for monitoring stream water quality in the Guanacaste region most affected by the introduced irrigated agriculture, particularly as this could be done and understood by residents.

Recommendations

Based on our research experience we have several recommendations that may be useful to groups conducting water quality monitoring in following years.

Our initial idea was to develop a plan at Palo Verde to monitor the potential impacts of agricultural and related activities, such as irrigation projects on water quality within an entire watershed. Both chemical and biological analyses were to be incorporated into overall water quality assessment. We were unable to achieve this goal for several reasons. It is with regard to these obstacles that we offer the following recommendations:

We recommend that more of these analysis be done for soils and rocks with deionized water. Such geological analysis could assist in understanding the Arenal Watershed's rain water buffering process and thus illuminate subsequent effects of water pollution.

This exercise shows that to assess watershed water quality the natural chemical characteristics must be understood from the geological characteristics.

One problem was purely logistical. At Palo Verde we did not have access to transportation as frequently as we needed in order to conduct a survey of potential monitoring sites and to groundtruth a plan derived from reference materials.

A second hindrance in achieving our goal was the lack of adequate materials in the OTS library that were necessary to use in the process of selecting monitoring sites. Maps of natural resources, such as soils, hydrography, and land-cover, and land-use, at a scale of at least 1:40,000, are instrumental in selecting monitoring sites.

In hindsight, it is just as well that we encountered difficulties in achieving our goal, because we discovered, by chance, that Fundacion Neotropica had already applied for a grant to develop a similar monitoring program. If OTS is serious about selecting sites for water quality monitoring that can provide baseline data for local communities and national agencies, those in charge of coordinating site visits and field problems should: a) be aware of previously organized efforts to develop water quality monitoring programs in the area; and b) communicate this information to OTS students before they begin their field problem on the subject. Hopefully, Fundacion Neotropica will obtain the grant and will be able to encourage local participation in their water quality monitoring program. If this occurs, OTS students may be able to participate in collecting data and have a rich learning experience while also collecting useful data. As an additional note, Martha Rosemeyer, a staff member at OTS, has been involved with a project on the OSA Peninsula that could serve as an example of how to develop a community-oriented water quality monitoring program.

The latter recommendation is most relevant at a site like Palo Verde, where the SENARA irrigation project is heavily influencing regional hydrography and land-use. Local communities could benefit from participating in a monitoring effort and could contribute greatly to collecting baseline data. In the case of a site, such as the Arenal watershed, a comprehensive program to monitor input sources at various points in the watershed would be extremely interesting from a purely ecological perspective. In the case of Arenal, as at Palo Verde, a set of maps would be an invaluable resource for selecting monitoring sites. Our group managed to test a number of sources in the Arenal watershed, however, our data interpretation and conclusions were limited by the scale of site-specific data on geology, soils, and hydrography. The results of the water quality analyses presented an interesting ecological conundrum that would be fruitful to pursue further. We recommend that if an OTS group visits the Arenal area in the future, they should be prepared ahead of time with a more complete set of mapped natural resource data, and should spend time analyzing the soils and water sources in the various parts of the watershed. Gathering such data might help to explain why the alkalinity is so high in the watershed, particularly in its upper reaches -- i.e., Cerro Chato -- which appeared to receive its main input from highly acidic rainfall. It would also be interesting to conduct more analyses on the geothermal springs near the Arenal volcano to serve as an extreme point of comparison in the watershed.

Table 1. Chemical Composition of Volcanic Bedrock in Arenal North Subwatershed.

Chemical Compound	Percent in Bedrock
SiO ₂	53.6
Al ₂ O ₃	19.9
Fe ₂ O ₃	3.9
FeO	4.2
TiO ₂	0.47
P ₂ O ₅	0.15
MnO	0.16
CaO	9.4
Na ₂ O	2.9
K ₂ O	0.5
H ₂ O	0.17
Total	100.00

Table 2. Arenal Water and Soil Water Quality.

Substrate	pH	Alkalinity ppm	Hardness ppm
soil	7.3	35	30
rock	3.0	0	110
rain water	4.5	5	0

Table 3. Beginners Protocol of Corobici Stream.

Group 1 Taxa	Group 2 Taxa	Group 3 Taxa
rifle beetle larva	crane fly larva	aquatic worms
non-pouch snails	shrimp	midge larva
dobsonfly larva		
dance fly		
caddisfly larva		
mayfly nymph		
# of taxa (N1) 5	# of taxa (N2) 2	# of taxa (N3) 3
grp index (N1x3=I1) 15	grp index (N2x2=I1) 15	grp index (N3x1=I3) 3

Stream Quality Assessment: good

Cumulative Index (CI=I1+I2+I3): 22

Total # of Taxa (N=N1+N2+N3): 10

Sample Size: 10

Table 4. Hilsenhoff Family Level Protocol of Corobici Stream.

Order and Family	# of Specimens (Nj)	Family Tolerance (Tj)	NjxTj
TRICHOPTERA (caddisfly)			
Hydropsychidae	88	4	352
Philopotamidae	1	3	3
Leptoceridae	1	4	4
MEGALOPTERA			
Corydalidae	2	6	12
EPHEMPTERA (mayfly)			
Ephemerellidae	2	1	2
Heptageniidae	2	4	8
Baetidae	2	4	8
COLEOPTERA (beetle)			
Elmidae	3	4	12
DIPTERA			
Empididae	1	6	6
Tipuliade	1	3	3
TOTAL	103		409

Stream Quality Assessment: good

Family Level Biotic Index

FBI = $\sum (N_j \times T_j) / N = 409 / 103 = 3.97$

Total # of Families: 10

Sample Size (N): 103

Figure 1. Palo Verde: Dissolved Oxygen and pH

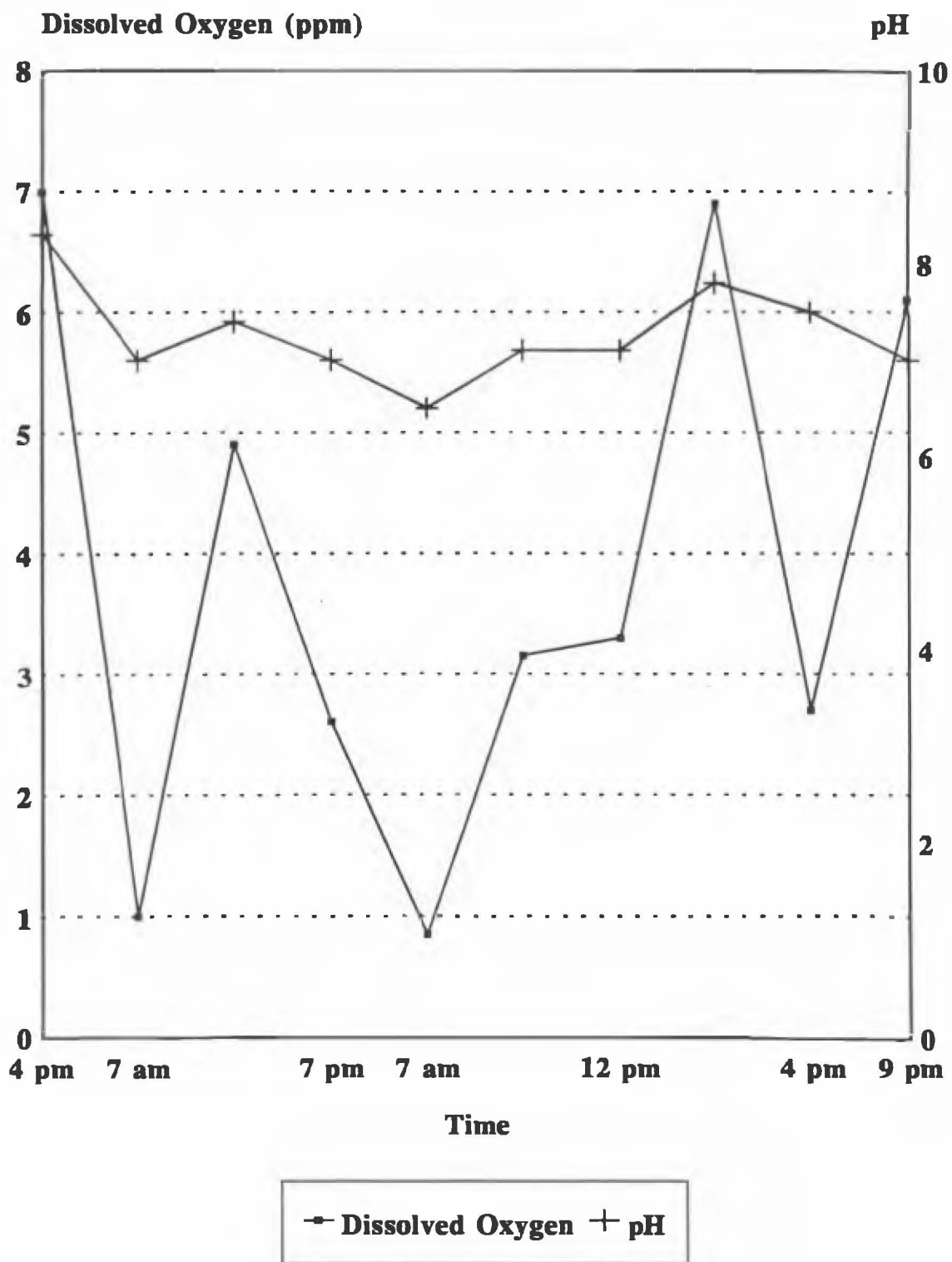


Figure 2. Palo Verde: Percent Oxygen Saturation and Water Temperature

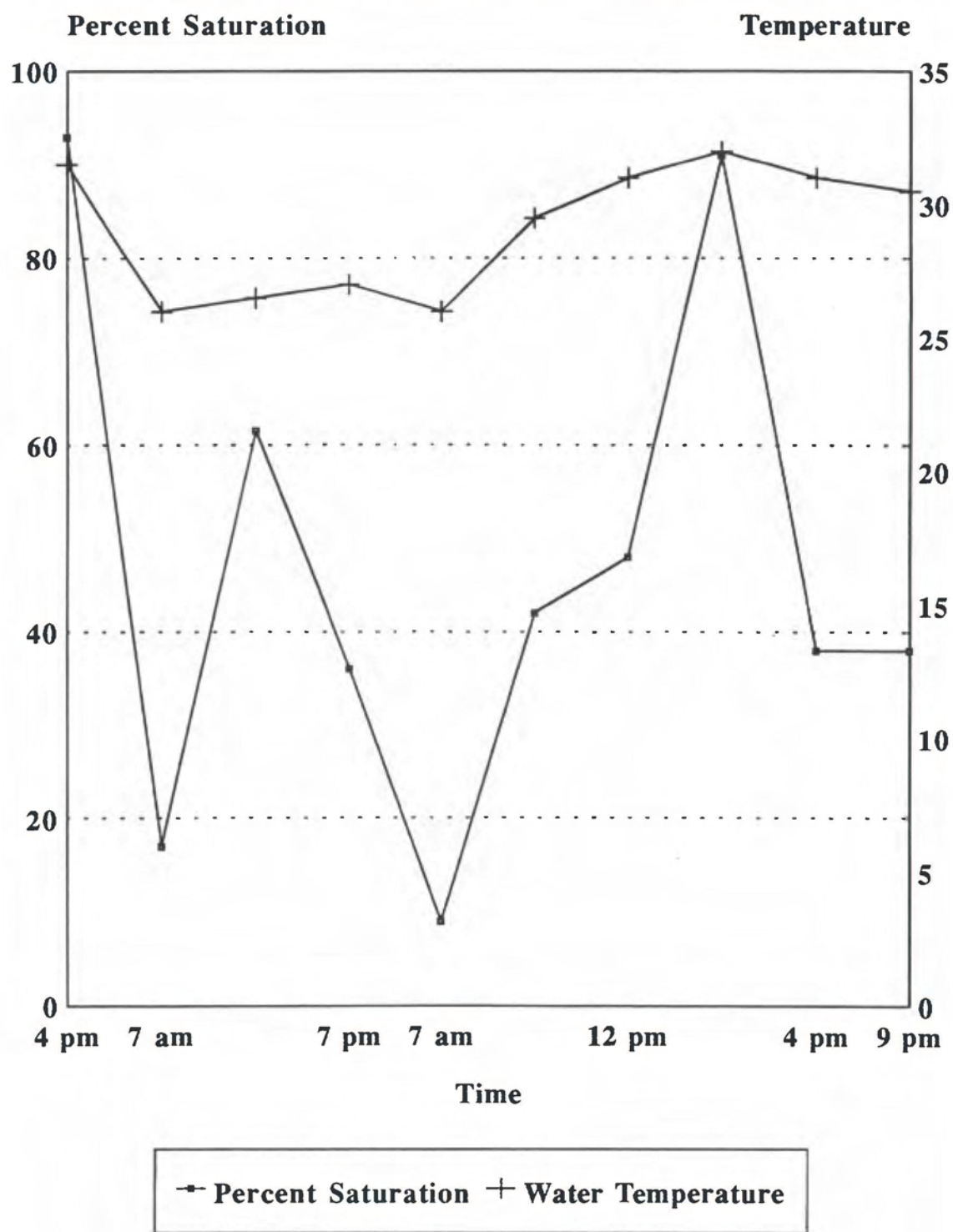


Figure 3. Palo Verde: pH and Alkalinity

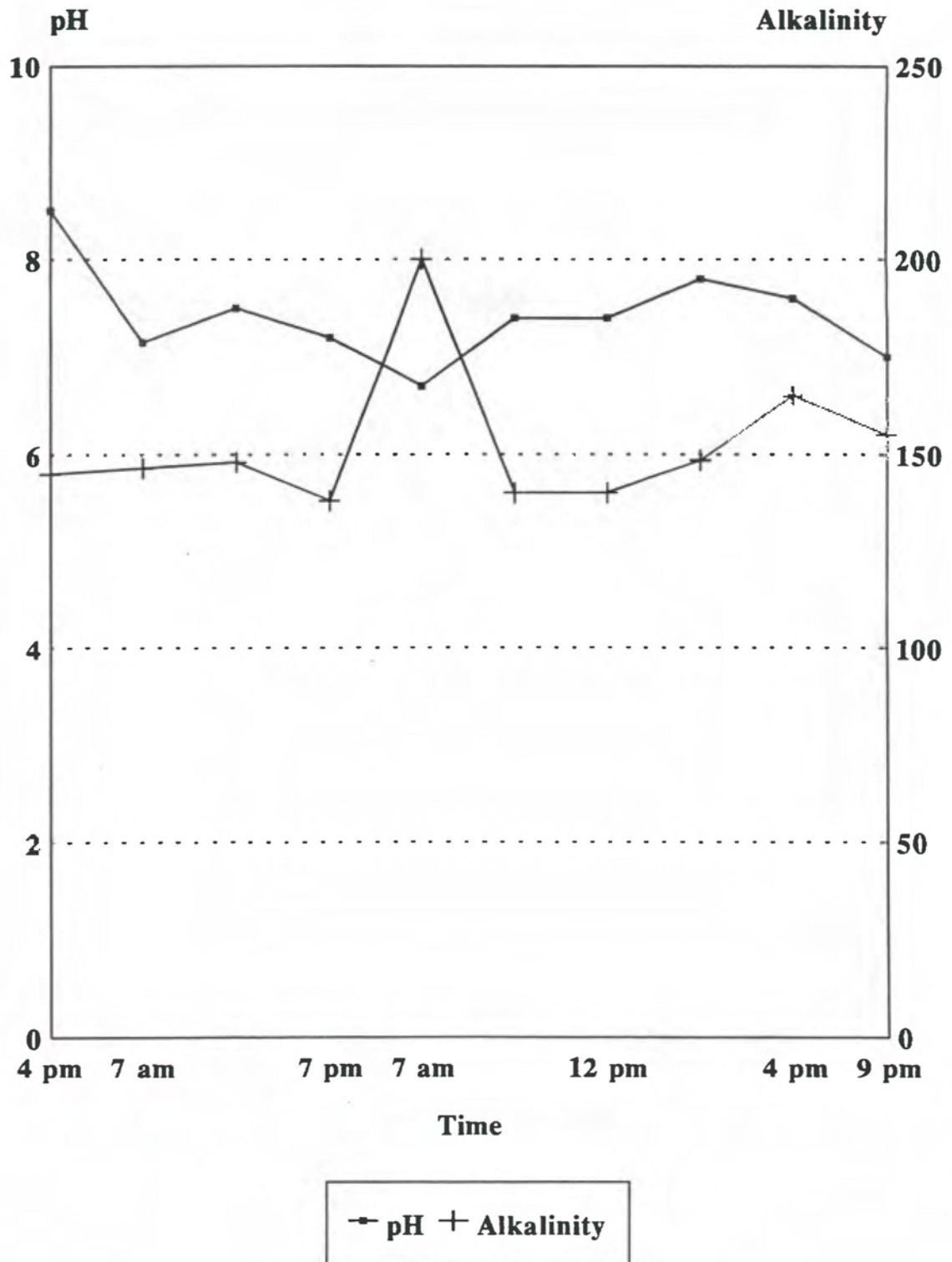


Figure 4. Palo Verde: pH and Hardness

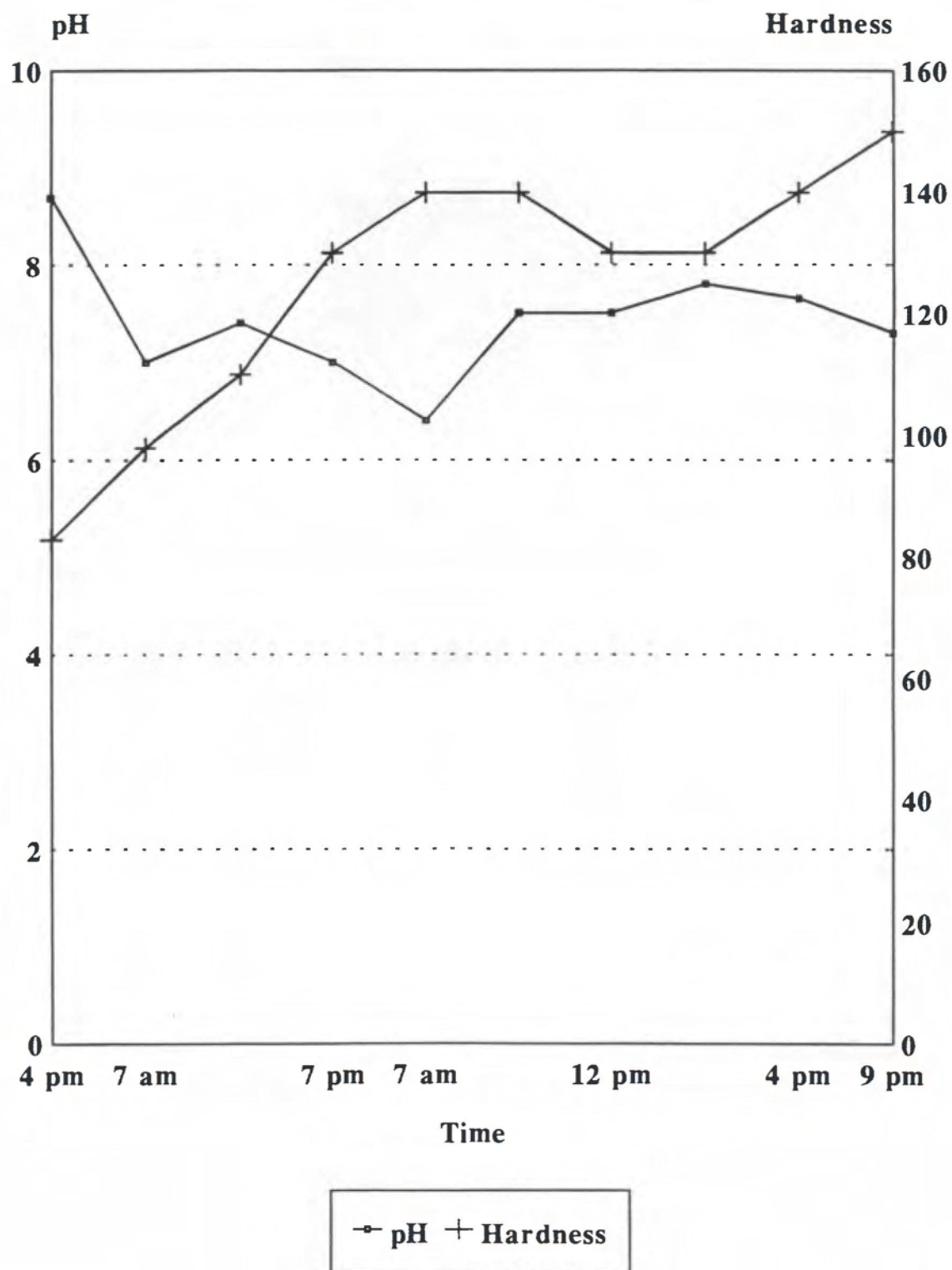


Figure 5. Arenal Watershed: Alkalinity Trends

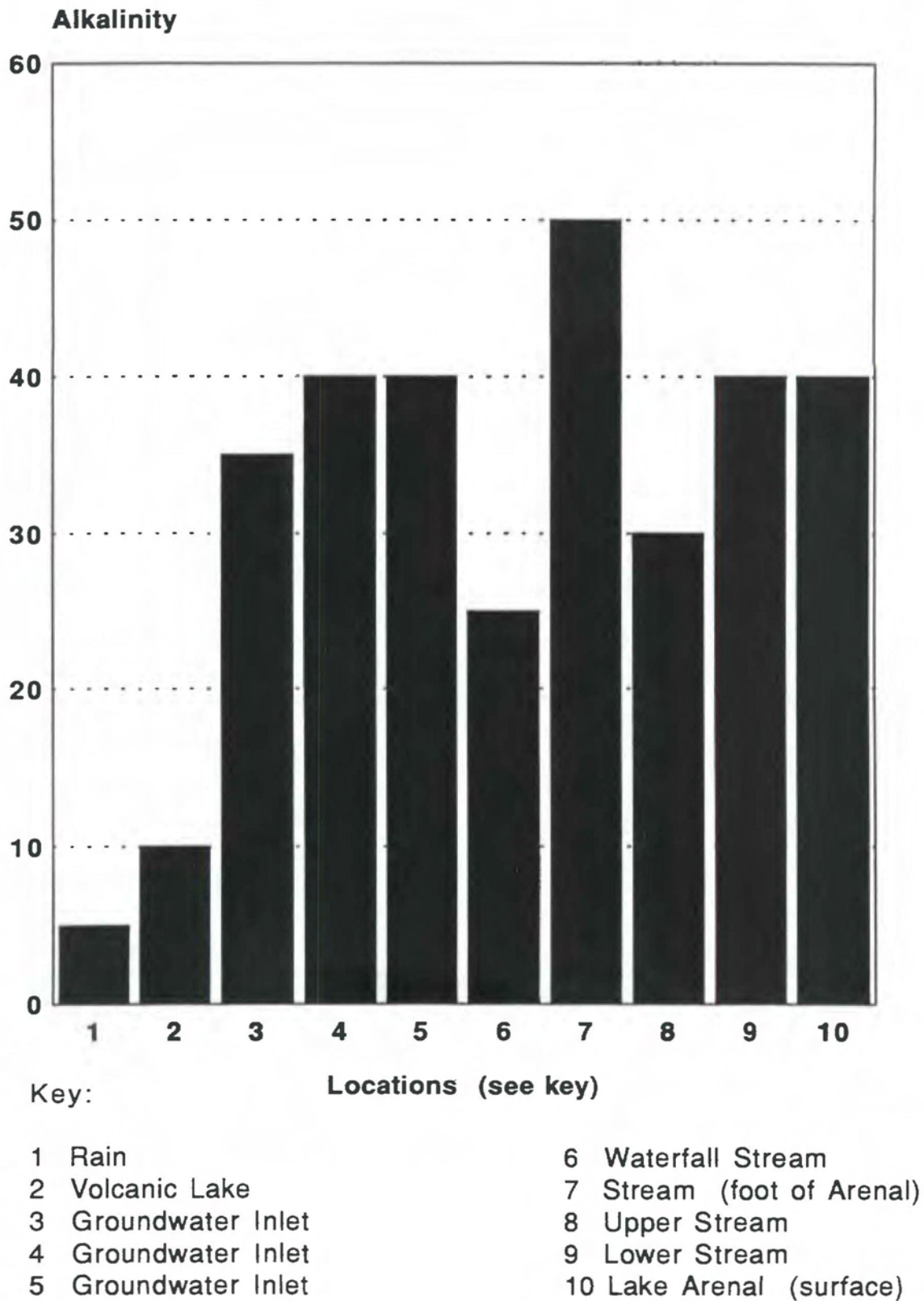
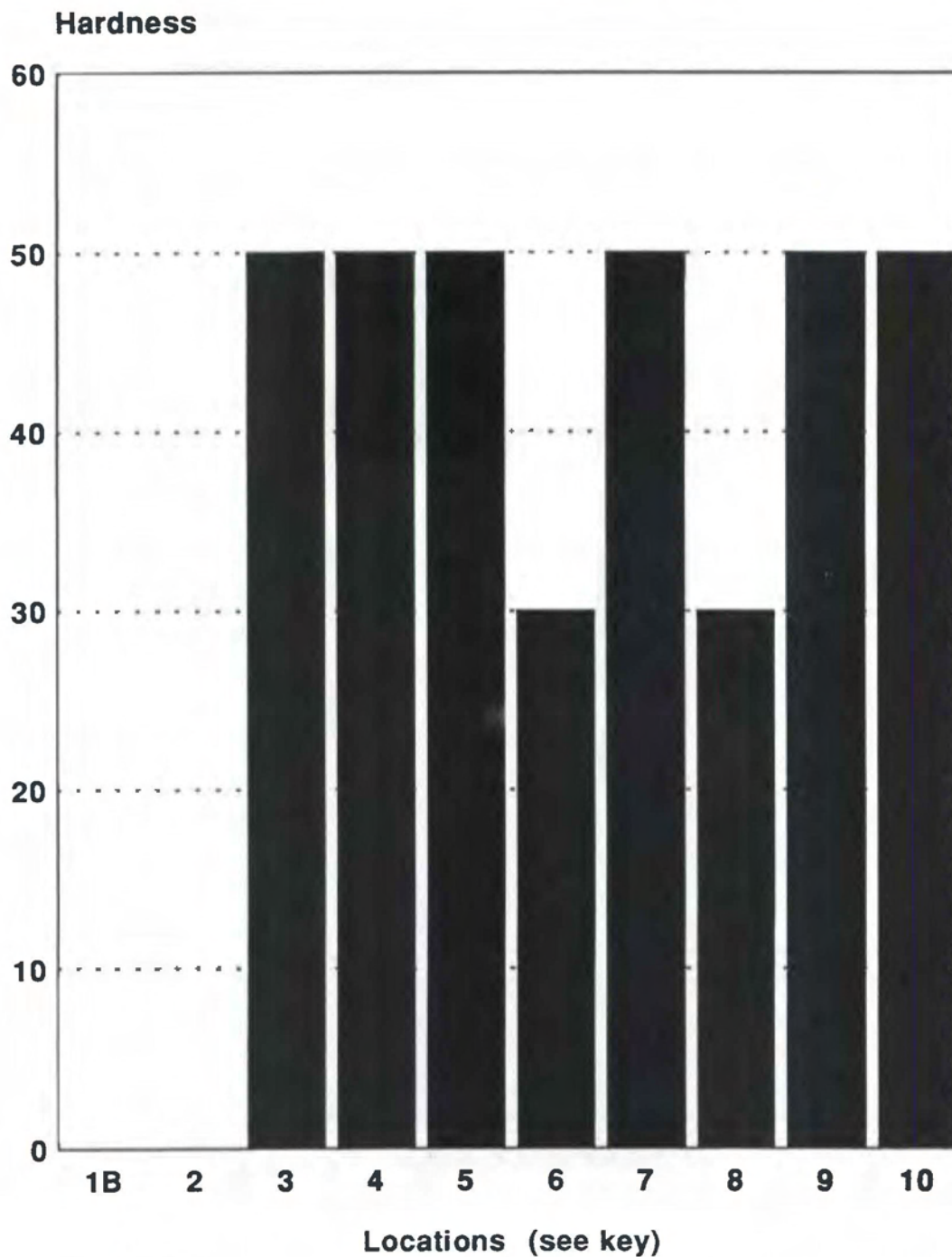


Figure 6. Arenal Watershed: Hardness Trends

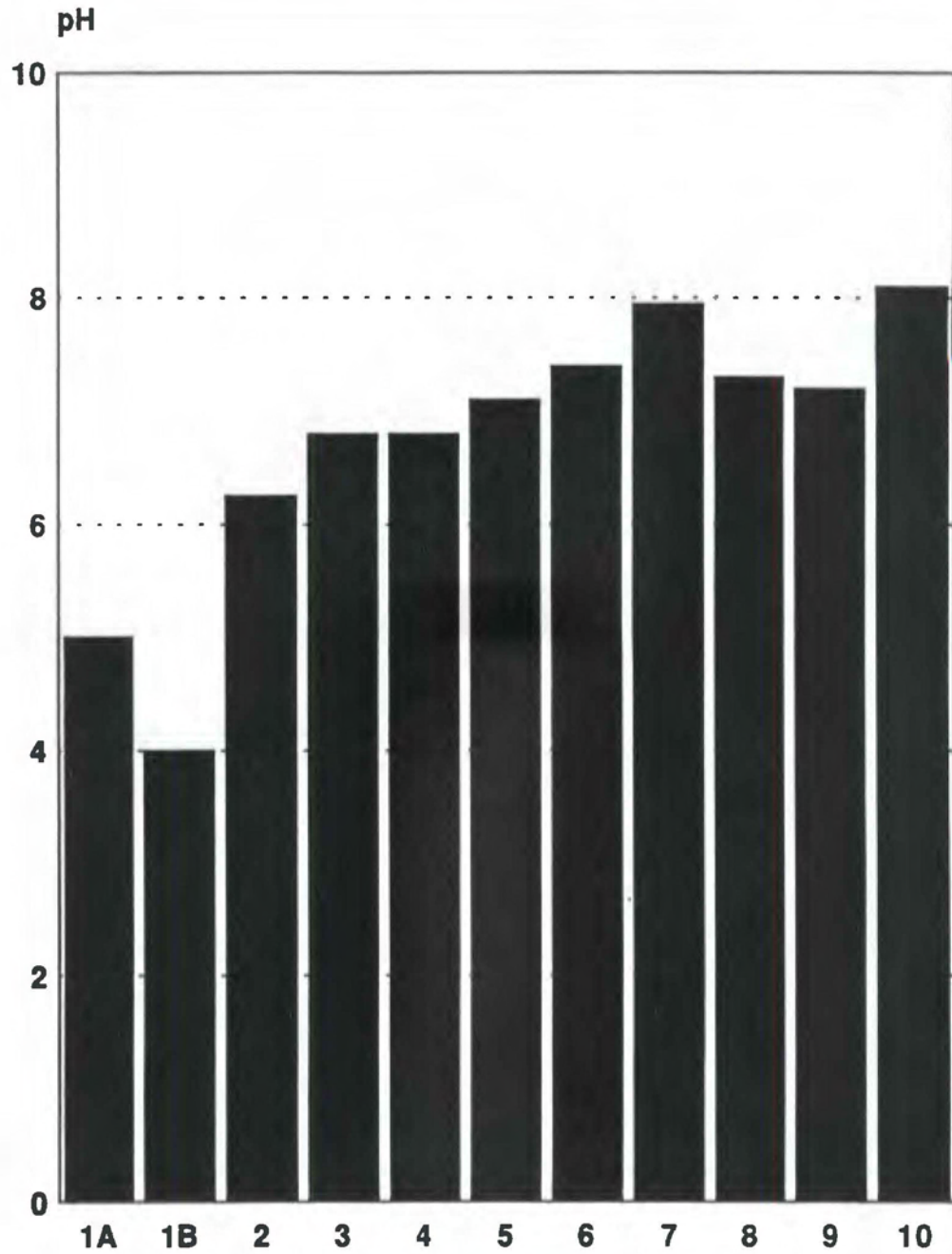


Key:

1B Rain
2 Volcanic Lake
3 Groundwater Inlet
4 Groundwater Inlet
5 Groundwater Inlet

6 Waterfall Stream
7 Stream (foot of Arenal)
8 Upper Stream
9 Lower Stream
10 Lake Arenal (surface)

Figure 7. Arenal Watershed: pH Trends

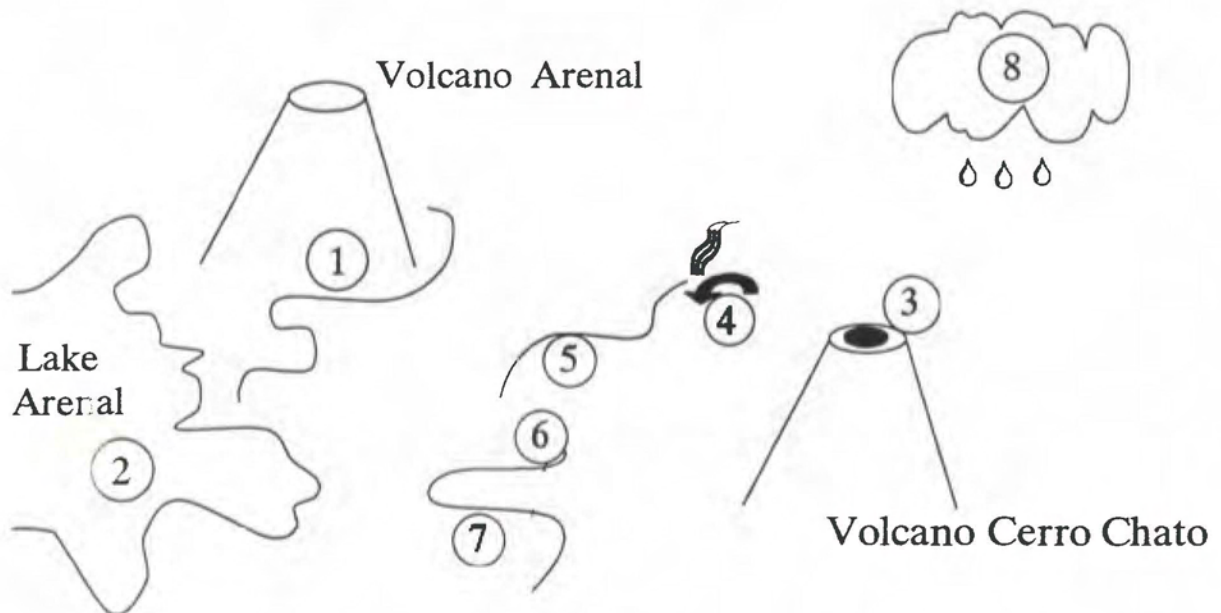


Key:

1A Rain
1B Rain
2 Volcanic Lake
3 Groundwater Inlet
4 Groundwater Inlet
5 Groundwater Inlet

6 Waterfall Stream
7 Stream (foot of Arenal)
8 Upper Stream
9 Lower Stream
10 Lake Arenal (surface)

Map 1. Sampling Points of Arenal Watershed



- Key:
- 1.) Stream at base of Arenal
 - 2.) Lake Arenal
 - 3.) Volcano Lake
 - 4.) Groundwater Streams (a,b,c)
 - 5.) Waterfall stream
 - 6.) Upper stream
 - 7.) Lower stream
 - 8.) Rain water

Appendix A

Water Quality Testing Parameters

The water quality testing included 6 parameters including: dissolved oxygen, total alkalinity, pH, total hardness, temperature and turbidity. These physical and chemical properties were measured using the LaMotte Chemical Company water quality test kit.

pH

The pH test indicates the acidity, or the concentration of hydrogen ions in a water sample. Water molecules contain both hydrogen and hydroxide ions. A high concentration of hydrogen ions ($\text{pH} < 7$) indicates an acidic solution, whereas a high concentration of hydroxide ions ($\text{pH} > 7$) indicates a basic solution. For each unit of change on the pH scale (1 to 14) there is a ten-fold change on the pH scale. The optimal pH for aquatic organisms falls between 6.5 and 8.2. The removal of carbon dioxide from the water by aquatic macrophytes may result in an increase in pH levels. Alternatively, sulfur dioxide and nitrogen dioxide, entering the system via rain or snow, may significantly lower the pH of a system. Many aquatic organisms are intolerant of even slight changes in pH, thus deviations in pH may significantly alter an aquatic system.

Alkalinity

Alkalinity is the measure of the buffering capacity of an aquatic system against acidic inputs. The surrounding soils, vegetation, organic matter and rocks contribute natural pH buffers, such as carbonate and bicarbonate, to the water system. These compounds help to neutralize acids and allow the system to resist pH fluctuations. Loss of buffering capacity may allow the pH to drop to levels intolerable for aquatic life. The initial addition of acid will slowly lower the pH of buffered water, but as the bicarbonate alkalinity gets consumed, the gradual decline may be followed by a rapid drop in pH. Alkalinity ranges of 100-200 ppm will stabilize a stream, however, ranges from 20-200 ppm are commonly found in fresh water (Deutsch, 1993).

Temperature

Temperature affects physical, biological, and chemical characteristics of water such as amount of dissolved oxygen, rate of photosynthesis, metabolic rate of organisms, and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Dissolved Oxygen

Dissolved oxygen is the amount of oxygen dissolved in water available to living organisms. The principal source of oxygen is the atmosphere, and it is mixed by water movement. The amount of dissolved oxygen is dependent on temperature, salinity,

volume of the watershed, and atmospheric pressure. Fertilizers and other human activities increase aerobic bacteria numbers. These aerobic bacteria consume the oxygen needed by plants and animals affecting microfauna and reducing biodiversity. Percent saturation depends on the temperature. Low values indicate that oxygen is being consumed in a faster rate than it is produced.

Hardness

Hardness refers primarily to the amount of calcium and magnesium in a water sample. Calcium leached from rocks is an important component for plant cell walls and the shells and bones of aquatic organisms. Magnesium is an essential nutrient for plants. Calcium levels below 10 ppm or less generally support only sparse aquatic organisms, creating an oligotrophic environment, whereas above 25 ppm systems are generally eutrophic. Typically, magnesium values range between 5-50 ppm. Seawater generally contains 400 ppm calcium and 1350 ppm magnesium. In general, "soft water" contains 0-20 ppm calciumcarbonate and "hard water" contains 121-180 ppm calciumcarbonate.

Turbidity

Turbidity is caused by suspended solid matter that scatters light passing through the water. Sediment and high algae concentrations contribute to turbidity. Turbid water is warmer than comparable clear water, has lower levels of dissolved oxygen, and lower biodiversity.

Appendix B

DEPTH PROFILE OF LAKE ARENAL

Depth	Dissolved Oxygen	Alkalinity	pH	Temperature	Hardness
Surface	8	40	8.2	25.5	50
1 meter	8.5	45	8.3	25.5	50
2 meters	8.3	45	8	25	40
3 meters	8	45	7.8	25	50
4 meters	5.6	45	8	24.5	60
5 meters	7.5	45	7.9	25	50
6 meters	6.8	40	8	25	50

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Guided Field Problem

PROSPECTING FOR ECOTOURISM: AN EVALUATION OF TOURIST OPERATIONS IN GUANACASTE PROVINCE, COSTA RICA

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Resumen

Este estudio evaluó y clasificó empresas turísticas en la provincia de Guanacaste en Costa Rica para determinar si aquellos empresas cumplen los requisitos para ser llamaasd "ecoturismo." Los criterios usados en la evaluación fueron: nacionalidad de los dueños, el impacto biológico, educación de historia natural para la comunidad y los turistas, énfasis en la experiencia cultural, creación de empleo local, estímulo de la economía nacional y esfuerzos adicionales para conservacion ambiental. Nuestros resultados indican que las empresas cumplen con diferentes requerimientos pero ninguno de ellos alcanza el puntaje necesario para la empresa "ecoturístico" ideal.

Abstract

This study rated tourism enterprises in the Guanacaste Province of Costa Rica to determine whether these enterprises fulfilled criteria considered necessary for "ecotourism". The criteria used were nationality of ownership, biological impact, natural history education for tourists and community, emphasis on cultural experience, generation of local employment, stimulation of national economy, and additional contributions to conservation efforts. Our results indicate that enterprises in that province occupy a continuum based on a combination of these characteristics; none achieved the maximum score available to an ideal ecotourism venture.

Introduction

Tourism has become increasingly important within the Costa Rican economy, currently ranking as its fastest growing segment. As of 1987, tourism was the third largest source of income, trailing only the banana and coffee industries (Boo, 1990). In 1993, tourism generated 500 million U.S. dollars for Costa Rica (Barboza, pers. comm.). With Costa Rica's rapidly growing population, and with increasing pressure on a dwindling natural resource base, tourism, especially that which is geared towards visiting natural areas, is being viewed by many as a more sustainable alternative to other land use methods. This new breed of tourism, termed ecotourism, has attracted a great deal of media, political, and entrepreneurial attention in recent years (Budowski, 1992).

The Ecotourism Society defines ecotourism as "purposeful travel to natural areas to explore the culture and natural history of the environment, taking care not to alter the integrity of the ecosystem, while producing economic opportunities that make the conservation of natural resources beneficial to local people". Additionally, ecotourism is often considered a method for stimulating the economy of the host country, while at the same time creating and maintaining a system of protected natural areas (Fennel and Engels, 1990).

The purpose of this study is to evaluate a sample of tourism operations in the Guanacaste province of Costa Rica with regard to how well they meet the criteria of an ecotourism operation, as defined by the Ecotourism Society and Fennel and Engels. These operations were chosen randomly, and ranged in size from small, locally owned and operated operations to large-scale, foreign owned hotels.

Study Site

The study site encompasses an area in southern Guanacaste province, stretching from the northwestern side of the Gulf of Nicoya east to Lake Arenal. Two national parks (Palo Verde National Park and Barra Honda National Park) lie within this region, as well as other significant tourist attractions such as Volcano Arenal and Lake Arenal itself. The importance of Guanacaste as a site for nature tourism is exemplified by its official designation as an ecotourism province by the Costa Rican government in 1992 (Barboza, pers. comm.).

Eleven tourism facilities were visited within the study area. Brief descriptions of each facility are as follows:

- 1) Las Lajas--small hotel in downtown Nuevo Arenal. Owned by a native Costa Rican. Las Lajas does not offer activities directly but will make arrangements for its guests. Its capacity is 6 double rooms.
- 2) Delta Hotel--small hotel in downtown Nuevo Arenal. A family business owned and operated by Arenal area natives. Delta caters to both foreigners and native Costa Ricans in town on business. Its capacity is 10 double rooms.
- 3) La Ceiba--14-hectare farm with a small cattle herd overlooking Lake Arenal. The owners and operators are a German couple who have lived in Costa Rica for 10 years. Capacity is 4 cabins with 2 beds each.
- 4) Les Heroes--Swiss-style hotel and dairy farm located on the slopes above Lake Arenal. Swiss owned with a capacity of 42 beds.
- 5) La Pacifica--Swiss owned hotel, restaurant, experimental farm and environmental education center located in the town of Canas. 2,000 hectares with 33 cabins.
- 6) Safaris Corobici--American owned river rafting operation in Canas utilizing the Rio Corobici.

- 7) Las Delicias--grassroots project initiated by the community of Barrio Cubillo located on the edge of Barra Honda National Park. Their main activity is offering guided tours of several caves found in the park. Capacity is 3 cabins with 4 beds each and 16 campsites.
- 8) Eco-Lodge--500 ha facility with three hundred ha of primary forest and 150 ha of secondary forest. Total capacity is 100 beds. Located near the town of Arenal and is Costa Rican owned.
- 9) Rancho Humo--1,000 ha cattle ranch with hotel and river tour operation located in the town of Puerto Humo on the Tempisque River. Costa Rican owned with 24 double rooms and eight 4-person cabins.
- 10) Hacienda Las Sillas--2,000 ha cattle ranch with a capacity of 5 double rooms.
- 11) Observatory Lodge--located at the foot of Volcano Arenal overlooking Lake Arenal. Capacity is ten 4-person rooms.

Methods

We rated tourism facilities based on 8 criteria suggested by the definition of ecotourism, as defined in the introduction. The criteria chosen were as follows: nationality of ownership and operation, potential for negative biological impact, availability of natural history education for tourists and for the local community, emphasis on cultural experience, generation of local employment, stimulation of national economy (import dependency), and the degree that the enterprise supported conservation efforts. The data were gathered through a series of interviews conducted at each of the tourist operations with the aid of a previously prepared questionnaire (Appendix 1). Tours of facilities and trails were also conducted whenever possible.

The data from the interviews were qualitatively assessed according to the criteria listed in Table 1.

Results

The final ratings derived from the survey data for the eleven tourist operations can be found on Table 2. The possible rating system ranged from a minimum value of -5 to a maximum value of 8. The ratings in our study ranged from a low of -1 for Les Heroes to a high of 6, for both Las Delicias and the Eco-Lodge. The average rating in our sample was a 3.1.

Discussion

Ecotourism has been promoted as an alternative to conventional tourism, seeking to avoid conventional tourism's worst cultural and environmental abuses while promoting the survival of cultures and creating monetary and social incentives for the preservation of nature. The joint emphasis on natural resource protection and sustainable development

appeals to both tourists and their hosts, and has lead to a growing number of ventures tailored to "ecotourists" and espousing an ecotourist philosophy.

Many expectations have been raised by the promises of ecotourism. Costa Rica has suffered from the failure of previous development schemes, such as those involving cattle and bananas, and ecotourism has been promoted as the new "magic solution" to the country's development problems (Luucke 1993, pers. comm.).

Our findings indicate that many of the tourism facilities in the Guanacaste Region of Costa Rica fail to fully meet the criteria of an ecotourism operation. Instead, the eleven operations lie on a continuum somewhere between that of conventional tourism and ecotourism. This analysis does not try to identify a point along this continuum where a line could be drawn to indicate where conventional tourism ends and ecotourism begins; each facility has a combination of characteristics that could be attributed to either one.

Even the operations with the highest rating had problems. While being developed, owned, and operated by a local cooperative and integrated into the local cultural landscape, the Las Delicias ecotourism project near Barra Honda National Park is negatively impacting the cave formations that are a major attraction of the site. If continued unmonitored, this resource could be severely degraded. Resident bat populations may also be impacted, but there was no information available to assess this. La Pacifica, which also rated well, offers educational programs to the local community, actively contributing to the development of a "conservation culture," but is owned by a foreigner, which results in the removal of resources from the host country's economy.

Our sample of facilities performed poorly on three criteria in particular--biological impact, natural history education for the community, and level of support for conservation. These deficiencies suggest several improvements to ecotourism operations. First, activities that impact the environment must be more carefully monitored and managed to minimize negative effects. Specific points of interest, such as Isla Pajaro in Palo Verde National Park, are highly sensitive and access should be more restricted than at present. Second, tourism operations are in a good position to act as conservation role models and assume greater responsibility for the resources they benefit from. At present, the tourist operations are not required to pay more than nominal fees for using protected areas. Investment of part of their profits in helping local or international conservation efforts or volunteering staff and or participant time to help with park management (such as trail maintenance or fire control) would be beneficial to all. And finally, one weakness that was consistently brought up was the lack of community integration through education or other programs. This is especially important because many reserve management problems such as poaching, "squatting", fire, and deforestation can be linked to the failure to integrate the needs of local communities into the management plans of protected areas (Allen, 1988).

Because ecotourism is being promoted as one mechanism for achieving such integration, it is important to examine who benefits and who pays from such enterprises. There is evidence that ecotourism endeavors are seen by many locals, particularly poor communities adjacent to reserve areas, as primarily benefiting foreigners and the wealthy segment of Costa Rica. In summarizing their opinion about the development of ecotourism in their region, a family in the town of Puerto Humo (adjacent to Rancho Humo) commented that "the wealthy get rich while we are left with the garbage".

The development of tourism and ecotourism in Costa Rica has been largely unregulated. Government policies have favored large, capital-intensive tourism projects. Local communities have little ability to mitigate the negative social, cultural and environmental impacts of tourism. Therefore, government, NGOs and reserve management planners need to work more closely with local people to develop small-scale locally based projects. Las Delicias near Barra Honda National Park was the only enterprise we encountered that was initiated and run by the local community. This project was only possible because of help from a San Jose based NGO, Fundacion Neotropica, that helped the community secure funding from an international conservation foundation.

There is indication that the government is beginning to respond to this problem. The Office of Tourism recently announced a new program to promote small-scale tourism development. This may be a significant step toward the empowerment of local communities in the stewardship of Costa Rica's natural resources and toward the development of true ecotourism enterprises.

Summary

Our study found that all of the tourist facilities sampled failed to fully meet the criteria of an ecotourism operation. While this may be the case for Guanacaste, it does not imply that ecotourism itself is unsuccessful or idealistic. The concept of ecotourism is still very new, and like all new ideas it will require an adequate system of regulations, incentives, and management practices to ensure that it can better fulfill its promise.

Table 1. Criteria Definitions for Assessment of Tourism Operations in Guanacaste Province, Costa Rica.

CRITERIA	RATING		
	-1	0	+1
Ownership	Foreign Owned or Foreign Partner		Domestically Owned and Operated
Biological Impact (BIOL)	Unregulated Impact on Specific Point of Interest, No Additional Management for Biol. Prot.	Negligible Impact on Specific Point of Interest	Active Management for Resource Protection
Education of Tourists (EDTR)		No Natural History Education Programs for Tourists	Natural History Education Programs for Tourists
Education of Community (EDCM)		No Natural History Education Programs for Community	Natural History Educational Programs for Community
Cultural Experience (CULT)	Emphasis on Imported Customs and Values	No Noticeable Cultural Emphasis	Immersion in Local Culture
Generation of Local Employment (EMPL)	Hire Majority of Labor from Outside Local Community	No Employees	Hire Majority of Employees Locally
National Economy (ECON)		Many Inputs Imported	Majority of Operational Inputs Can Be Supplied Domestically
Contribution to Conservation Effort (CONS)	Resistance to Paying Park Fees	No Additional Contributions	Additional Monetary or Volunteer Contributions to Resource Mgmt/Conservation Org.

Table 2. Criteria Ratings for Tourism Operations in Guanacaste Province, Costa Rica.

	OWNERSHIP	BIOL	EDTR	EDCM	CULT	EMPL	ECON	CONS	TOTAL
MAX	1	1	1	1	1	1	1	1	8
LAJA	1	0	0	0	0	1	1	0	3
DELT	1	0	0	0	1	1	1	0	4
CEIB	1	1	0	0	0	0	1	0	3
HERO	-1	-1	0	0	-1	1	1	0	-1
PACI	-1	1	1	1	0	1	1	1	5
CORO	-1	0	1	0	0	1	0	1	2
DELI	1	-1	1	1	1	1	1	1	6
ECOL	1	1	1	1	0	1	1	0	6
RHUM	1	-1	1	0	0	-1	1	-1	0
SILLA	1	-1	0	0	1	1	1	0	3
OBSV	1	-1	1	0	0	1	1	0	3

MAX = Maximum score for ideal ecotourism operation

LAJA= Las Lajas Hotel

DELT= Delta Restaurant

CEIB= La Ceiba

HERO= Les Heroes

PACI= La Pacifica

CORO= Corobici Safaris

DELI= Las Delicias

ECOL= Eco-Lodge

RHUM= Rancho Humo

SILLA= Hacienda Las Sillas

OBSV= Observatory Lodge

Appendix 1

Ecotourism Survey Questions

- (1) Who are the owners and where are they from?
How many years have you been in business?
What was the previous use of this land?
- (2) What is your current capacity?
- (3) How many visitors?
Seasonality of visitation?
Origin of visitors?
What sort of clientele do you cater to?
What are your rates?
Can you estimate the average length of stay?
How do you advertise?
Do you have contracts with booking agents/tour companies/airlines?
- (4) How much land (ha) do you have?
How much forested/pasture/agriculture etc.?
- (5) What activities are provided for the visitors?
How are these activities dispersed?
Do you have nature trails?
Do they identify flora and fauna or historical points of interest?
Do you have environmental education programs?
Do you have a library or other educational resources?
- (6) How do your clientele use protected and other natural areas?
Do you pay fees to use protected areas?
How do you think your establishment contributes to the conservation effort in Costa Rica?
Carrying capacity of environment?
- (7) How many people do you employ?
What is the seasonal pattern of employment? How many people in each sector (restaurant/ecoactivities/maintenance, etc.)?
Where are your employees from?
Do you require (or prefer) English speakers?
Is any special training provided?
Do you employ Naturalists?
What sort of community interactions/programs do you have?

Appendix 1 continued.

- (8) Where do you buy supplies? Equipment?
- (9) Do you need special operating permits?
How difficult is the permitting process?
- (10) Do you have future plans to expand?

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Guided Field Problem

RICE FARMING IN GUANACASTE

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Resumen

El reciente proyecto de riego de SENARA, el Servicio Nacional de Aguas Subterráneas, Riego y drenaje ha alterado los métodos del cultivo de arroz en el Valle del Tempisque en el distrito de Guanacaste. Por medio de entrevistas informales estos cambios fueron investigados. Los resultados indicaron correlaciones entre el acceso al agua, el uso de agroquímicos y los ingresos económicos.

Abstract

The recent irrigation project of SENARA, the National Groundwater, Irrigation, and Drainage Service, has altered rice farming practices in the Tempisque Valley of the Guanacaste district. These practices were investigated through informal interviews. The results indicated correlations among access to water, agrochemical usage, and economic returns.

Introduction

In the 1970s a major hydroelectric project was built on Lake Arenal, diverting water from Costa Rica's Caribbean slope. In 1983 the Arenal-Tempisque Irrigation Project (PRAT) began using water below the dam to irrigate the lowlands of the Guanacaste Province. The irrigation project promises a continuous water supply to the Tempisque Valley, located between the coastal highlands and the Guanacaste Range. Water draining from the PRAT flows into the Tempisque River on the western edge of the Guanacaste district, eventually reaching the Gulf of Nicoya.

The topography of the Tempisque Valley consists of relatively flat terrain with clay vertisols and isolated limestone hills. The flat areas are suitable for irrigated rice production, but the dry Pacific Coast climate has traditionally limited farmers to a single crop of dry land rice. The PRAT, administered by the National Groundwater, Irrigation and Drainage Service (SENARA), has enabled production of irrigated rice, allowing two harvests per year. When completed, the three phase project is expected to irrigate 60,000 hectares within the Tempisque Valley.

The Institute of Agricultural Development (IAD) selects recipients of project lands from a large pool of applicants. Irrigated land in 10 ha parcels has already been distributed to 60 families at Bagatzi. Land will be distributed to 1045 families by the end of the second phase. Since most recipients have no experience in irrigated farming, the Ministry of Agriculture and Livestock (MAG) provides agricultural extension services.

Conversion to intensive irrigated rice production is increasing agricultural impact on the watershed. Both the rice cash crop system and the mixed cash/subsistence farming systems are likely to affect water flow, nutrient cycling, and biodiversity. The use of fertilizers and pesticides within these systems introduces contaminants that are potentially detrimental to the watershed. This study attempts to describe agricultural systems and to assess farmers' ecological awareness through informal interviews of local farmers and their families. We were specifically interested in how agrochemical use differs among four farm types varying in tenure, size, irrigation, and source of technical advice. We expected the results to provide insight into: the economic and environmental sustainability of these systems; potential impacts on the watershed; and future research needs.

Method

The study relied on informal interviews to ascertain land management systems, practices and perceptions. The interviews were conducted on June 25-26, in the communities of San Ramon de Bagaces, Bagatzi and Falconiana. The interviewees were selected from households of non-irrigated farms--both with and without title to the land--as well as irrigated farms (see Table 1). The manager of a large commercial irrigated farm was also interviewed. Sites were selected in order to represent the diversity of the area's rice farming systems, including both subsistence and cash crop farms. The questions concentrated on socio-economic topics and the farming cycle (see Appendix D). Particular attention was given to agrochemical use.

System Description

Guanacaste farmers with irrigated fields plant two crops per year, one during the wet season and another during the dry season. Only one crop of non-irrigated rice is planted, on a schedule paralleling the wet season irrigated system.

Land preparation is mechanized. Stubble from the previous crop is tilled into the soil. Fields are then usually compacted using a fungiadora tractor with large metal wheels. This process is usually repeated several times during a one to two month period prior to planting.

The most common rice varieties are CR 18-21, a high-yielding variety, or CR 11-13, a more resistant variety. Planting methods vary among the sites. Catalina, the large farm, uses aerial planting, while the small farmers use tractors or plant manually, some

using hired labor. One farmer at San Ramon hires someone to simultaneously till and plant his parcel using a tractor. The tractors are primarily rented, but a group of farmers in Falconiana have collectively purchased a tractor for tilling and planting.

Organic fertilizers are not applied at any of the sites. Most farmers fertilize three times during each cropping cycle: at planting, after the herbicide application during the three-leaf stage, and at the time of spike formation. Fertilizers are spread by hand or included in a liquid chemical mixture sprayed onto the crop.

Insecticides, herbicides, and fungicides are applied at all farms. Application techniques, rates, and chemical choices vary among the sites. Aerial applications are used by the large farm for all chemical inputs. Non-irrigated farms primarily use backpack sprayers, while aircraft are commonly employed in project systems. The first herbicide application follows shortly after planting. Later in the maturation process, additional herbicides are applied. Insecticides are usually applied at least twice during the season. The first application is after emergence and the final application is at the time of spike formation. Additional pesticides are used when necessary. Fungicides are applied when needed during the growing process. Often two or more chemicals are applied together.

In non-irrigated systems the cropping schedule is dependent upon rainfall, while farmers in irrigated systems control water levels in their fields through a series of canals. Initially, fields are kept moist, but not flooded. After rice plants reach a height of approximately 10 cm, the fields are kept flooded until harvest.

Harvesting is mechanized. Farmers at Bagatzi and San Ramon rent harvesters and hire their operators. All rice in the area is sold directly to processing plants.

Factors Influencing Agrochemical Inputs

Agrochemical inputs of the four farming systems are compared in Table 2. Small irrigated farms tend to focus on preventative versus responsive pesticide applications. A majority of applications in the Bagatzi system are based on a fixed schedule, while only 14% (3 of 21) occur upon observation of pest problems. In contrast, approximately 46% (17 of 37) of the pesticide applications in San Ramon are in reaction to pest outbreaks.

Only responsive pesticide applications are used in Falconiana farming systems (although a direct comparison between these farms and rice production would not be valid). Despite the economic constraints of the small farmers, chemical inputs among all farms appear similar. However, the high percentage of responsive inputs prevents accurate determination of total pesticide input.

Approaches to pesticide application seem to be influenced by the following: credit availability, technical information, and pesticide resistance.

Bank loans include stipulations such as water access and regimented pesticide and fertilizer use. Therefore, irrigated farms have easier access to credit from banks. In addition, banks require crop insurance, which is unavailable to non-irrigated farms with or without title to the land. Thus, such farmers turn to other sources of credit, including agricultural stores, cooperatives, or rice processors. All farmers without irrigation expect to have it within two years, which would facilitate access to bank credit. The likely consequence is that they will adopt a regimented chemical input system similar to that of Bagatzi.

In the case of farmers without title to their land, credit is almost impossible to obtain. Many work as wage laborers in order to supplement their incomes and to purchase inputs for subsistence crops. Economic instability discourages use of preventative applications, encouraging a responsive approach. Farmers without title recognize that the constant threat of eviction precludes investment in preventative pesticide applications.

The source of technical information available to the farmer influences pesticide application approaches. Irrigated farms generally receive advice from hired technicians, either private or from a cooperative. In Bagatzi, the technician assumes financial responsibility for crop failure due to pest damage. Thus, the technician may encourage a greater input of chemicals than necessary, while the costs of preventative pesticides fall on the farmer. Since none of the farmers interviewed had previous experience with rice cultivation, they are unlikely to question this arrangement. Some even refer to the technician as "El Doctor." The one Bagatzi farmer who no longer receives technical advice has the only irrigated farm with a responsive orientation.

San Ramon farmers cultivating non-irrigated rice either consult agrochemical stores or MAG agents for advice. Farmers who consult stores for advice are unlikely to have a preventative orientation. Rather, they apply recommended pesticides only in response to outbreaks. Agents from MAG provide information similar to that provided by irrigated farm technicians, recommending preventative chemical input. The Falconiana farmers' lack of technical assistance, combined with extreme economic constraints, allow pesticide input only as a reactive strategy.

A high input, preventative approach encourages pesticide resistance, as well as secondary pest outbreaks resulting from the loss of predators. Expensive, preventative pest control techniques used on irrigated farms are likely to drive resistant pest varieties onto less chemical-intensive farms. For example, the manager of the large farm noted that "hoja blanca" is a new pest problem that is treated with fungicide, but that surrounding farms are unable to treat as effectively. Thus low input farmers may be forced onto the pesticide treadmill by their wealthier, chemically-inclined neighbors.

Perceptions

We asked interviewees to comment on the environmental effects of their neighbors' farming practices and on their attitudes toward the future. The responses appeared to depend upon whether or not the farm had irrigation.

Environmental Effects

On the whole, farmers with irrigation do not feel that their neighbors' farming practices have any impact on them. An exception was a farmer in Bagatzi receiving irrigation water from a neighbor's field during the dry season. He described the water as dirty. He expressed concern about siltation and weed seeds rather than chemical contamination. In fact, some farmers we interviewed fish in drainage from the irrigation system.

Farmers without irrigation generally see pesticide use by their neighbors as a problem (with the exception of two farmers in San Ramon de Bagaces, who were neighbors). They complained of damage to their vegetable crops by broad-leaf herbicide drift from aerial applications on irrigated rice farms. One farmer reported dead shrimp in the river following aerial spraying on neighboring farms. Another farmer mentioned an incident of children developing skin problems related to aerial spraying.

Although farmers are generally aware of pesticide toxicity, they often fail to take appropriate precautions when applying agrochemicals. Some farmers do not seem to understand that these chemicals have chronic as well as acute health effects. Of the farmers who hand spray their fields, four do not use protective gloves or a mask due to the expense or discomfort involved. The son of one of the interviewees, who is a wage laborer on a large rice farm, believes that only skin contact with pesticides is harmful and that inhaling the fumes is not.

Perceptions of the Future

In general, those interviewed are somewhat optimistic about the future. For the farmers with irrigation, optimism is related to the stability of their recent yields. However, the large commercial farmer thought that yields had decreased due to an inferior quality of seeds supplied by the distributor. The optimism of farmers without irrigation is linked to the prospect of receiving irrigation in the near future and the accompanying change to low-risk, high-input rice cultivation. Two farmers are uncertain about the future. One expressed this in his lack of conviction about future actions. Another is concerned about proposed economic liberalization of the Costa Rican rice market.

Present Economic Situation of the Farmers

We noted differences in the economic lifestyle of farmers of the three communities. Bagatzi houses are concrete, have tiled patios, radios, and fences. We saw new bicycles and new clothes. San Ramon houses are wooden, but solidly built. Only one radio was noted. Furniture is simple and rustic. There appears to be the greatest range of lifestyles here. Falconiana homes are wooden and two of them appear old and rather dilapidated. Clothes and furniture are well worn.

From farmer reports of input prices, amounts used, and yields, we calculated 'typical' household agricultural budgets for the San Ramon and the Bagatzi communities (Table 3). Yields and gross receipts of the irrigated farms are twice those of the non-irrigated farms. Income above variable costs is almost three times as high, explaining our initial observations of income disparity. Surprisingly, San Ramon farmers' estimated outlay for agrochemicals is close to that of their Bagatzi counterparts.

Net income above variable costs depends on the price of rice. Currently, rice sells for 1780 colones per unprocessed quintal, but farmers gave a low price of 1200 and a high of 2000 colones. As seen in Table 3, San Ramon farmers are more vulnerable to rice price fluctuations than are Bagatzi farmers. Both make a reasonable income in high price years, but in low price years San Ramon farmers fail to break even. The yield variability reported by two San Ramon interviewees points to a high risk enterprise.

The cultivation of subsistence crops buffers the risk for small farmers throughout the world. All the San Ramon farmers grow other crops: maize, beans, fruits for home consumption; maize, melon, and peppers for local markets. Of the systems studied, Falconiana and Bagatzi farmers stand at either end of a spectrum, the former growing more subsistence crops, the latter less. Though the Bagatzi farmers grow fruit trees in dooryard gardens, only one rents an additional quarter hectare for subsistence maize. Additionally, the San Ramon farmers have non-crop sources of income: one rents out farm machinery; one operates a tree nursery; and two own cattle which they graze on land they rent. Unlike the Bagatzi farmers, they do not depend on rice production for their economic survival.

All San Ramon farmers (and Falconiana) see irrigation as the most important means of improving their agriculture; they expect SENARA to provide them water in the near future. Two said they would try a variety of "new crops," such as tomatoes and chilies, when irrigation came.

At present there is no economic reason for Bagatzi farmers to reduce their use of agrochemicals: they are prospering with them. Furthermore, no one seems to be developing alternatives to help Guanacaste rice producers break out of their chemical-intensive system.

Conclusion

Agrochemicals are used intensively on all but the poorest of the farms we visited, generally without appropriate health and environmental precautions. However, little has been done to evaluate or mitigate the impact of nitrates and agrochemical residues on human health and the environment. Based on the information we obtained, we suggest that MAG, SENARA and other agencies, along with local communities and co-ops, consider the following steps to investigate and reduce the impacts of agrochemical use:

- Regular sampling of soil and water at the field, community, and irrigation project levels;
- Long term monitoring of the health of residents;
- Assessing effects on wildlife, particularly game and fish species;
- Informing farmers and their families of the health risks posed by local agricultural practices;
- Eliminating credit and insurance conditions that force farmers to use prescribed agrochemical packages;
- Educating extension agents and farmers in integrated pest management and polyculture techniques.

Because most local farmers are particularly reliant on technical advice, we believe that education of extensionists will be the most efficient route to more sustainable agricultural systems. Officials suggested that non-traditional export crops will become more important in Guanacaste in the near future. This shift would appear to be an excellent opportunity for a simultaneous shift to agricultural practices that minimize impact on human health and the environment.

Table 1. Site Characteristics.

Site	Respondents	Irrigation	Size	Crop Type	# Titles
San Ramon	4	No	sm	Cash	2
Bagatzi	3	Yes	sm	Cash	3
Falconiana	3	No	sm	Subsist	0
Catalina	1	Yes	lg	Cash	1

Table 2. Pesticide Application Trends and Social Factors.

Site	Pesticide Application*		Credit	Insurance	Tech Info
	Prevent	Responsive			
Catalina	**	**	-	-	Private
Bagatzi	86%	14%			
1	8	0	Bank	Yes	Co-op
2	9	0	Bank	Yes	Co-op
3	1	3	Bank	Yes	None
San Ramon	54%	46%			
1	4	5	Store	No	Store
2	4	5	Store	No	Store
3	3	2	Store	No	Store
4	9	5	None	No	MAG
Falconiana	0%	100%			
1	0	4	Other	No	None
2	0	6	None	No	None

* Number of pesticide applications refers to the number of applications of each chemical brand, summed over all brands. The actual number of applications is lower due to mixing of brands.

** Catalina has a longer list of chemical brands than any other farm interviewed, however, information regarding the number of applications of each chemical is unavailable.

Table 3. Variable Costs.

INPUTS	Variable Costs	
	SAN RAMON	BAGATZI
Mech-Preparation	128,000	160,000
--Spraying	---	36,000
--Harvesting	15,525	31,441
Hired labor -- Plant	---	5,000
--Weeding	---	5,000
Seeds	80,000	180,000
Water	---	25,000
Advice	---	30,000
Agchem--Insectics	25,320	27,472
--Fungicides	10,800	18,000
--Herbicides	65,880	104,850
--Fertilizers	409,442	467,705
Agchem-Subtotal	511,442	618,027
Abchems as % TVC	(70%)	(57%)
Total	734,967	1,090,468
Yield (QQ/Ha)	67.5	136.7
Price (Cos/QQ)	1725	1725
Gross Agric Income	931,500	2,358,075
Variable Costs	-734,967	-1,090,468
Income Above VC	196,533	1,267,607
(In \$U.S.)	\$1,404	\$9,504
Inc Above VC/Ha	24,567	126,760
Rice Price	Net Inc/Ha (SRam)	Net Inc/Ha (Bag)
2000 Co/QQ	\$308	\$1174
1750 Co/QQ	\$176	\$905
1500 Co/QQ	\$67	\$686
1200 Co/QQ	-\$78	\$393
1000 Co/QQ	-\$174	\$198
(In \$ U.S.)	\$176	\$905

Appendix I

Interview Questionnaire

Part I: Background information

1. Number of years lived here
2. Where lived before.
- 3a. Previous occupation.
- 3b. Previous experience with rice.
4. Reason for move.
5. Size of household. Number of children.
6. Does the family help in the field?

Part II: Crops and land

1. Member of SENARA / IDA / Cooperative?
2. Do you own the land? (rent?)
3. Number of hectares?
- 4a. Credit? (Y/N) - from where (Bank/coop/other)?
- 4b. Insurance? (Y/N)
- 4c. Extension? (Y/N)

Part III: The crops

1. System type? (Rice/Mixed); (Subsistence/Cash)
2. Which RICE variety?
3. Month(s) of planting.
4. Source of seed.
5. Amount of seed per hectare.

Part IV: Labor and Machinery (Manual, Mechanized, Family, Hired) *[Include PRICES if known.]

1. Preparation of land.
2. Planting.
3. Irrigation.
4. Weeding.
5. Pest control.
6. Harvesting.

Appendix I continued.

Part V: Insecticides/Herbicides/Fungicides, etc.

- | | | | | |
|---------------------|--------|--------|--------|--------|
| 1. Where purchased. | | | | |
| 2. Insecticides: | NAME 1 | NAME 2 | NAME 3 | NAME 4 |
| When applied. | | | | |
| Why applied. | | | | |
| Doses. | | | | |
| Price. | | | | |
| 3. Herbicides: | NAME 1 | NAME 2 | NAME 3 | NAME 4 |
| When applied. | | | | |
| Why applied. | | | | |
| Doses. | | | | |
| Price. | | | | |
| 4. Fungicides: | NAME 1 | NAME 2 | NAME 3 | NAME 4 |
| When applied. | | | | |
| Why applied. | | | | |
| Doses. | | | | |
| Price. | | | | |
| 5. Others: | NAME 1 | NAME 2 | NAME 3 | NAME 4 |
| When applied. | | | | |
| Why applied. | | | | |
| Doses. | | | | |
| Price. | | | | |

Part VI: Irrigation

1. Irrigated?
2. When applied? Frequency?
3. Control of water used? (Y/N) [HOW?]
4. Cost.
5. Perception of cost.

Part VII: Fertilizer (natural/chemical)

1. If used.
2. How often? / When?
3. Amount.

Part VIII: Harvest

1. Amount.
2. Where sold/marketed?
3. What done with residue?

Part IX: Future

1. Harvest trends.
2. Means of improvement. (e.g. irrigation, fertilizer, variety, etc.)
3. Affected by practices of other farmers.
4. Optimistic/Pessimistic/Apathetic.

**CENTRAL
VALLEY**

COSTA RICA

Guided Field Problem

SOILS

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Resumen

Se analizaron suelos de fincas de lechería, plantaciones de café y fincas de verduras en el Valle Central. El análisis incluyó las siguientes pruebas: la respiración del suelo, el material orgánico, el porcentaje de humedad del suelo, la densidad, la textura, el pH, los insectos del suelo y los lombrices.

Abstract

Soils from dairy farms, coffee plantations, and vegetable farms in the Central Valley were analyzed. The analysis included tests for soil respiration, organic matter, percent moisture, bulk density, texture, pH, soil insects, and earthworms.

Introduction

The soils in the San Jose province of Costa Rica are predominantly Andisols that support coffee, vegetable, and dairy industries. Andisols are relatively young soils composed of allophane clays derived from volcanic materials. They are generally well-drained soils, high in organic matter and moisture content, though often deficient in phosphorous due to the strong binding affinity of allophane clays for phosphorous. The relatively high fertility of Andisols has encouraged extensive agricultural development near San Jose. In this study, we tried to determine the impacts of different agricultural approaches upon the following factors affecting soil quality:

Soil Respiration

To measure respiration in our soil samples an incubation method that measures the level of carbon dioxide (CO₂) was employed. A set of two samples were created from each area that soil was obtained and put in separate flasks. One sample from each set was sterilized in an autoclave to assure no respiration would occur due to microorganisms in the soil. These samples were used as controls. The other samples were left intact.

A test tube with a pre-measured amount of sodium hydroxide was then introduced into each flask. Sodium hydroxide combines with CO₂ when present thereby reducing its volume. The flasks were then sealed and allowed to incubate for 48 hours.

After this time period the samples were opened and the NaOH was combined with an indicator and then titrated with hydrochloric acid. The amount of HCL added was then used in an equation that yielded the amount of CO₂ present.

Organic Matter

Subsamples of each composite soil sample were analyzed for percent organic matter using the Walkley and Black digestion method (1938). Percent organic matter ranged from 5.2 to 13.4 for the eight samples. Because of suspicious results from the vegetable soils, the test was repeated for these three samples. Variations among repeated samples were 12 to 33 percent from their original values. Because only analysis of vegetable samples was repeated, results from the second analysis are not included in this report.

Percent - Moisture

As any moisture in soils can bias the results of most soil tests, soils data is generally expressed on a dry weight basis. To determine the percent of moisture, the weight of soil samples was recorded prior to and after overnight drying of the samples in an oven at 110°C. (Generally, samples are dried at 60°C to prevent the loss of organic matter in the drying process, however, due to time constraints this was not possible.) The difference between the wet and dry weights of the sample gives the moisture content. $(\text{wet weight} - \text{dry weight} / \text{dry weight}) * 100 = \% \text{ moisture}$.

Bulk Density

The contents of a 215 ml can (soil core) were dried and weighed; this figure was divided by the volume of the container to calculate the bulk density of the soil sample.

Texture

Texture is defined as the particle size composition of a soil sample. Based on size, soil particles can be divided into sand (>0.2 mm), silt (0.002 mm < x < 0.2 mm), and clay (< 0.002 mm). Soils are classified by texture on the basis of the percentages of sand, silt and clay.

The sand fraction promotes infiltration and drainage, and susceptibility to erosion, whereas clay has a high water holding capacity but poor infiltration and percolation. Soils richer in clay content are more capable of resisting erosion. In addition, due to the electrostatic and physical nature of the clay particles or aggregates, the clay together with organic matter can strongly influence both moisture retention as well as the storage and release of minerals and nutrients for plants. This exchange of cations and anions with soil water is also dependent on both the pH and the type of clay.

A composite of 10 arbitrarily chosen sub-samples was analyzed from each plot for texture. The sub-sample consisted of a volume of soil, approximately 30x30x15 cm³, scooped out with a shovel.

The method used was a modification of the Bouyocos hydrometer method (Storie, 1970). The method is based on the fact that sand, silt and clays differ markedly in their settling characteristics when a soil slurry or solution is left undisturbed. At any given time, the density of the suspension will indirectly indicate the fraction that has already settled.

Sixty grams of wet soil was shaken overnight in solution to which sodium metaphosphate was added to disperse the clays. The soil slurry was then poured into a graduated glass cylinder and topped to 1000 cc volume, which included the hydrometer. The slurry was then thoroughly shaken for a minute before the hydrometer was gently placed in the center of the cylinder. Readings of the hydrometer were taken at 40 seconds and at two hours duration. Temperature was measured immediately after each hydrometer reading. The percentages of clay and sand were calculated after accounting for the use of wet soil instead of dry as is normally done. At 40 seconds all the sand was assumed to have settled and clay within two hours. The equation used was:

$$\% \text{ sand} = 100 - (\text{hyd. reading} + (T-20)*0.3).$$

pH

Ten ml of each soil sample was suspended in 25 ml of deionized water using a mechanical stirrer. The pH of each suspension was measured using an Orion Research meter.

Insects

Samples were collected to an approximate depth of 10 cm using 500 cc core sample/bulb pullers. These instruments were made from pvc tubing that was shaved to a relatively sharp point on one end, and covered with fine mesh on the non-shaved end. Before collecting samples, above ground vegetative biomass was removed, but samples included vegetative biomass contained within the soil. Three samples were collected at each site. At the dairy site these samples were kept separate, but at the other sites, samples were aggregated. After collection, samples were removed from the instruments in order to break up the soil and reduce the compaction of the soils that frequently results from the sample collecting process - pounding the instrument into the ground. This is necessary to allow the insects to move within the soil column. Samples are replaced in the instruments and placed on an open-air incubator. Instruments are placed several centimeters below 50 watt light bulbs. Beneath each instrument is a funnel that is placed in a collection bottle half-filled with acetyl alcohol. The heat from the light bulbs slowly dries the soils and causes insects in the soil column to move away from the heat source.

Once insects reach the bottom of the soil column, they crawl through the mesh and fall down the funnel into the collection bottle.

Earthworms

Three samples, approximately 900 cc, were collected at each site. Samples were sorted and the number of worms were recorded. Results are presented in number of worms per kilogram. Samples were aggregated at all sites except at the dairy pastures, where they were kept separate.

Dairy Soils

We compared soils under three different levels of use from dairy cattle operations for various indicators of site quality (See Table 1). Site D-1 is a large dairy operation with approximately 4.5 cows/ha. Site D-2, a small farm with 8-10 cows/ha., represents intensive land use for dairy cattle management in this study. Site D-3 represents an ungrazed site. Here the small farmer harvests grass as a source of feed for his dry-lot cows.

Both D-1 and D-2 have been producing dairy cattle for over 20 years, and both use only chemical fertilizers. The soil of site D-2 showed evidence of mechanical disturbance and movement.

Our soil analyses show that the small farmers lands, (sites D-2 and D-3), contains more highly degraded soils than the large farmers site (D-1). Compared to D-1, both samples from the small farm had lower clay content and organic matter, reducing potential for these materials to contribute to nutrient retention and cation exchange capacity. Soil analyses showed the grazed land (D-2) to have the highest bulk density and sand content, and the lowest organic matter of all eight soil samples (see Table 1).

Based on information about the grazing intensity and frequency on this land, we concluded that the cattle were having a negative impact on the soils -- increasing soil compaction, reducing water infiltration, and decreasing the amount of organic matter introduced to soil from vegetation, and microorganism and earthworm activity. We cannot, however, entirely attribute the soil condition to grazing impact. The site had clearly been mechanically disturbed by heavy machinery. Such disturbance has likely increased soil erosion and contributed to the leaching of some soil minerals by altering soil structure.

Collecting the data on earthworms as number/volume (cubic centimeters (cc) of soil) is not the ideal method to use, but due to limited time and equipment, we had to use it. Ideally we would have measured biomass of earthworms represented as kg/ha. Counting the number of earthworms can be misleading and skew data analysis. Worm fragments may be overrepresented in the sample size. In addition, since the size and

weight of earthworms varies greatly, a numerical representation does not accurately represent the potential magnitude of their effect on physical and chemical soil properties.

Worm counts were only conducted at sites D-1 and D-2. The total counts between these sites were markedly different. D-1 contained an average of 5.8 worms per 1000 cc of soil, whereas D-2 only contained an average of 1.1 worms per 1000 cc of soil. These results support the data from the soils analyses which showed that soils having higher compaction and less organic matter contain fewer earthworms.

Within site comparisons of earthworm counts also revealed interesting results. At both D-1 and D-2, our sampling technique was to examine three diverse soil/vegetation conditions. At each site we sampled areas where it appeared that soils were highly compacted by cattle activities, areas where grazing activity appeared to be moderate, and areas where grazing activity appeared to be slight. In each case, the total earthworm counts fell in largely spaced increments along a gradient where the lowest number occurred in the most compacted soils, and the highest number in the soils least impacted by grazing activity. These results support other research (Lavelle), indicating that earthworm activity increases soil porosity and water infiltration, and improves soil fertility. Most literature (Lavelle) discusses the positive impacts of earthworms on physical and chemical properties. However, it is interesting to note that in some case studies in tropical soils, earthworm activity has contributed to soil degradation. In such cases, earthworms mineralize the soils at a rate greater than that which plants are able to absorb the liberated minerals. The net effect is to increase leaching of materials from the soils.

If we assume that the soils on the two sites exhibited similar chemical and physical soil properties prior to the dairy operations, we can infer from our soils analyses that the more intense grazing activity on D-2 has degraded those soils. Due to the extremely small sample size, it is not feasible to make further inferences about the relationships between overall soil quality and land tenure. However, in the future, sample sizes could be increased to examine the possibility that smaller farmers begin their dairy operations on poorer quality soils that are more susceptible to degradation by cattle grazing.

Coffee Soils

A comparative study of the soils of organic and conventional coffee plantations was carried out on two adjacent lots at the Britt Company. The purpose of the study was to determine the sustainability of the two systems, however, our results were inconclusive.

The organic coffee plantation is in its third year of production. Previously, the land was a pasture. In contrast, the conventional coffee plantation at Britt has been in cultivation for more than fifteen years. The two sites are similar in many respects: their close proximity, a slope of less than one percent, and a similar altitude.

Some of the results were more pronounced than others. The bulk density of the soils of conventional coffee was higher than that of organic coffee. This can be attributed to a lesser content of organic matter and a higher incidence of compaction in the conventional plot. The organic soils are less compacted, possibly due to the tilling three years ago during field preparation. The presence of fewer worms in the organic coffee field might also be a result of the more recent land preparation, during which worms may have been killed. Due to possibly higher temperature (less shade), the organic plot, is at present, less hospitable for worms as compared to the conventional plot.

The higher percentage of both clay and organic matter found in the organic coffee field implies a greater capacity to hold nutrients and minerals in the soil. It also enables the soil to absorb copper (from the copper sulfate fungicide, which is applied on both organic and conventional coffee fields), which would otherwise be toxic to the plants or be washed away in runoff. However, it is also possible that the displacement of phosphate from the organic-clay complex caused by the absorption of sulphate may be beneficial to the coffee plants.

A difference in the pH figures was obtained when testing the organic and conventional soils (5.9 and 5.3, respectively). Unfortunately, we were unable to attribute this difference to anything in particular.

This pilot study began with the intention of studying the sustainability of both organic and conventional coffee. However, as there were no significant differences in the data, no conclusions regarding a more and less sustainable farming system can be drawn.

Vegetable Soils

Three farms (V1, V2 and V3) were selected for soil analysis. V1 was a combined sample taken from two lettuce fields (one newly planted and one mature) of the organic farmer who was interviewed. V2 was a neighboring farmer's lettuce field (mature). In this field some organic practices were being used. V3 was a cabbage field (newly planted) of the conventional farmer who was interviewed.

Textures among the three farms differed in that V1 was coarsest, V2 was somewhat finer, and V3 had a noticeably higher amount of clay. V3 also had a higher bulk density than V1 or V2. V3 appeared more compacted, which is reflected in the relatively high bulk density and low percent moisture. It is unclear if these differences are due to management or location, since V3 was some distance from V1 and V2. Percent organic matter for the three farms ranged from 10.7 to 13.4. These figures are within the expected percent organic matter range for these Andisols. Surprisingly, the organic farm had lowest organic matter. This circumstance may have been due to sampling between crop rows, instead of within rows, especially for the organic farm which had more defined bed-like ridges on which the crops were growing. pH was slightly higher for the organic farm, possible due to liming. No worms were found in

either V1 or V2 (V3 was not sampled). This may have been due to the intense rain at the time of sampling. CO₂ evolution was higher in V1 than V3. The autoclaved controls for these samples were very close to the value for the NaOH used for this analysis, leading one to assume these values to be fairly accurate. If this is the case, microbial activity was probably higher in the organic farm than the conventional farm. Soil insect counts were the same in V1 and V3. In summary, the organic farm's soil apparently had more sand, lower bulk density, higher pH, less organic matter, more moisture, and more microbial activity than the conventional farm.

Table 1. Various Agricultural Approaches Affecting Soil Quality.

Forms	C1 ^a	C2 ^b	D1 ^c	D2 ^d	D3 ^e	V1 ^f	V2 ^g	V3 ^h
% sand	47.0	11.5	8.1	8.9	13.2	14.7	12.3	18.8
% silt	23.7	11.5	8.1	8.9	13.2	14.7	12.3	18.8
% clay	29.3	38.6	31.0	26.2	27.3	30.8	45.0	56.4
Bulk Density	.856	.671	.767	.892		.670	.577	.11
Organic Matter	10.0	11.8	9.4	5.2	7.5	10.7	13.4	12.9
pH	5.3	5.9	5.6	5.7	5.7	5.7	5.3	5.4
% moisture	58.4	60.0	52.1	44.2	56.0	87.9	80.5	77.3
Worms per 1000cc	3.4	1.6	5.8	1.1		0		0
CO2 mg/g-day	-.05	-.13	-.12	.05	.49	.47		.37
Insects	1dip	5mite		3col	1dip		1dip	1dip

^a conventional coffee plantation

^b organic coffee plantation

^c large dairy operation with approximately 4.5 cows/ha

^d small farm with 8 - 10 cows/ha

^e ungrazed site

^f 2 lettuce fields (one newly planted and one mature)

^g mature lettuce field

^h newly planted cabbage field

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Guided Field Problem

ECONOMICS OF COFFEE PRODUCTION AT THE CENTRAL VALLEY, COSTA RICA

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Abstract

A study of the economics of coffee production was done in order to compare the profitability of organic and conventional coffee production systems. The analysis focused on the differences in the variable costs of the two systems. The study showed that the conventional coffee production system is more profitable on per hectare basis. Sensitivity analysis showed a higher breakeven yield and income above variable costs for conventional coffee production system at all prices. However, given unforeseeable yield constraints, an organic coffee farmer may be at an advantage because of lower breakeven yield. Although a conventional coffee production system seems to be more profitable, it might be unsustainable environmentally, especially when environmental costs are considered.

Introduction

Coffee is one of the major cash crops grown for export in Costa Rica. The crop is grown by both small farmers and big farmers who own large coffee plantations. Coffee production is at present being done under two systems referred to as conventional and organic production systems. The difference between the two systems is based on the use of chemicals. In the organic coffee production system no chemical fertilizer or pesticides are used, and instead organic fertilizers like chicken manure and coffee pulp are preferred. The conventional system is the opposite of the organic system in terms of fertilizer and pesticide used. Most small farmers use the organic system, while most big farmers use the conventional system or a mixture of the two. Based on market demand and requirements, organically produced coffee has a higher price than conventionally produced coffee. In this study, the economics of production in the two systems is examined.

Objectives

The objective of this analysis is to determine the profitability of the two systems based on the differences in their variable costs.

Method

Our analysis focused mainly on the differences in the variable costs of the two production systems, fertilizers, weed control, harvesting, and pruning. Much of our information was obtained from Cafe Brit, located in the Central Valley, a large coffee producer and processor that has areas using both conventional and organic methods of coffee production. Our figures for the variable costs were obtained mainly from Cafe Brit data. However, the Ministry of Agriculture data were also consulted. Often times the Ministry of Agriculture cost data was 50% lower on a per hectare basis. For yield we used both Ministry of Agriculture and Cafe Brit data. The price per fenaga of coffee cherries was obtained from Cafe Brit. With this data we calculated the total costs, receipts, and income above variable costs for both the organic and the conventional systems. With these figures we performed a sensitivity analysis to determine the break even yield and the break even price.

Results and Discussion

Given the current price, yield, and variable costs, our analysis indicates that the conventional coffee production system is more profitable on a per hectare basis. For example, using the current price and variable costs, the income above variable costs for the organic and conventional system is 162460 and 242352 colones per hectare, respectively (Tables 1 and 2).

Our sensitivity analysis shows, at all prices applied, the income above variable costs is higher for the conventional system than the organic system. However, the break even yield is higher for the conventional system at all prices (Tables 3 and 4). This indicates that an organic coffee farmer can operate profitably at lower yields than a conventional coffee farmer. In this case, given unforeseeable yield constraints, an organic farmer may be at an advantage.

Conclusion

Although organic coffee production seems to be less profitable under this method, it seems to be environmentally acceptable in the long run. Taking into account the environmental costs associated with conventional system, it might therefore be unsustainable environmentally.

Recommendations

A further analysis, which will consider all costs involved in the two systems including environmental costs, is necessary before a strong conclusion can be drawn.

Table 1. Production Economics for Organic Coffee Production System Using Variable Costs.

Item	Quantity	Price	Total
Receipts	40	9200	368000
Fertilizer			
Chicken manure/			
Coffee pulp (qq)	434.78	50	21739.13
Application (mdays)	25	1160	29000
Weed control (mdays)			
June	5	1160	5800
August	5	1160	5800
October	5	1160	5800
December	5	1160	5800
Total			73939.13
Harvesting			
Picking and transportation	40	3000	120000
Pruning (mdays)	10	1160	11600
			205539.1
Income above variable cost			162460.8
Breakeven price			5138.48
Breakeven yield			22.34

Table 2. Production Economics for Conventional Coffee Production System Using Variable Costs.

Item	Quantity	Price	Total
Receipts	65	8000	520000
Fertilizer (qq)			
Complete	24	1450	34800
Nitrogen	6	1200	7200
Labour (mdays)	10	1160	11600
Pest/weed control			
May:			
Roundup (Lts)	2	1850	3700
Labour (mdays)	2	1160	2320
July:			
Roundup (Lts)	2	1850	3700
Nematocide (Lts)	4	1352	5408
Labour (mdays)	2	1160	2320
Total			71048
Harvesting			
Picking and transportation	65	3000	195000
Pruning (mdays)	10	1160	11600
			277648
Income above variable cost			242352
Breakeven price			4271.507
Breakeven yield			34.706

Table 3. Sensitivity Analysis - Organic Coffee Production.

	Yield			Price	
	Income Above Variable Costs	Breakeven Price		Income Above Variable Costs	Breakeven Yield
	162460.8	5138.478		162460.8	22.34120
20	-21539.1	10276.95	5000	-5539.13	41.10782
30	70460.87	6851.304	6000	34460.87	34.25652
40	162460.8	5138.478	7000	74460.87	29.36273
50	254460.8	4110.782	8000	114460.8	25.69239
60	346460.8	3425.652	9000	154460.8	22.83768
70	438460.8	2936.273	10000	194460.8	20.55391
80	530460.8	2569.239	11000	234460.8	18.68537
			12000	274460.8	17.12826
			13000	314460.8	15.81070
			14000	354460.8	14.68136

Table 4. Sensitivity Analysis - Conventional Coffee Production.

	Yield			Price	
	Income Above Variable Costs	Breakeven Price		Income Above Variable Costs	Breakeven Yield
	242352	4271.5		242352	34.71
20	-117648	13882.4	5000	47352	55.53
30	-37648	9255.0	6000	112352	46.27
40	42352	6941.2	7000	177352	39.67
50	122352	5553.0	8000	242352	34.71
60	202352	4627.5	9000	307352	30.85
70	282352	3966.4	10000	372352	27.77
80	362352	3470.6	11000	437352	25.24
			12000	502352	23.14
			13000	567352	21.36

Guided Field Problem

COMPARATIVE ENERGY ANALYSIS OF ORGANIC AND CONVENTIONAL VEGETABLE FARMS

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Resource Person: Chela Vasquez

Resumen

Este estudio compara la eficiencia energética entre una finca orgánica de lechuga y una finca inorgánica de repollo en la región de Zarcero en Costa Rica. Nuestros resultados indican que la finca inorgánica de repollo es cinco veces más eficiente que la finca orgánica de lechuga; no podemos distinguir si aquel efecto puede ser atribuido al sistema agricultura, a la hortaliza cultivada, o a una combinación de los dos.

Abstract

This study compares the energy efficiency of an organic lettuce farm with that of an inorganic cabbage farm in the Zarcero region of Costa Rica. Our results indicate that the inorganic cabbage farm is five times more efficient than the organic lettuce farm; we are unable to distinguish whether this effect is due to farming system, crop grown, or a combination of both.

Introduction

The world's human population depends upon plants and animals to convert solar energy into forms of energy available to humans for food or fiber. As the hunter-gatherer strategy for procuring food declined, humans have relied increasingly on direct manipulation of their environment to produce these plants and animals. Agricultural efforts entail a high investment of human, animal, wood, and fossil fuel energy. In order to meet the caloric needs of a burgeoning population with a finite supply of arable land, it is important to maximize the efficiency with which this energy input is converted to energy forms for human consumption.

In the Zarcero highland valley of central Costa Rica, small farmers have traditionally relied on heavy inputs of energy-rich chemicals. Recent farming initiatives, however, are turning toward alternative agricultural systems that are less reliant on these energy-rich chemicals. This study examines two 1-1/2 ha Zarcero vegetable farms, one conventional and one organic, to compare their energy flows and the efficiency of their energy conversion.

Materials and Methods

Based on a preliminary visit to the farms, general descriptive models of the rough energy flows of the two farms were developed. These models described the energy flow for a single crop. Because the two farms did not have any crops in common, lettuce was analyzed for the organic farm of Luis Eladio & Orlando Rodriguez Vargas and cabbages for the conventional farm of Luis Angel Castro. Based on inputs and outputs identified in these models, interviews were conducted with the owners of the two farms to determine the input amounts of fuel, labor, chemicals, fertilizers, and other sources of energy inputs. Crop yield was used to determine total output.

In order to standardize the energy units for all inputs and outputs, each was converted to its kcal value using energy conversion factors. All analyses were based on values for one hectare of crop per year. The final energy efficiency ratio for each crop was determined by adding the total energy for inputs and comparing it to the total energy of the crop yield.

Results

Tables 1 and 2 show the unconverted commodity and labor inputs, conversion factors (CF) and converted energetic values per hectare per year for the conventional and organic vegetable crops. Tables 3 and 4 show both crop yield outputs in weight and energy per hectare per year, as well as the energy efficiency ratios. The conventional farm has an energy efficiency of 1:1.82, total labor input of 1806 h/ha/yr, total material input of 13,536,795 kcal/ha/yr and a cabbage yield of 25,898,400 kcal/ha/yr. The organic farm has an energy efficiency ratio of 3.24:1, a total labor input of 1833 h/ha/yr, total material input of 19,092,117 kcal/ha/yr, and a lettuce yield of 6,133,600 kcal/ha/yr.

Discussion

Our results suggest that the conventional cabbage farm is energetically efficient, with a net energy profit of 1 to 1.82. The organic lettuce farm is not energetically efficient, with a net energy loss of 2.64 to 1. The categories of energy expenditure indicate that, in terms of energy, the conventional and organic farms are equally labor intensive but not equally material intensive. The organic farm depends on 40% more material energy inputs, due primarily to a high value of charcoal and chicken manure in the bocachi input. This high material energy input, combined with a slightly lower yield on the organic lettuce farm, make the conventional cabbage vegetable farm almost five times as energy efficient as the organic lettuce farm.

Unfortunately, we were unable to perform the intended comparison of efficiency between organic and conventional farming systems. The farms we examined had no crops in common; the energy flow systems differed in two variables--type of farming and crop

grown. Without further controls we were unable to draw conclusions about the comparative efficiency of either of these variables alone.

There are a couple factors that may contribute to the differences in efficiency ratios between the two farming systems. One fundamental difference between the two farms is that the organic farm has only two harvests per year, while the conventional has three. This difference considerably impacts the yield/ha/year, which is reflected in the energy ratio. Another is simply the difference in weight between units of lettuce and cabbage. Because the plants are roughly the same size, the same number of plants can be planted on one hectare. Upon harvest, however, the average cabbage head weighs approximately twice as much as the average lettuce head, which affects the yield/ha/year and again the energy ratio. Cabbage also has a higher kcal/kg conversion factor than lettuce. Cabbage may, therefore, be more inherently efficient in converting energy than lettuce.

The scope of this analysis was limited. Important energy components such as soil chemical energetic storage and runoff were not considered. The energy values for long-term environmental costs and benefits were also excluded, though these probably reflect significant differences between conventional and organic farming and are a fundamental issue in the analysis of sustainability of different farming systems. Water pollution caused by conventional chemical inputs, for instance, was not assessed. Likewise, this analysis does not reflect possible long-term improvements of soil condition caused by the high-energy bocachi. Such improvements could mean that the organic system will require less bocachi input in the future, making the farm relatively more energy efficient. If the bocachi input were reduced to 10% of its current value, for instance, the organic farm's energy ratio would increase to an energy-efficient value of 1:1.15. In conventional systems, on the other hand, high-energy chemical inputs are more likely to remain constant or possibly increase.

The restrictions of our study design make this energy flow analysis of limited value in analyzing differences between conventional and organic farming systems and the sustainability of their efficiency conversions over time. However, given the parameters we considered, we found the conventional cabbage farm to be a more efficient converter of input energy than the organic lettuce farm.

Table 1. Inputs to Inorganic Cabbage Farm.

Input	Amount	CF*	Energy
	(kg/ha/yr)	(kcal/kg)	(kcal/ha/yr)
Cabbage Seeds	1.00	24,750	24750
Calcium, Lime	1800.00	315.00	567000.00
Herbicide	3.00	110071.00	330213.00
Fungicide	43.40	110071.00	4777081.40
Insecticide	61.35	85679.00	5256406.65
Fertilizer N	135.00	14702.00	1984770.00
Fertilizer P	405.00	3000.00	1215000.00
Fertilizer K	135.00	1595.00	215325.00
Barro Magnesium	6.00	14702.00	88212.00
TOTAL COMMODITY			13536795.05

Labor	Amount	CF	Energy
	(h/ha/yr)	(kcal/hr)	(kcal/ha/yr)
Nursery	20.00	306.00	6120.00
Soil Prep	600.00	516.00	309600.00
Transplant	160.00	306.00	48960.00
Chem. Appl.	626.00	306.00	191556.00
Weeding	100.00	516.00	51600.00
Harvest	300.00	306.00	91800.00
TOTAL LABOR	1806.00		699636.00

TOTAL ENERGY INPUT (kcal/ha/yr)	
Commodity	13536795.05
Labor	699636.00
Total	14236431.05

* Conversion factor estimates were obtained from Adams 1975, Pimental & Pimental 1977, Pimental 1984, Vasquez 1985, Vasquez 1992, and Wayne Oldegard, pers. comm.

Table 2. Inputs to Organic Lettuce Farm.

Input	Amount	CF	Energy
	(kg/ha/yr)	(kcal/kg)	(kcal/ha/yr)
Lettuce Seeds	2.40	3480.00	8352.00
Charcoal	3140.00	4515.00	14177100.00
Chicken Manure N	56.16	14702.00	825664.32
Chicken Manure P	14.40	3000.00	43200.00
Chicken Manure K	12.60	1595.00	20097.00
Rice Husk	1195.00	1830.00	2186850.00
Rice Flour	216.00	3333.00	719928.00
Repellant N	0.12	14702.00	1764.24
Repellant (Garlic)	12.00	1565.00	18780.00
Repellant Pepper	36.00	3500.00	126000.00
Insecticide Leaf	4.00	260.00	1040.00
Truck Fuel (L)	84.40	11414.00	963341.60
TOTAL COMMODITY			19092117.16
Labor	Amount	CF	Energy
	(h/ha/yr)	(kcal/hr)	(kcal/ha/yr)
Nursery	96.00	306.00	29376.00
Soil Preparation	96.00	516.00	49536.00
Transplanting	144.00	306.00	44064.00
Bocachi Prep.	800.00	516.00	412800.00
Bocachi Appl.	64.00	516.00	33024.00
BioChemical Prep	112.00	306.00	34272.00
BioChemical Appl.	224.00	306.00	68544.00
Harvesting	288.00	306.00	88128.00
Transport Driving	9.00	306.00	2754.00
TOTAL LABOR	1833.00		762498.00
TOTAL INPUT (kcal/ha/yr)			
Commodity	19092117.16		
Labor	762498.00		
Total	19854615.16		

Table 3. Output (Yield) and Efficiency Ratio for Inorganic Cabbage Farm.

Total Cabbage Yield (kcal/ha/yr)		
Amount	CF	Energy
(kg/ha/yr)	(kcal/kg)	(kcal/hr/yr)
108000.00	239.80	25898400.00
ENERGY EFFICIENCY RATIO	Input: Output	1:1.82

Table 4. Output (Yield) and Efficiency Ratio for Organic Lettuce Farm.

Total Output		
Yield	CF	Energy
(kg/ha/yr)	(kcal/kg)	(kcal/ha/yr)
34000.00	180.40	6133600.00
ENERGY EFFICIENCY RATIO	Input: Output	3.24:1

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Guided Field Problem

ECONOMIC ANALYSIS OF DAIRY FARMING

Authors: Ankila Hiremath and Pamela Stedman
Faculty: Wayne Odegard and Upton Hatch

Abstract

An economic comparison of two **dairy** farms was made to determine relative profitability and viability of small-scale versus large-scale systems. Important differences were found in input costs and incomes.

Objective

To compare the economic viability of large-scale and small-scale **dairy** farming in the Central Valley.

Methods

Two **dairy** farmers in the Coronado region were interviewed to obtain information on expenses and revenues. Several stores were also visited. A cash flow statement was created using the information gathered. Only variable costs (cash flow) were considered, since information on capital investment was not readily available.

Large Farm

The large dairy farm, La Dorbel, has 40 ha, of which 12 are regularly used for pasture. 54 cows are kept. They are fed concentrate, mineral supplements, and bananas. They graze all day. A rotation system is used; the cows graze on one-quarter to one-half hectare per day, while the remaining pasture is fertilized and given time to recover. Four full-time and one half-time employees care for the cows and pasture maintenance.

Milk production averages 18.5 liters per cow per day. Milking machines are used. Milk is sold to Borden's processing plant. Prices are variable and have fallen recently. Although there is an agreement between the government and the dairy union to keep milk prices at 45 colones per liter (to the producer), currently Borden is paying 40 colones per liter for the first 600 liters produced by this farm and 18 colones per liter for the remainder. Milk production on the farm has recently been reduced from 1000 liters to 750 liters per day.

The cows produce about one calf every 14 months. All male and some female calves are sold immediately. The remainder are raised on the farm as dairy cows. About six to seven cows are culled each year.

Small Farm

The small dairy farm has 3.5 ha, co-owned by Carlos Garcia and his brother. 28 cows are kept. They are fed concentrate, mineral supplements, bananas and cut forage. Some of this hay is cut on the farm and some is purchased. The cows are kept in semi-confinement. Some cows are grazed for a few hours a day on municipal land, for no charge, and some on rented land, on a per head basis. The land used for growing forage is occasionally fertilized. Garcia and his brother work full-time on the farm, with some additional help from family members. Garcia's wife devotes some time to raising calves and making cheese.

Milking is done by hand. Production averages 13.5 liters per cow per day. Milk is sold to a cooperative, Coop Coronado. The price paid by the coop has fallen recently because of market conditions and heavy debt incurred by the coop. Until recently, the coop paid about 30 colones per liter; now it occasionally pays as little as 3 colones per liter. Garcia has been unable to find another market for the milk. His wife makes about eight kilos of cheese every other day, which requires purchase of fuel wood. Cheese is sold in local markets.

Cows produce about one calf every other year. Some calves are sold and some are raised on the farm as replacements. About one cow is culled per year.

Results

The large farm is clearly a more profitable operation than the small farm. Net revenues for the large farm are about 9 million colones per year, as compared with 3.5 million for the small farm. Costs and revenues were calculated on a per cow basis, as well as totals. Per cow costs for the large farm were almost double per cow costs for the small farm. However, per cow revenues were substantially higher for the large farm, leading to higher net revenues. The difference in revenues results from differences in yields and differences in prices. Because the small farm has very little land, it has high expenditures for basic foodstuffs (cut forage, bananas and rented grazing). The large farm, on the other hand, has readily available pastures, and spends more on productivity-raising inputs such as concentrate, medications and mineral supplements. This means that the cows on the large farm have consistently higher milk yields; they also produce calves more frequently.

The price differential arises because of market outlets. The large farm sells to Borden, which pays more per liter of milk than the coop to which the small farm sells. The small farmer has been trying to sell to Borden, since the coop began to have

difficulties, but because of the flooded market, neither Borden nor Dos Pinos is willing to accept new producers.

The cost of labor is not clearly reflected in the cash flow statement. The large farm hires labor, so these costs are included in total expenses. All work on the small farm is done by family labor, so these costs are not included in the worksheet. If family labor was awarded even minimum wage, production costs for the small farm would be closer to those for the large farm and profits would be substantially lowered.

Sensitivity analyses were carried out for milk prices and concentrate prices. The breakeven point, based on milk price, are very different for the farms. Breakeven price for the small farm is about 4 colones per liter, while it is 15 colones per liter for the large farm. This is not surprising given higher per cow costs for the large farm and the fact that labor costs are not included for the small farm. Concentrate prices are relatively unimportant, within the likely range of prices.

Dairy Farming: Cash Flow Worksheet

Operating Expenses	Prices	Small Farm per cow	Large Farm per cow	Total Costs Small Farm	Total Costs Large Farm
			# cows:	28	54
Concentrate	1,080 bag	28,080	43,200	786,240	2,332,800
Purchased Forage	3,000 month	3,000		84,000	
Bananas	7,500 pile	13,900	7,250	389,200	391,500
Minerals	140 kilo	2,555	6,132	71,540	331,128
Grazing Rental	4,200 year/cow	4,200		117,600	
Low-cost Fertilizer	1,160 bag	250		7,000	
High-cost Fertilizer	1,450 bag		5,480		295,920
Medicines	3,000 per cow		2,890		156,060
Artificial Inseminations					
Two-year	900 per cow	900		25,200	
14 month	1,550 per cow		1,550		83,700
Labor					
Hired	150 hour		36,500		1,971,000
Family					
Utilities & Energy					
Electricity					
Low-intensity	810 week	1,500		42,000	
High-intensity	2,460 week		2,370		127,980
Wood	1,875 truck	3,900		109,200	
TOTAL OPERATING EXPENSES	29,275	58,285	105,372	1,631,980	5,690,088
Revenues	Prices	Small Farm per cow	Large Farm per cow	Total Revenues Small Farm	Total Revenues Large Farm
			# cows	28	54
Milk					
Coop Price	30 litre	147,825		4,139,100	
Industry Price	40 litre		270,100		14,585,400
Cheese	300 kilo	36,600		1,024,800	
Calves	4,500 calf	2,250	3,870	63,000	208,980
TOTAL REVENUES		186,675	273,970	5,226,900	14,794,380
NET PROFIT		128,390	168,598	3,594,920	9,104,292

SENSITIVITY ANALYSIS

Milk Price:

Small Farm (Coop)

3	(130,270)
6	283,640
9	697,550
12	1,111,460
15	1,525,370
18	1,939,280
21	2,353,190
24	2,767,100
27	3,181,010
30	3,594,920
33	4,008,830
36	4,422,740
39	4,836,650
42	5,250,560
45	5,664,470

Large Farm (Industry)

3	(4,387,203)
6	(3,293,298)
9	(2,199,393)
12	(1,105,488)
15	(11,583)
18	1,082,322
21	2,176,227
24	3,270,132
27	4,364,037
30	5,457,942
33	6,551,847
36	7,645,752
39	8,739,657
42	9,833,562
45	10,927,467

Concentrate Price:

Small Farm

900	3,725,960
950	3,689,560
1,000	3,653,160
1,050	3,616,760
1,100	3,580,360
1,150	3,543,960
1,200	3,507,560
1,250	3,471,160
1,300	3,434,760
1,350	3,398,360
1,400	3,361,960

Large Farm

900	9,493,092
950	9,385,092
1,000	9,277,092
1,050	9,169,092
1,100	9,061,092
1,150	8,953,092
1,200	8,845,092
1,250	8,737,092
1,300	8,629,092
1,350	8,521,092
1,400	8,413,092

Guided Field Problem

HOW MANY KILOCALORIES IN DAT THAR GLASS OF MILK?

Author: Christopher Rosin
Faculty: Wayne Odegard and Chela Vasquez

Resumen

Las dinámicos del flujo de energía de dos fincas lecheras de la Valle Central (Coronado) fueron analizados. Las fincas, una grande y una pequeña, fueron comparados en términos de ingresos y rendimientos del sistema de producción. Se formaron conclusiones acerca de la eficiencia de los dos sistemas.

Abstract

The energy flow dynamics of two Central Valley (Coronado) dairy farms are analyzed based on kilocalorie units. The farms, one large and the other small, are contrasted according to inputs and outputs to their production systems. Conclusions are drawn regarding the relative efficiency of the two systems.

Introduction

The uplands above San Isidro de Coronado in San Jose province are home to numerous dairy establishments. All of the dairy farms contend with similar physical and socioeconomic issues. Dairy cows are kept primarily on steep unimproved pasture with concentrate supplements during milking. This system is the result, in part, of small land holdings and increasing land values associated with urban encroachment. The manager of the La Dorbal farm, Professor Quijarano, estimated the value of the 80 hectares at 2 million dollars. The current oversupply of milk also precludes more intensive systems as farm owners are unable to invest in improved pasture or further mechanization. Despite the surplus of milk, research (although directed at alternative fodder to replace imported concentrates) emphasizes improved efficiency based partially on increased production. Neither of the farmers visited, however, indicated an intention to leave the business in face of these problems. Instead, they blamed a lack of efficiency and poor marketing of an unsympathetic agricultural minister and tight export markets.

The two farms visited for the study can be differentiated on the basis of size, market access, and available capital. The larger of the two included 80 ha (twelve of which were utilized as pasture for the dairy cows), 54 milking cows, and an electric

milking machine. Cows were rotated on a system of 35 pastures (apartos) of approximately .25 ha separated by electric fencing. A circuit of the pastures was completed about once a month with a fertilizer application to the grass when cows were moved from an aparto. The cows also received bananas (to lessen the pressure on the pasture), molasses and mineral salt supplements in addition to concentrates. Overall production on the farm was 6,825 kg/ha/yr or about 18 l/cow/day. The milk was sold to Borden at 40 colones per liter for the first 500 liters and at 15 colones for any surplus. As a result, the manager undertook practices to reduce production (i.e. less concentrates). The manager perceived dairying as an important social element in the Costa Rican economy which provided employment and healthy food.

The smaller farm, owned by the Garcia brothers, consisted of 28 milk cows owned jointly, 3.5 ha of grass pasture which was augmented by rented land, and an electric cooler. Cows were grazed on either public or rented private land. The pasture owned by the brothers was harvested on a cut-and-carry basis and fed to the herd prior to milking. Grass from a local tree plantation was purchased for use in a similar manner. Fertilizer was occasionally applied to the owned pasture. The small farm also included bananas, molasses, mineral salts, and concentrates, although in more limited quantities due to cash flow. The brothers were only able to sell approximately 200 l/day as their cooperative was indebted and virtually bankrupt. They supplemented their income through local sale of milk and cheese equivalent to about 50+ l/day. Their perception of dairying was that of a trade and means of subsistence. They looked primarily to external means--e.g. better markets at home and abroad--to improve the situation of dairy farmers.

The object of the study was to compare the two farms on the basis of energy flows. Assessed in terms of kilocalories/hectare/year (kcal/ha/yr), the energy efficiency of the farms could be compared. Given the characteristics of the farms, variations could be attributed to differentiation in size of operation, feeding methods, security of market, and philosophy of farming. Conclusions can then be drawn regarding the relative sustainability and viability of the farms.

Methods

The process of obtaining energy flow information consisted principally of informal interviews. Each farm was interviewed twice, the second interview allowing for gaps in information to be filled. Those interviewed were asked to describe their production methods, specifying quantities of direct inputs to the dairy system. Sun and water were not included in calculations as these were equally available to all farms. The energy of farmer owned pasture is determined as its maintenance inputs. Quantities for electricity and veterinary services were assessed by cost in Colones. Once quantities were established, kilocalorie values were assigned to each activity.

Energy Flow Analysis Discussion

The analysis of energy flows of the two dairying systems indicates that both are energy intensive. The high energy input ratios (2.42:1 for La Dorbal and 3.76:1 for the Garcia farm, see Table 1) reflect the conversion of low grade vegetable energy to milk and meat. The energy values measured in kilocalories per hectare per year (kcal/ha/yr) for feed concentrate and molasses are the greatest of the selected inputs for each system. These levels suggest the reliance on external inputs shared with many Costa Rican dairies. The manager of La Dorbal stated an interest in a dry lot, cut-and-carry forage system using leguminous trees and better grass varieties. He calculated that such a system would cut his per liter production costs in half (from \$0.29/l to \$0.15/l). He also suggested that the system should be extended to smaller farmers. The change to on-farm forage and protein production would also affect energy flow ratios as concentrate inputs (and possibly fertilizer and veterinary inputs, as well) were reduced and replaced by pasture upkeep and labor values. The energy received by the cow would not change, but a greater percentage would come from within the system.

In comparing the efficiency ratios of the farms, La Dorbal appears to be the more efficient producer. In addition to the concentrate and molasses, the larger farm had relatively high input values for bananas and fertilizer. Each of these inputs was principally directed at pasture improvement. The fertilizer (a complete 10-30-10 in the wet season with additional urea during the dry season) was applied to resuscitate pasture following a grazing rotation. The bananas (those which did not meet export standards) were expected to replace some of the grazing by the cows and reduce their impact on the pasture. In general, bananas were only used during the summer months on the large farm due to their cost.

The labor, veterinary, and electricity input values are considerably lower than those described above. These values further emphasize the conversion of energy from vegetable to animal matter as the primary energy consumer on the dairy. The extensive management of cows in pasture is reflected in relatively low labor and medicinal needs. Labor is limited to the daily rotation and milking of cows and fertilizer application. Often, workers will assume tasks in other farm activities not associated with the dairy system to complete the work day. The manager believed that cows feed on pasture were less liable to disease. Electricity energy values, which are based on cost, may reflect either machinery efficiency or artificially low utility costs.

On the farm of the Garcia brothers, off-farm grass contributed a large energy input. Due to minimal pasture acreage, the brothers rented pasture on a per head basis and cut grass at a local tree plantation for fodder. The value for grass was determined by average cow intake reduced by the on-farm grass production potential. As the grass was cut at a distance and carried back to the barn, this input also contributed to high labor (human and ox) inputs for the smaller farm. At least a third of the work day and most of the ox-time was devoted to bringing grass to the barn for the cows. The impact on the fertilizer

inputs was the opposite. In comparison, the energy input for the small farm was an order of magnitude less than that of the large farm (Tables 1 and 2). The cows not entering the pasture and trampling the grass and the limited resources of the smaller farm also contributed to differences in fertilizer application. Electricity and medicinal inputs were relatively inconsequential. The small farm only had the milk pasteurizer and the farmers recognized no particular disease problems.

The small farm also assumed a high input in the cheese making process. The primary inputs are the firewood and the labor of Carlos Garcia's wife. Firewood (mostly rests from saw mills) is used to elevate milk temperature for 4-5 hours with the intention of accelerating microbial action. This is done every two days. The process involves converting 100 kg of milk to 8-10 kg of cheese. No definitive answer was given regarding the use of the resulting whey, although using it to supplement calf feed would retain the energy within the system.

The energy output of the two farms is comparable. The total output per cow differs by less than 1%. The energy flow and the resulting efficiency ratios indicate, however, that the Garcia's require greater inputs for similar production. Ignoring the cheese production improves the ratio of their farm to 3.33:1, but still exceeds that of La Dorbal by a large margin. The basis for the difference in inputs would lie primarily in the grass and labor inputs of the small farm.

Conclusions

Perhaps the best means of comparing the two farms is on the basis of input and output per cow. Based on this assessment, both farms exhibited fairly equal production levels, although the small farm required better than 4 million kcal. more per cow in inputs. The discrepancy in input levels can be contributed primarily to the additional labor and wood inputs which the small farm required in order to provide fodder and in the process of marketing their product as cheese. Without these additional inputs, the efficiency of each farm is similar. The extreme energy demand of the farms is to be explained in the energy entropy involved in the conversion of vegetable to animal matter.

The greatest difference in the farms relates to their managers perceptions of dairy in the future. The manager of the larger farm placed improvement within the broader spectrum of future production methods and marketing. On the smaller farm, on the other hand, the immediacy of capital limitations focused attention on current and past abuses of their marketing potential.

Table 1. Energy Flow for La Dorbal Farm, Coronado.

Inputs:			
	kg/ha/yr	kcal/kg	kcal/ha/yr
Feed			
Concentrate	5980	3100	18,538,000
Grass	n/a	n/a	n/a
Molasses	3285	3370	11,070,450
Bananas	1733	871	1,509,443
Medication	13,000	15	195,000
Insemination	6916	15	103,749
Mineral salts	6994	15	104,910
Electricity*	12,167	15	182,505
Fertilizer	850	15583	11,545,550
Labor	1095	191	209,145
Totals			43,358,752
 Outputs:			
	kg/ha/yr	kcal/kg	kcal/ha/yr
Milk	22,812	738	16,835,256
Dry cows (culls)	1461	3308	482,968
Calves	56.25	3308	186075

*Electricity energy values were based on the value of the input in Costa Rican Colones.

Table 2. Energy Flow for Garcias' Farm, Coronado.

Inputs:			
	kg/ha/yr	kcal/kg	kcal/ha/yr
Feed			
Concentrate	22,325	3,100	69,207,500
Grass	23,360	170	3,971,200
Molasses	4,380	3,370	14,760,600
Bananas	5,943	871	5,176,353
Veterinary*			
Medicine	n/a	n/a	n/a
Insemination	8,857	15	132,855
Mineral salts	27,976	15	419,640
Electricity*	12,000	15	180,000
Fertilizer	78	15,583	1,215,474
Human**	3,754	191	717,014
Oxen***	2	1,772,600	3,545,200
Total			111,130,585
Outputs:			
	kg/ha/yr	kcal/kg	kcal/ha/yr
Milk	30,626	738	22,602,129
Cheese	357	5,830	2,081,310
Whey	2,231	632	1,408,521
Dry cows (culls)	75	3,308	248,100
Calves	73	3,308	241,011
Total			29,581,170

* Veterinary and electricity energy values are based on the value of the input in Costa Rican Colones.

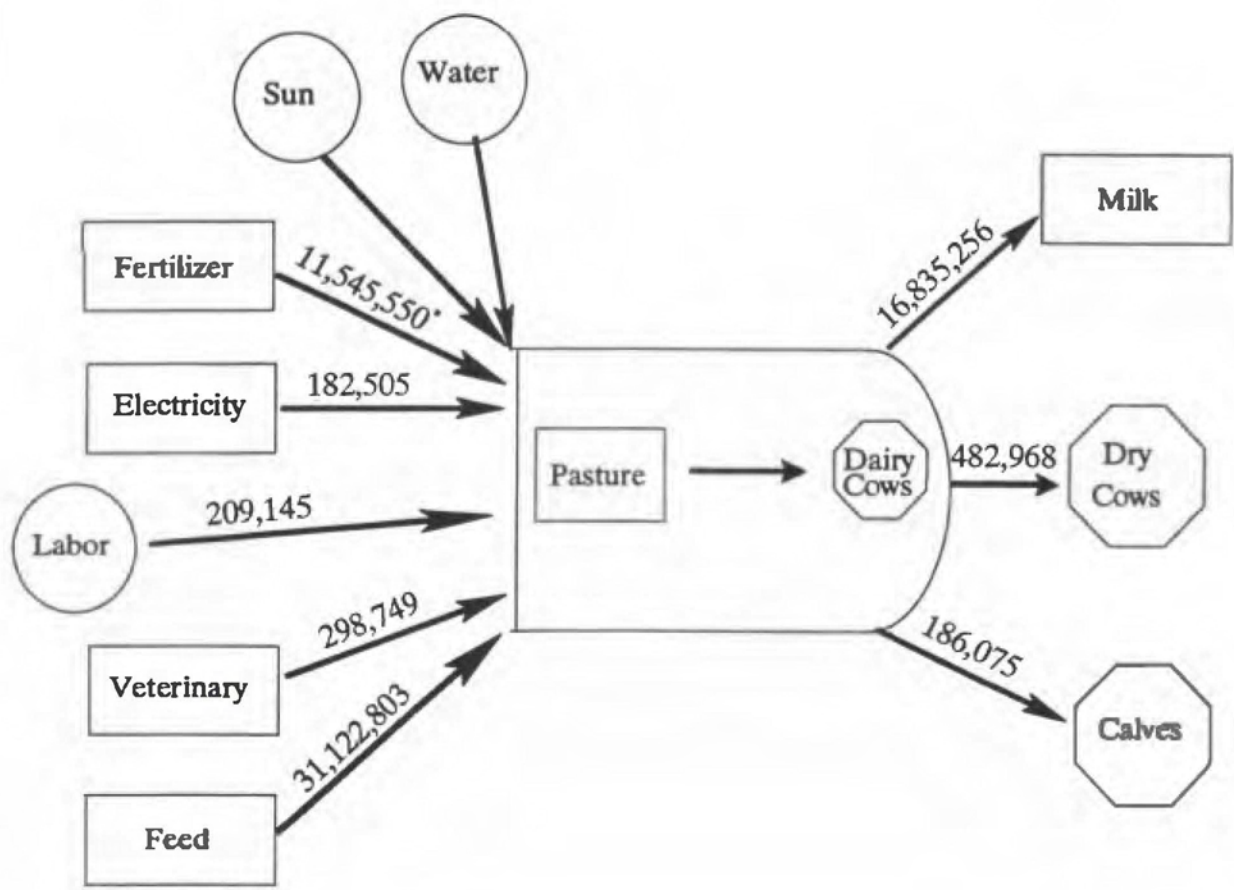
** Human labor input is based on hourly caloric use values.

***Ox labor is determined by the inputs necessary to maintain the animal--e.g. grass, feed, etc.

Table 3. Efficiency Ratios for Dairy Farms in Coronado.

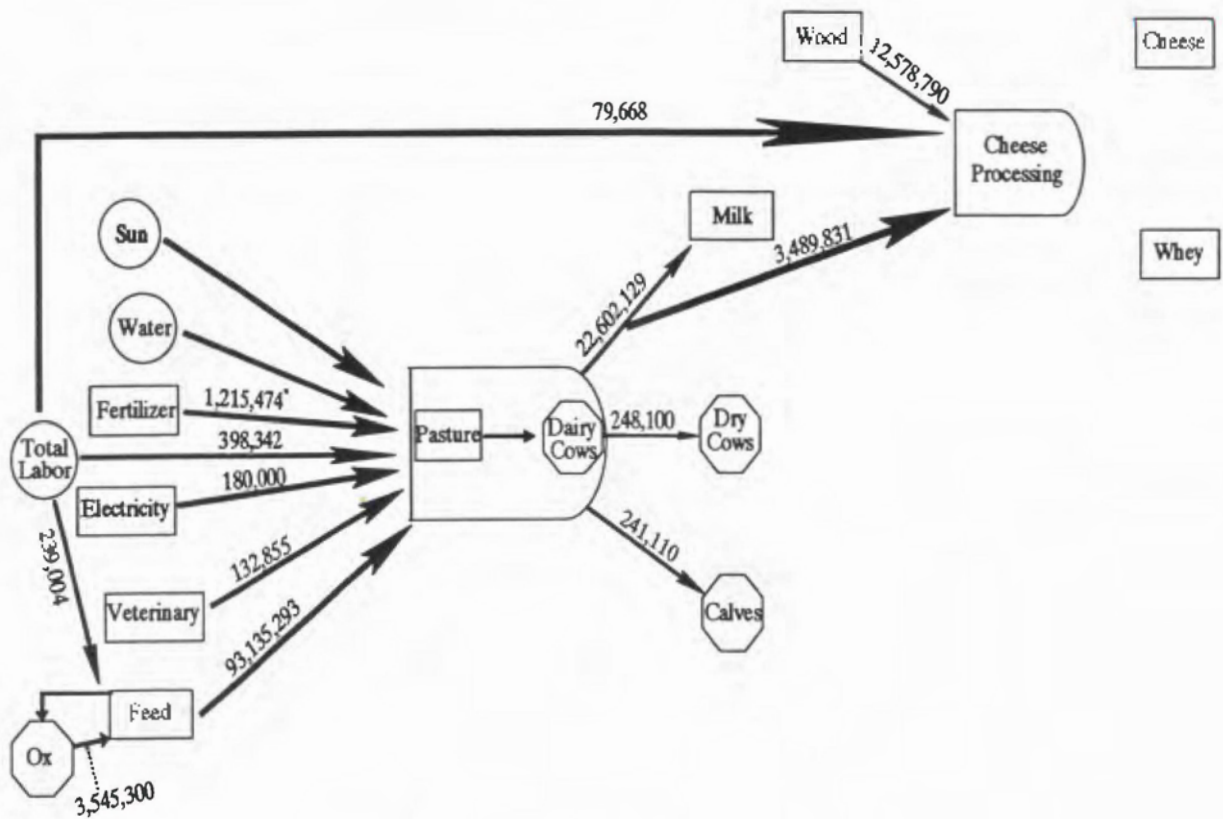
	La Dorbal	Carlos Garcia	Combined
in: kcal/ha/yr	43,358,752	111,130,585	154,489,337
out: kcal/ha/yr	17,504,299	29,581,170	47,085,469
in: kcal/cow/yr	9,635,278	13,891,323	23,526,601
out: kcal/cow/yr	3,889,844	3,697,646	7,587,490
efficiency	2.48:1	3.76:1	3.10:1

Figure 1. Energy Flow Diagram for La Dorbals' Farm.



* All values are in kcal/ha/yr.

Figure 2. Energy Flow Diagram for Garcias' Farm.



* All values are in kcal/ha/yr.

Guided Field Problem

A COMPARISON OF THE INSECT BIODIVERSITY FOUND ON ORGANIC AND CONVENTIONAL FARMS

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Faculty: Dr. Michael Williams

Resumen

Se estudio la biodiversidad de insectos en cultivos tanto convencionales como organicos de cafe y vegetales. Se utilizaron trampas colocadas en un hueco en el suelo para atrapar a los insectos. A pesar de que el cultivo convencional de vegetales mostro mayor diversidad en terminos del numero total de taxa, el valor del indice de diversidad propuesto por Margalef fue mas alto para el cultivo organico. El cultivo organico de cafe mostro mayor diversidad tanto en el numero de taxa como para el indice de Margalef. Los factores que tuvieron influencia sobre estos resultados y recomendaciones para futuros estudios se discuten en este articulo.

Abstract

Insect biodiversity was examined in vegetable and coffee crops cultivated under both conventional and organic farming systems. Pit-fall traps were used to sample the insect fauna. While the conventional vegetable farm had higher diversity in terms of total number of taxa, Margalef's diversity index value was higher for the organic vegetable farm. The organic coffee plot was more diverse both in terms of total number of taxa present and as measured by Margalef's diversity index. Factors influencing these results and recommendations for future study are discussed.

Introduction

Although conventional high-input farming methods still predominate in Costa Rica, organic farming practices are being undertaken with greater frequency by farmers as health and environmental concerns influence agricultural markets. Organic farming techniques include eliminating the use of chemical pesticides, herbicides, fungicides and fertilizers by allowing natural predators and other beneficial insects to regulate populations of crop pests and disease-causing organisms. This implies that such techniques would have a positive effect on the insect fauna and overall health of agricultural systems.

The objective of this study was to determine the influence of organic versus conventional farming practices on overall insect biodiversity and natural enemy complexes in agricultural systems. We hypothesized that insect biodiversity would be greater in

organic farming systems. This was tested against the null hypothesis of no difference in insect biodiversity between organic and conventional farms.

Site Description/Vegetables

The organic and the conventional vegetable farms were situated in the same valley in Heredia. The organic farming methods combined the use of natural insect repellents and fungicides with the composting of bocachi. A lettuce plot on the organic farm was used in this study. The lettuce crop was mature and the alleys between the rows were filled with rotting plant material and growing vegetation. The plot was bordered by a road, two windbreaks, and another field of lettuce.

The conventional farming methods included repeated applications of petrochemical pesticides and herbicides. A plot of young cabbage was selected for insect trapping. The cabbage crop was probably newly transplanted, and both rows and alleys were free from any vegetation. The field was bordered with windbreaks on all four sides.

Site Description/Coffee

Organic and conventional coffee fields owned by Britt Coffee, Inc. in Barva, Heredia Province were sampled for their insect diversity. Both plots were approximately 1 ha in size and were planted with a Cotura variety of coffee. Young *Erythrina* sp. and bananas (*Musa* sp.) were planted as shade trees in the organic coffee plot. The conventional coffee was growing beneath mature *Erythrina* sp. and *Inga* sp. trees.

Methods (Vegetables and Coffee)

Pit-fall traps were used to sample the insect fauna in the organic and conventional crop fields. Nine traps were placed in each field in a 3 x 3 grid layout. Each trap consisted of a 14 ounce plastic cup with a 78 mm top diameter placed into the ground flush with the soil surface. 2.5 cm of mildly soapy water was put into each cup and a plastic bag was suspended above the cup with 3 sticks to prevent the entry of rain water. Traps were left in the fields for 72 hours (vegetables) and 24 hours (coffee) and then collected. Invertebrates were then removed from each trap sample, sorted to the Family level, and the number of individuals in each Order was tallied. Representatives of the Order Collembola were not counted due to the large numbers of individuals collected. Instead, their relative abundances in each sample were estimated.

Results (Vegetables)

Coleoptera, Diptera and Collembola were the most family rich orders in the conventional farm represented by 14, 9, 7, and 5 families each (Table 1). In the organic farm Coleoptera was represented by 11 families, Diptera by 8, Hymenoptera and Hemiptera 6, and Homoptera and Collembola by 4 families (Figure 1). Two families of Hemiptera were found in the conventional farm and two Thysanoptera in the organic farm. The remaining orders were represented by one family in each order in both farming systems.

The number of individuals of Collembola exceeded by several orders of magnitude the number of individuals of all the other orders caught from the conventional farm. Collembola were also abundant in the organic farm. The number of individuals were estimated (5,000 organic/50,000 conventional) because time and lab constraints did not allow precise counting. Diptera in the conventional farm were relatively abundant (approximately 1,500) when compared to the other orders captured, whereas, in the organic farm there were only 161 individuals (Figure 2). Hymenoptera and Coleoptera were represented by 180 and 155 individuals, respectively, in the conventional farm and 55 and 103 in the organic. Hemiptera had 2 individuals/order in both farms, Homoptera one in the conventional and 2 in the organic. Lepidoptera and Orthoptera had one in each site, while Thysanoptera, Neuroptera, and Syphonaptera had one individual each in the conventional, whereas these orders were not represented in the organic farm.

When considering predator species, such as Arachnids and Scarabid beetles, a greater number of individuals were represented in the conventional farm: 50 spiders and 45 Scarabids in the conventional compared to 30 spiders and 33 Scarabids in the organic farm.

When considering only the total number of taxa, the conventional farm had higher insect diversity than the organic farm and we could not reject our null hypothesis. However, when applying Margalef's index of diversity which accounts for both species richness and relative abundances [$D=(S-1)/\ln N$; where S = # of taxa and N = # of individuals] (Margurran, 1988), the organic farm was more diverse ($D=4.78$) than the conventional farm ($D=3.5$). If Collembola are excluded, the difference is even greater with the organic farm having significantly higher diversity ($D=6.16$) than the conventional farm ($D=4.50$).

Results (Coffee)

The organic coffee plot had greater insect biodiversity both in terms of the number of families and the number of individuals. The overall family-level diversity was nearly twice as high in the organic plot as in the conventional, reaching 31 families vs. 16

families (Figure 3). In no case did an order contain more families in the conventional plot than in the organic. Most notable were the orders Hemiptera (7 organic to 1 conventional) and Diptera (8 organic to 3 conventional).

With regard to absolute numbers of individual insects, the orders Hymenoptera and Diptera, and the spider order Araneae exhibited the greatest difference in favor of the organic site (Figure 4).

The Coleoptera were slightly higher at the conventional site, but otherwise more individuals were found at the organic site for any given order. The one exception were the Collembola, which were much more numerous at the conventional site.

The organic site also had far more predators than the conventional site. Most notable among the predators were the Formicidae, which were nearly twice as abundant at the organic site.

Finally, Margalef's diversity index (Margurran, 1988) was performed on the data collected from both sites. The number of Collembola were estimated to be 500 for the organic site and 3500 for the conventional site. For the organic site $D=4.49$ and for the conventional site $D=1.83$.

Discussion (Vegetables)

Although we failed to reject our null hypothesis that organic farming would have greater insect biodiversity than conventional farming when considering only the number of taxa, there are several possible explanations. First, the exponential increase in Collembola and fungus flies in the conventional farm could be due to the increased amount of undecomposed organic matter in the conventional farm's soil. Because the organic farmer applied already decomposed compost, there was far less food for detritus feeders such as collembola and fungus flies. Hymenoptera were present in both systems, but more abundant in the conventional farm. Because the Hymenopteran family, which we found in the conventional farm, preys on fungus flies this could explain their greater abundance.

Perhaps most important, because the crop plants in the organic farm were more mature and weeds had not been removed by herbicides, ground cover in the organic farm was much greater. Numerous refuges and hiding places for predators and their prey were available. In the conventional farm, plants were very small and there was very little ground cover. Predators were forced to search greater distances to find their prey, and prey also had to search more to find refuge and food. Therefore, the probability of being caught in the conventional farm was much greater and may have significantly affected our results.

A full interpretation of our results would require specific information on the ecological role of the species that were captured. For example, the organic farm had more species of Hemiptera (6:15) which have a fairly high pest potential. Sap feeders (Homoptera) were also higher in the organic farm. Because the organic farmer was not using pesticides but rather repellent, we would expect to find more potential pests. However, the organic farm also had a greater proportion of predatory Carabid beetles than the conventional farm, which may indicate a better predator-prey balance in the organic field.

When both species richness and abundance are considered, insect diversity followed the shape of a normal curve expected in an "undisturbed" ecosystem and, therefore, scored higher when compared to the conventional system ($D=4.78$ and $D=3.50$, respectively). The skewed distribution of abundances in the conventional farming system is a possible sign of environmental degradation, but the interpretation of these results is very complex (Magurran, 1988).

Discussion (Coffee)

The higher levels of biodiversity in the organic plot can be explained by the lack of herbicides and fungicides that were used. Although actual pesticides were not used, herbicides function in much the same way by destroying the undergrowth of weeds and fungi which serve as food for many different insects (Williams, pers. comm.). This was in fact the case, as the organic plot contained noticeably more undergrowth than the conventional plot.

The resulting simplification of the ecosystem also accounted for the lower level of predators in the conventional plot, as they did not have as many prey species upon which to feed. The large number of ants (Formicidae) at both locations can partially be explained by the presence of *Erythrina* sp. trees, which contain extra-floral nectaries, providing the ants with an additional food source.

With regard to family-level biodiversity, the explanation for the much higher numbers of Hemiptera could be explained by the fact that Hemiptera are phytophagous, and they may be feeding on the weedy undergrowth of the organic site. Most of the Diptera families found were fungal feeders, and even though the fungicide copper sulfate was applied to both locations, the added ground cover at the organic site may provide a food source for the Diptera.

Our study found that an organic system of coffee growing results in greater levels of insect and spider biodiversity both in terms of diversity of taxa (alpha diversity) and in terms of the number of individuals within a taxa (beta diversity). This difference can be attributed to the lack of herbicide application in the organic plot, which allowed for an herbaceous groundcover that provided a wider range of both habitats and food sources.

Furthermore, the use of coffee pulp also contributed to the wider range of ecological niches in the organic plot. The more complex ecosystem of the organic plot also provided a greater range of food types, as well as a larger number of prey animals, to the predatory insects and spiders within the organic coffee location.

Recommendations

The following list of recommendations might aid future investigators in their research.

Using the two different crops of lettuce and cabbage leaves our conclusions tenuous. In order to truly compare insect biodiversity between organic and conventional farming, the crops of the study plots should be the same. Furthermore, analysis would be more meaningful if crop age and geographical location were similar.

When setting pitfall traps, attempt to sample the edge and the center of fields equally.

Using only pitfall traps biased our data in favor of ground dwelling insects, thus under-representing the arboreal species. In future studies multiple sampling techniques would help rectify this bias. In addition to pitfall traps, the following traps should be used: sticky traps, beat sheets, sweep nets, and visual sampling.

Time permitting, multiple replicates are necessary to discern any real trend in ecosystem biodiversity. Similarly, pitfall traps should be collected daily, as insects decompose quickly in the tropics. The alternative would be to use antifreeze in the traps to preserve the specimens. Also, several variables are important to consider when planning trapping replicates. In order to better understand the dynamics involved in the farming system, traps should be placed in tandem with major events such as harvest/planting, chemical applications, and tillage. In addition, major variables such as rain, slope, and soil type might be recorded and used to interpret data.

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Table 1. Insect Taxa Found in Organic and Conventional Farms.

Order Family Subfamily	Common Name	Food Habits	Pest Potential
Collembola	Springtails	det/fung	moderate
Onychiuridae			
Isotomidae			
Sminthuridae			
Hemiptera	Bugs	phyto	high
Cydnidae	Burrower Bugs	roots/pl	high
Miridae	Plant/leaf Bugs	plant	high
Lygaeidae	Seed Bugs	sap/insect	moderate
Scutelleridae	Shield-Backed	plant	high
Hymenoptera			
Ichneumonidae	Wasps	ins. para	none
Braconidae		ins. para	none
Formicidae	Ants		
Myrmicinae		seed/fung	low
Formicinae		insect	low
Diptera			
Sciaridae	Dark Fungus Gnat	Fung/root	moderate
Mycetophilidae	Fungus Gnat	Det/fungus	moderate
Tipulidae	Crane Flies	Det/plant	moderate
Psyononidae	Moth Flies	Detritus	low
Chironomidae	Midges	Scavengers	low
Drosophilidae	Fruit Flies	Fruit/veg	high
Agromyzidae	Leafminer flies	plant	high
Anthomyiidae		plant	high
Muscidae	House flies	Detritus	low
Orthoptera			
Acrididae	Grasshopper	plant	high
Gryllidae	Cricket		none

Table 1 continued.

Order Family	Common Name	Food Habits	Pest Potential
Lepidoptera			
Arctiidae	Tiger Moth	plant/leaf	high
Homoptera			
Delphacidae	Plant Hoppers	sap	high
Cicadellidae	Leaf Hoppers	sap	high
Aphididae	Aphid/Plant Lice	sap	high
Coleoptera			
Carabidae	Ground Beetles	insects	none
Staphylinidae	Rove Beetles	insects	none
Curculionidae	Snout Beetles	plant	high
Chrysomelidae	Leaf Beetles	phyto/root	high
Scarabidae	Scarab Beetles	dung/det	none
Nitidulidae	Sap Beetles	sap/fung	low
Elateridae	Click Beetles	plant	high
Meloidae	Blister Beetles	plant/in-	high
Rhizophagidae	Root-eating Beetles	roots/in-	low
Alleculidae	Comb-clawed Beetles	plant/fungdetrit	low
Thysanoptera			
Phlaeothripidae	Thrips	spores/in-	moderate
Araneae	Spiders	insects/	none

Key for the figures:

Col: Coleoptera	Neu: Neuroptera
Syp: Syphonaptera	Lep: Lepidoptera
Hom: Homoptera	Ort: Orthoptera
Hym: Hymenoptera	Ara: Arachnidae
Dip: Diptera	
Hem: Hemiptera	
Thy: Thysanoptera	
Cim: Colembola	

**Figure 1. Number of Families/Order
in the Vegetable Farm.**

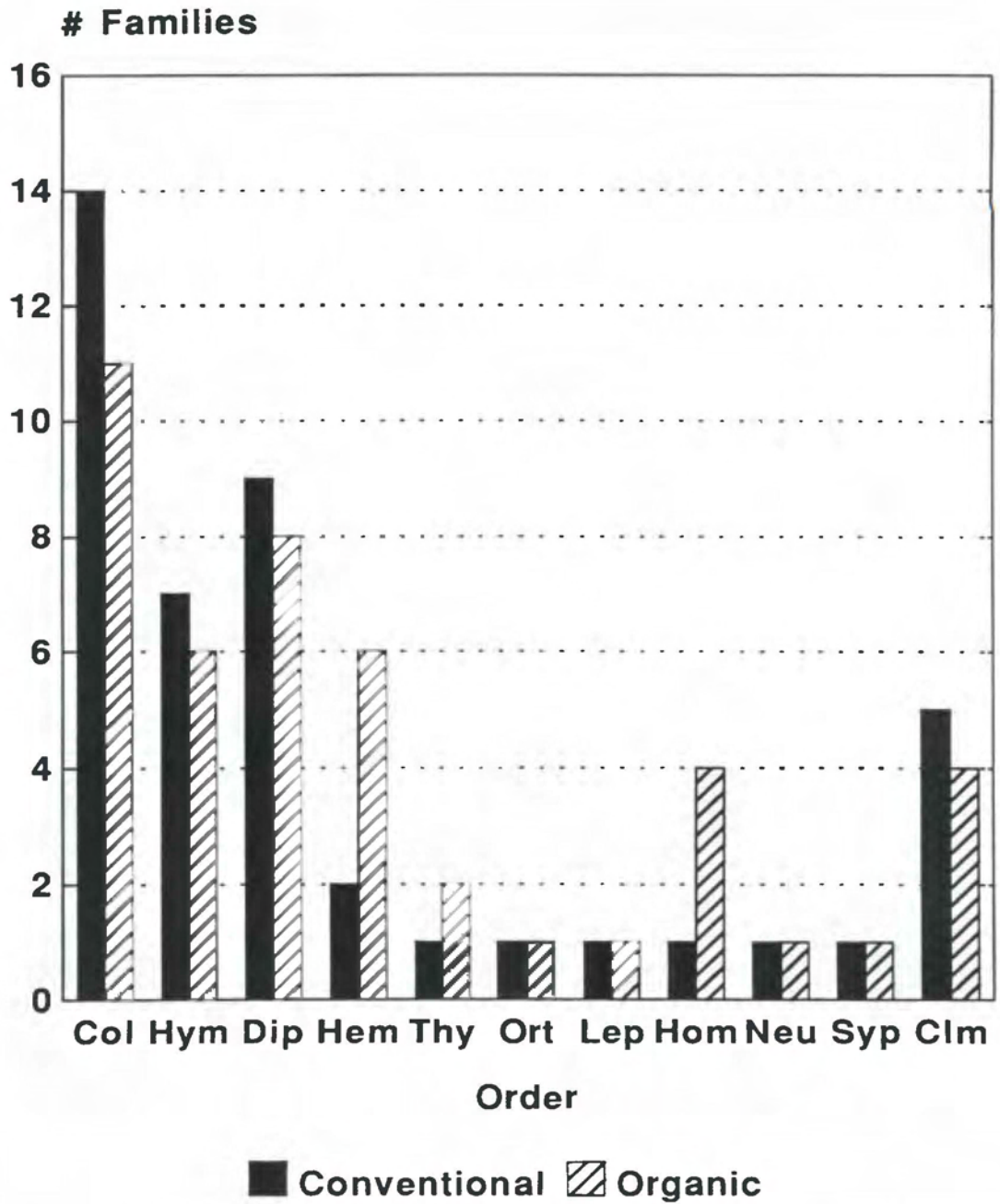


Figure 2. Number of Individuals/Order in the Vegetable Farm.

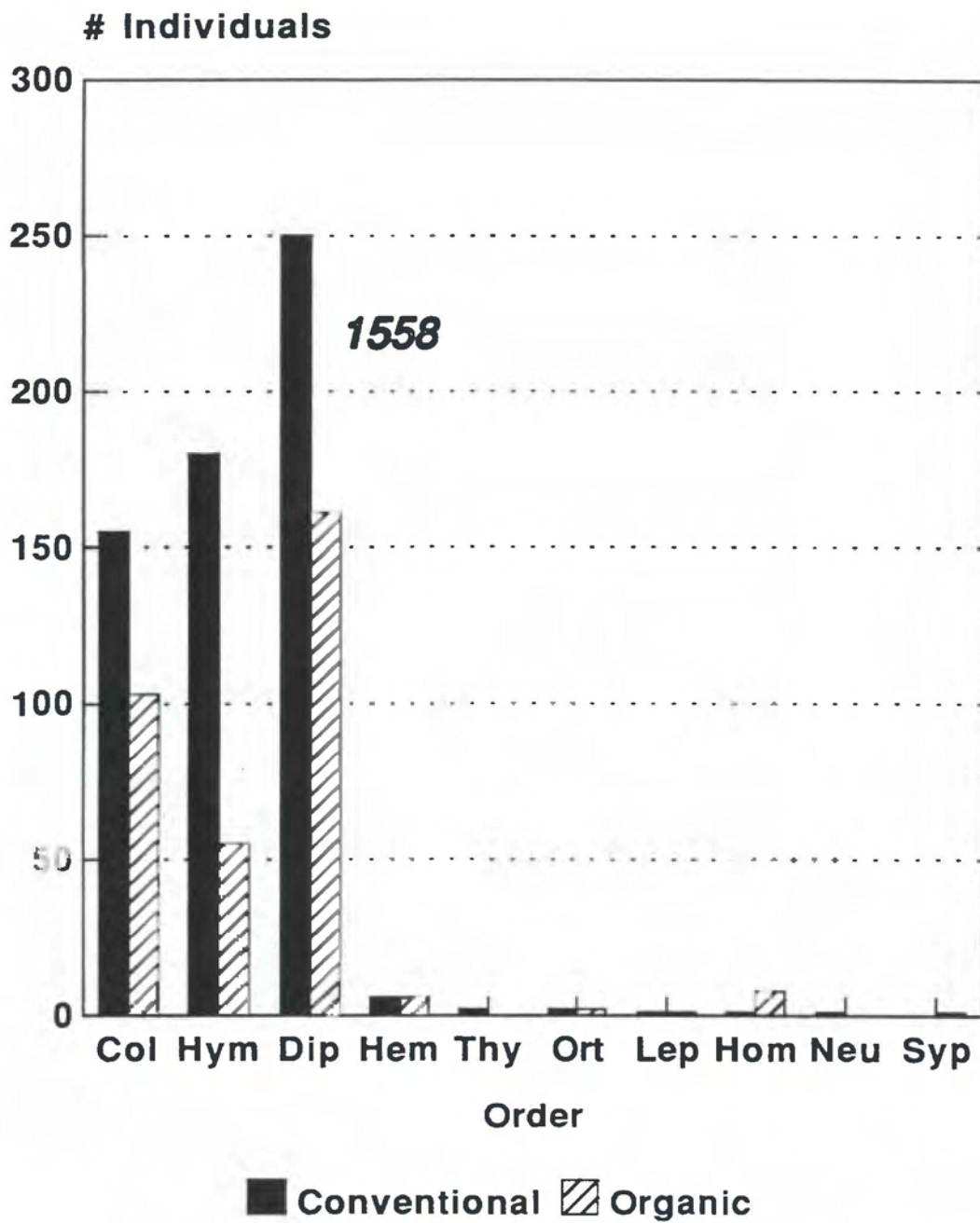


Figure 3. Number of Families/Order for Coffee Plantations.

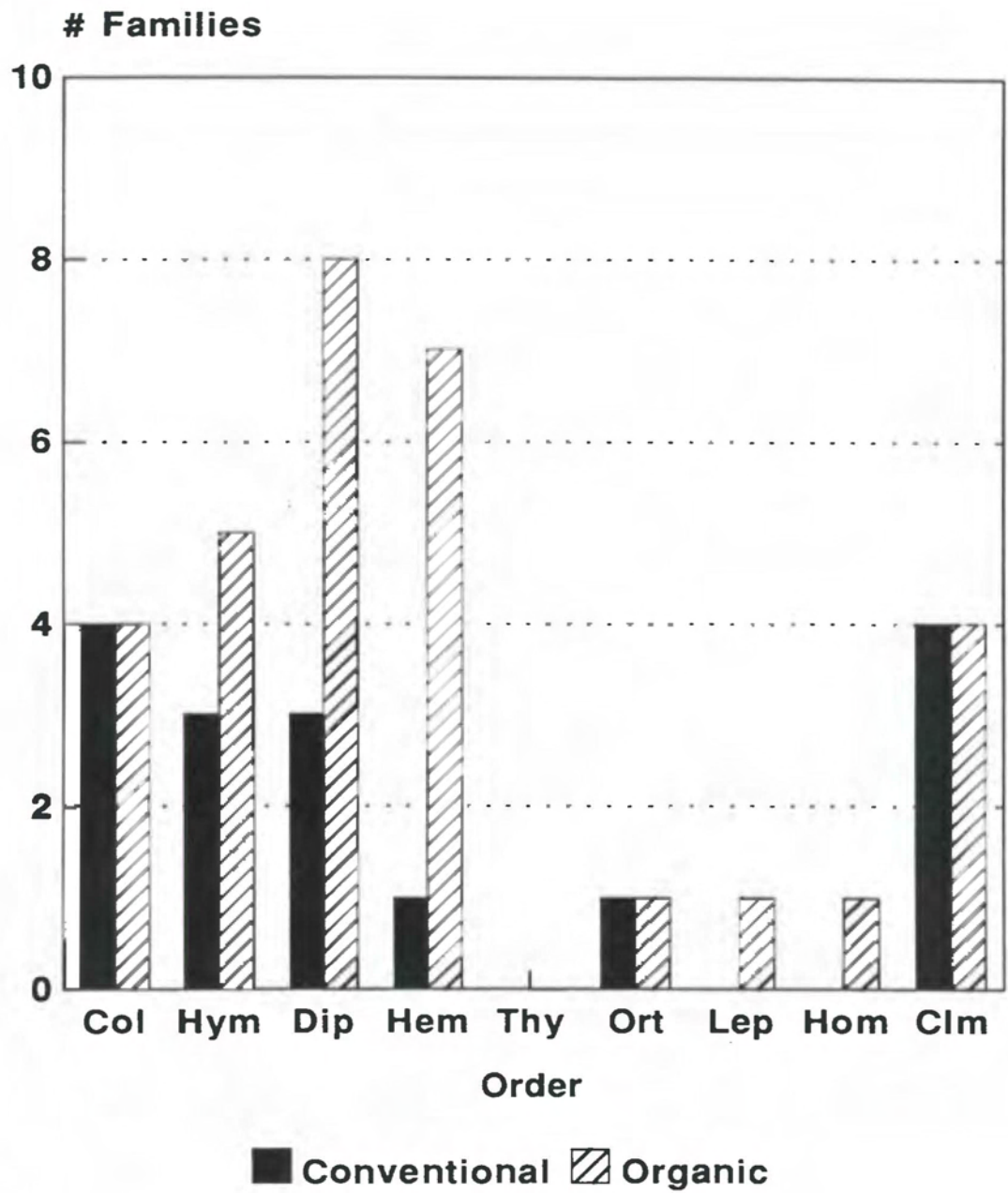
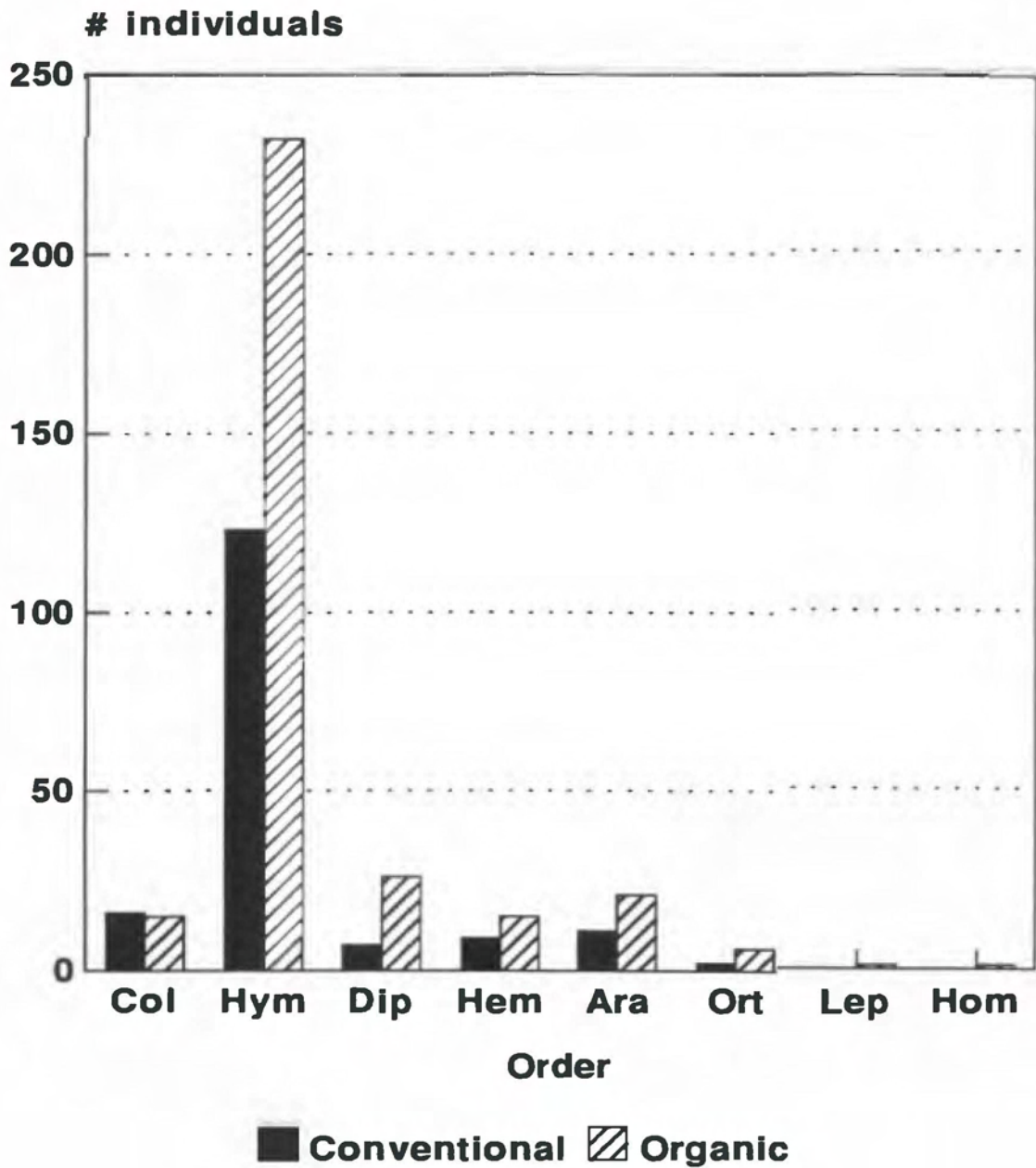


Figure 4. Number of Individuals/Order for Coffee Plantations.



LA SELVA
COSTA RICA

Guided Field Problem

A COMPARISON OF OLD GROWTH AND IMPACTED FOREST PALM DENSITIES AT LA SELVA

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Faculty: David Clark

Resumen

En este estudio se examinaron siete especies de palma para determinar la abundancia relativa en diferentes clases de tamaño. El anexo Sarapiquí de La Selva, el lugar de la investigación, sufrió presión de extracción de palmas hasta 1981. Tradicionalmente, tres de las especies han sido cosechadas para palmito: *Euterpe macrospadix*, *Iriartea deltoidea*, and *Socratea exoriza*. Las cuatro especies que quedan no se consumen: *Astrocaryum alatum*, *Astrocaryum confertum*, *Prestoea decurrens*, and *Welfia georgii*. Un estudio parecido que se llevó a cabo en el bosque primario fue usado en una comparación. Pronosticamos que la densidad de las poblaciones de las palmas grandes y las palmas comestibles serían más pequeñas en el anexo Sarapiquí. Vimos que nuestros pronósticos parecieron correctos, pero sólo ciertas clases de tamaño fueron significativos estadísticamente. Sospechamos que resultó así debido a la pequeña escala de nuestro estudio.

Abstract

In this study seven canopy and subcanopy palm species were examined to determine relative abundances of different size classes. The Sarapiquí annex of La Selva, the area examined, prior to 1981 was subject to relatively high palm extraction pressure. Three of the species studied have traditionally been harvested for their heart of palm: *Euterpe macrospadix*, *Iriartea deltoidea*, and *Socratea exoriza*. The four remaining species are not used for consumption: *Astrocarym alatum*, *Astrocaryum confirtum*, *Prestoea decurrens*, and *Welfia georgii*. A similar study carried out in the old growth forest of the original La Selva annex was used for comparison. We predicted that population densities of both the larger and edible palms would be lower in the Sarapiquí annex. We found that our predictions appeared correct, though only certain size classes proved to be statistically significant. It is suspected that this was due to the relatively small sample size in our study.

Introduction

Canopy and subcanopy palm species play a vital role in neotropical rain forests. They are an important food source for several species of birds and mammals, and many are of economic and cultural value. Local communities have traditionally extracted wild

palms, however, and the impacts of this removal on the forest's structure and population dynamics have not been well researched.

Different areas within the La Selva Biological Research Station have been subjected to varying degrees of pressure from palm extraction, making it an ideal site to study the impacts of extraction. The original ("old") La Selva annex is primarily old-growth forest, with no known palm extraction. A previous study conducted by David Clark and associates in this area documented the distribution and density of canopy and sub-canopy palms. This, however, had not been done in the more recently acquired Sarapiquí annex, once subject to heavier harvesting pressure. We chose to conduct a similar inventory in the more recently acquired Sarapiquí annex. This annex was acquired by OTS in 1981, and since then, has been allowed to regenerate. Forests in this annex are now classified as secondary or highgraded forests.

The size and density distribution of seven canopy and sub-canopy palm species in the Sarapiquí annex was studied and compared with similar data collected in old growth forest in old La Selva. Three of these species--*Euterpe macrospadix*, *Iriartea deltoidea*, and *Socratea exoriza*--are harvested for their heart of palm (palmito), while the remainder--*Astrocaryum alatum*, *Astrocaryum confertum*, *Prestoea decurrens*, and *Welfia georgii*--are not. A comparison of the species distributions in these two areas may help clarify how the forests respond to harvesting pressure.

The purpose of our study was to test two hypotheses. The first predicted that population densities of taller palms would be lower in the secondary/high-graded forest than in the old-growth forest. Furthermore, that this decrease in the palm density may specifically reflect a decrease in edible palm species due to their economic and cultural value. The second hypothesis was that the frequency of large edible palms relative to inedible palms would also decrease in the secondary/high-graded forest.

Methods

Within the Sarapiquí annex, the Sendero Jaguar and the Sendero Sarapiquí trails were utilized as access routes to the sampling points. Grid markers from the La Selva grid system were used as sample points. Sampling points were located by taking a compass bearing at 100 m grid intervals along the right side of the trails to ensure that all sample points fell within the reserve. Of the 14 samples taken, three were separated by intervals greater than 100 m. If the grid post was less than 20 m from the trail, then the nearest post to the left side of the trail was used. This was done to prevent the inclusion of trails within the sampled areas.

The sampling method, intended to be consistent with Clark's Old La Selva methods, consisted of two components. First, palm species were sampled using the closest individual point sampling technique (Grieg-Smith, 1983). Palms were divided into four size classes (1-5m, 5-10m, 10-15m, and >15m). Heights were verified using an

extendable measuring tube. The species and distance from the grid marker to the closest individual in each size class was recorded. The area sampled was limited to a radius of 20 m from the post. The second component involved taking presence/absence information for the seven palm species under study. This survey used an unlimited sighting radius around the grid marker.

Results

We computed population density for each of the four size categories in our sample using the closest individual method: $\text{Density} = \{10,000/4\} * \{1/(\text{mean closest distance})^2\}$ (Grieg-Smith 1983, p.49). Mean closest distance was the variable we actually measured. To compare the densities of the two forests, we compared the mean closest distance in each size class between the two studies. Since all 14 samples taken from the Sarapiquí annex were on ultisols, only those samples from old La Selva located on ultisols (329 out of 570), were used for comparison. (Raw data sets were too large to include here but are on file with D. Clark at La Selva.)

The non-parametric categorical rank sum test was performed for each of the four size categories to determine statistical significance of differences in closest palm distances between new and old La Selva. Table 1 summarizes the results. For the 1 to 5 meter ($p=.0651$), 5 to 10 meter ($p=.1358$), and greater than 15 meter ($p=.3254$) size classes, the differences in distances to nearest palm and thus palm density were insignificant. For the 10 to 15 meter palm size class, however, there was the expected statistical difference between old and new La Selva distances and densities ($p=0.0013$), new impacted La Selva having lower palm density.

A chi-squared 2 x 2 contingency table was used to determine whether the expected relationship existed between forest type (old growth versus impacted forest) and the relative frequency of edible vs. non-edible large palms (Table 2). We found that in the 10 to 15 m size class, there was no significant relationship between the two ($p=0.1910$). In the greater than 15 m size class, however, we found that the two were dependent. As expected, we found a statistically significant shift toward a smaller percentage of large edible palms in the Sarapaquí annex.

Discussion

Although all of the size classes show a trend toward fewer palms in the disturbed forest, this difference is significant only in the 10 to 15 m category. There is a distinct drop in palm densities in this size category. The history of palm harvesting in this area may help explain this decrease.

Palmito has probably been harvested in the present La Selva boundaries since 1952, when Juan Heison, the second legal owner of the land, began farming, grazing cattle, and selectively logging cedar on the land. As the region became more populated,

palmito harvesting likely increased, experiencing a dramatic increase in the 1970s, when squatter communities were established in nearby Braulio Carillo National Park. According to Don Isaias--the current foreman at La Selva, lifetime local resident, and ex-palmito-harvester--most of the palms chosen to be harvested for their heartwood are less than 10 meters high.

The Sarapiquí annex has now been protected for 12 years. Before 1981, many of the trees which should have been in the current 10 to 15 m category may have been below 10 m., and therefore vulnerable to harvest. Harvest pressure on these trees before protection may explain why so few of them were able to grow into the 10 to 15 m size class. Unfortunately, there is very little data available on the growth rates of palm species. *Welfia georgii* has been estimated to grow an average of 2 - 3 meters per decade (Lieberman et al., 1988). This figure could support our hypothesis, although *Welfia* growth rates were found to be highly variable and would probably differ from other palm species.

In both large size classes, we also observed a trend toward decreasing relative frequency of edible palm species. This trend supports our hypothesis that in disturbed areas there is lower relative frequency of edible palm species, probably due to harvesting pressure. The statistical insignificance found in the 10 to 15 m size class may be due to the small number of samples in our study.

We therefore found support for both of our hypotheses, though our small sample size made it difficult to test for statistical significance of those results. Studies with more extensive sampling would probably confirm our findings. Considering harvesting pressure from before 1981 has considerably altered the structure of the palm populations in the Sarapiquí annex, it would be interesting to investigate how this change in palm populations will affect the perpetuation of palm species. It is possible that the lack of palms in the 10 to 15 m size class could result in a lack of the reproducing adults necessary to maintain viable populations. This depressed population could also adversely affect birds and mammals that rely on palm seeds. However, without information on the life histories of canopy and subcanopy palms, it is difficult to predict changes in palm reproduction in the future.

This lack of information warrants further research on palm species, as they are an integral part of old growth rainforests. Changes in their population structure and dynamics will significantly affect the forest ecosystem. Although in many cases it is too late to reverse past forest damage, an understanding of how forests continue to react to past impacts would be invaluable to forest managers.

Acknowledgements

We owe thanks to David Clark, Leo Campos, and William Miranda for sharing their time and expertise with us on this project.

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Table 1. Comparison of Canopy and Subcanopy Palm Densities in Old Growth (old) and Secondary/Highgraded Impacted Forests (impacted).

Size Class (m)		Mean Dist.(m)	Density (#/ha)	Rank Sum p
1 to 5	old	2.54	388.27	0.0651
	impacted	2.88	300.51	
5 to 10	old	5.83	73.58	0.1385
	impacted	7.41	45.55	
10 to 15	old	8.27	36.52	0.0013
	impacted	12.26	16.62	
> 15	old	7.45	45.03	0.3254
	impacted	7.91	39.99	

Table 2. Chi Squared 2 x 2 Contingency Tables to Compare Edible vs. Non-Edible Large Palms (10 to 15 m and greater than 15 m) in Different Forest Types.

10 to 15 m tall	Edible palms*	Non-edible palms*	Total
Old Growth	192	137	329
Impacted Forest	6	7	13
Total	198	144	342
p=0.1910			
>15 m.	Edible palms*	Non-edible palms*	Total
Old Growth	265	64	329
Impacted Forest	8	5	13
Total	273	69	342
p=0.0465			

* Numbers represent the frequency with which these species are the closest individual to the sampling point in that age class.

Guided Field Problem

A FOLK TAXONOMY OF MELIPONIDAE BEES IN THE SARAPIQUE REGION OF COSTA RICA

Authors: Ceal Smith, Keith Taulbee, Nick Shorr, and Donald Mee

Group Members: Ceal Smith, Keith Taulbee, Nick Shorr, Donald Mee, Jeff Zimpfer,
and Pantalao Munishi

Faculty: Jeff Bentley

Abstract

A folk taxonomy for Meliponidae bees was constructed, and compared to the more conventional system of scientific classification. The two systems shared several similarities, and convergence at the species and genus level occurred in instances in which the bee in question was of significant importance. Despite the vastly different approaches in constructing these two taxonomies, the two systems were quite similar, as seen by the fact that the folk taxonomy matched the scientific taxonomy at divisions of the family level and higher.

Introduction

The purpose of this project was to learn the regional folk taxonomy used for Meliponidae bees in the locality of Sarapique, Costa Rica. Folk taxonomies provide an interesting contrast to scientific taxonomies and may offer important ecological, physiological, and behavioral insights to the understanding of species.

In contrast to scientific taxonomies, which rely on phylogenetic (evolutionary) relatedness (based upon morphological and molecular traits), folk taxonomies are based on observation and direct experience. Embedded in the folk taxonomy is a wealth of information about the organism including ecological and biological information such as habitat use, abundance, and behavior, as well as practical information on the human-uses of a given organism.

Methods

We decided to approach this study with no priori assumptions. We felt that this type of study required an open mind and an attitude of discovery that allowed the informant free rein in relating the classification system to the group. As the process evolved, we began to form a loose framework of classification. Based upon this simple structure, the following categories were devised and subsequently used in questioning new informants:

- (1) Local names and synonyms
- (2) Size: in relationship to "Maria seca" the prototype
- (3) Color or distinctive markings
- (4) Honey characteristics
 - a.) quality for food, and
 - b.) medicinal uses
- (5) Repugnance as an indicator of docility or aggressiveness
- (6) Hive characteristics
 - a.) hive entrance architecture used for hive location and identification,
 - b.) height of hives in trees
 - c.) habitat selection and tolerance to domestication

After we had accumulated a complete list of named bees from our first three informants, we printed these names on separate index cards to make a little "deck". This deck was presented to our last two informants with the request that they sort them into piles reflecting how they thought they ought to be grouped (for "pile-sort" methods, see e.g. **). Because these two informants were academically-trained biologists, we stressed that they try to "think like campesinos" and group the bees accordingly.

Five people were interviewed. Isaias Alverado, Don Carlos, Don X, Ronaldo Vargas, and Carlos Valerio. Isaias, the foreman of La Selva's physical plant, has lived in the community for more than thirty years and grew up nearby. Don Carlos, an IDA *parceleiro* for the past seven years, lived previously in Guanacaste province, where he grew up. Ronaldo Vargas, a staff entomologist of La Selva, grew up in the southern part of Costa Rica. Carlos Valerio, a biologist and OTS course-coordinator, is from the Arenal region of Guanacaste.

Results and Discussion

One way of viewing a folk taxonomy is in comparison to the largely analogous system of scientific taxonomy. The distinctions between levels of organization in a folk taxonomy are based on the degree of importance or conspicuousness of a particular group of organisms (Bentley, 1993), while a scientific taxonomy is based on phylogenetic relatedness. In cases where the species is either very useful or very common, such as the Maria Seca bee, the folk taxonomy is as sophisticated as the scientific system. Often times the folk taxonomy can be even more sophisticated as subtle behavioral differences are noticed, which may escape the eye of an entomologist who may only view a prepared specimen. In cases of lesser importance, such as the Aragle bees, which are perceived as a dirty pest, but which do not cause great harm, the classification often includes a general group of species which share similar characteristics. Finally, a folk taxonomy, as opposed to a scientific taxonomy, can vary from region to region, as evidenced by the number of synonyms for certain groupings of bees in our study.

Just as scientific taxonomies are subject to different interpretations depending upon the traits and techniques used for classification, so are folk taxonomies. Folk taxonomies are fluid and somewhat individualist, but nevertheless, we were impressed and surprised by the parsimony of opinion among our informants in classifying the eleven types of bees.

This study was very brief and did not allow for species verification. Some interesting findings included substantial knowledge of the informants regarding bee entrance architecture, competition between species, and interesting behavioral information. Furthermore, the knowledge of the rarity of "Congo" bees by one of the informants could be one way in which local wisdom, preserved within a folk taxonomy, could prove to be a potential source of information regarding the need for preservation of certain species.

We were surprised by the lack of knowledge about bees as pollinators. Perhaps because the European honey bee has replaced native bees, this is not important to local people. The key traits used for classification were based upon use value (as honey producers) and degree of "nastiness". Hive architectural traits were often noted as an indicator of how to distinguish different (good and bad) groups.

Table 1 demonstrates this trend, common among all of the informants, to divide bees into three general categories: small bees, large bees, and bad bees. The Maria Seca, Jicotico, and Jicote Limon are all small bees, which are basically beneficial. The Peladora, Chupojo, and Arrarle can be of several different sizes. However, they were always grouped together by the informants as being either annoying or potentially dangerous to people. The Varsino, Congo, Picusare, and Castella bees are nearly always grouped together as large bees, despite their behavioral differences.

Finally, the informants defined a bee as something that bites and makes honey, as opposed to a wasp, which stings. When asked whether the introduced Castella bee was a bee or a wasp, because it has a sting, the informants responded that it had to be a bee because it made honey, and a wasp does not make honey. Even at the more general levels of taxonomic distinction, a folk taxonomy relies upon easily observable behavioral characteristics which are often linked to the potential utility or disutility (honey production versus stinging) of the group of organisms.

Conclusion

The folk taxonomy is a method in which non-scientists classify the organisms which are important to their daily life. In the case of bees, which are important to farmers for many reasons, they are classified primarily for their honey production, potential danger, and hive structure, all of which are easily observable. Ironically, although bees are important pollinators, and are critical to the health of a farmer's crop, very little is known about their role as pollinators, which would be more difficult to observe.

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Table 1. Bee Traits Used for Folk Taxonomy.

Common Name (Genus)	Key Character	Size/Color/Hive Architecture/ Abundance	Honey Quality/ Other Uses
Maria Seca /Mariola (<i>Trigona jaty</i>)	easily domesticated/ many people keep them	small/yellow /hives low in trees/abundant, very docile	excellent honey /eyes, sore throat, makes children talk
Jicotico (<i>Melipona</i>)	hive entrance small/l bee at a time		
Jicote Limon (<i>Melipona</i>)	honey tastes like lemon	bigger/yellow	good for cough
Peladora (<i>Oxytrigona</i>)	burns the skin	black resin at entrance	not important
Chupojo (<i>Trigona</i>)	curious bee/sucks at eye ducts	small/black/ small colonies/ abundant	good, but produces very little
Arrarle (many spp.)	Gets in hair/ bites/eats excrement	variable/11 mm maximum	no good
Varsino (<i>Melipona</i>)	mottled color	big (14 mm)/ mottled/common	good/abundant
Congo (var. spp.)	biggest/biting (18mm)	black-brown/ hive high/rare	excellent, but produces little
Picusare/ Tacanique	medium	black-yellow/ small entrance	good
Castella/ Africanisado	big/stings	hives outside <u>dangerous</u>	good, lots/only in dry season

Group Field Problem

SPIDERWEB DISTRIBUTION IN TREE BUTTRESSES

Authors: Pamela Stedman, Laura Howard, Jagdish Krishnaswamy, and Ellen Pederson
Faculty: Carlos Valerio

Resumen

Se estudio la distribucion y tipo de telaranas en las bases de tres arboles en un bosque tropico humedo. Los resultados indican que existe una amplia estratificacion y ocupacion de nichos entre las aranas, dependiendo de la forma, orientacion y estructura de las telas aranas.

Abstract

A study of spider web distribution by type and height was done in the buttresses of three rain forest trees. The results indicate that there is significant stratification and niche occupancy among spiders based on shape, orientation, and structure of web.

Introduction

There are more than 5000 species of spiders in the world; about 1000 occur in La Selva Biological Reserve. All spiders produce egg sacs and silk and all prey upon invertebrates. This similarity in ecological characteristics raises the question of niche division among species sharing narrow habitats. By producing webs of different size, mesh, and shape, several species can share the same area. The relative distance to each other and the distance to the ground, as well as the inclination of the webs, will determine the type of prey that will fall into the web, such as insects falling from the canopy into a horizontal or inclined web, flying horizontally into a vertical web, or insects emerging from the ground directly into a web (Table 1). Other spiders run, attack, and ambush the prey. Each family has a characteristic strategy.

Objectives

The objectives of this study was to determine the spatial distribution of spiderwebs on tree buttresses in the Arboretum at La Selva Biological Reserve and to determine the division of food resources among different spider families.

Methods

Three buttress producing trees (*Hyeronima* sp. and *Terminalia*) were selected for this study. Size of the tree at breast height was measured and size of buttress were categorized as small, medium or large. Spiderwebs were made visible by shaking a sock containing cornstarch powder at different altitudes of the tree (Valerio's Method). Type of web, diameter, distance to, and type of its nearest neighbor were measured as well as the inclination and distance from the ground.

Results

1) Height vs. Web

The vertical sheet web was most variable in web placement ranging from 3 to 78 cm, however, the mean height was 10 cm. All other web types were generally found below 20 cm, although the range was spread between 1 and 40. The flat orb was the web located closest to the leaf litter (Figure 1).

2) Size vs. Web

The vertical orb had the largest mean size with the vertical sheet the next largest. The inclined orb, flat orb, dome sheet and domito were the smallest webs with means from 3 to 20 cm. The vertical sheet, flat sheet and funnel were of medium height with median heights from 10 to 40 cm. The highest overall variability was found in the vertical sheet, vertical orb, the flat sheet and the funnel (Figure 2).

Distance of webs from ground

Webs were not evenly distributed vertically. More than half of all the webs (60%) were located below 20 cm. Nearly a third of the webs (27%) were between 30 and 99 cm, whereas only 17% were located above 100 cm.

Frequency of types of webs

The flat sheet, inclined orb, and the dome were the most numerous webs summing to 90, 65, and 55, respectively. The domito, vertical sheet, and vertical orb accounted for approximately 25 webs each. Funnel webs numbered 15, whereas flat orbs were the least numerous with only 7 (Figure 3).

Density of webs

Almost 50% of all the webs were located within 10 cm of another web, whereas nearly 30% of the webs were within 20 cm. Only 10% were within 30 cm of a web and fewer than 3% had distances as great as 40 to 50 cm separating webs (Figure 4).

Discussion

More than half the webs were located in the bottom 12% of the sampling height. Since the buttresses are severely angled, the area at the base of the tree is much larger than the top of the sampling area. The high percentage of webs located at the base of the tree may reflect an unequal sampling area and fail to be biologically significant.

Most webs were located within close proximity to a neighboring web and very few (<3%) were more than 40 cm apart. The density of spider webs may indicate a commensal relationship among closely situated webs. Alternatively, densely packed webs may enhance competition. Most likely, densely clustered webs reflect the physical constraints of the buttresses. Since most of the webs need at least two surfaces from which to anchor silk supports, locations on the buttress walls might foster competition for space. Higher up the tree, there would be fewer structures from which to hang a web.

The largest webs, (inclined and vertical orb, and vertical sheet), were found for the spiders with flying insects as their main prey items. A larger surface area would be most effective in catching flying insects. The smallest webs include the dome and the domito whose structures are designed to catch jumping or crawling prey. The small web size may reflect prey abundance, physiological constraints, or competition.

The three most numerous types of webs were the inclined orb, the flat sheet, and the dome. The varied prey items of each of these spiders include: flying, falling, and jumping insects. The specialization of the webs may allow these three species to coexist in high numbers by reducing potential competition for prey.

The vertical distribution of web types shows a trend in flying insect preying spiders build webs higher, those that prey on falling insects below them, and jumping insect feeders are lowest. The location of the webs seems to indicate a trend which may facilitate resource use. The highest webs would seem to be better suited to capture flying insects. The falling feeders would benefit from capturing any prey that might escape from above and fall into their webs. Spiders preying on insects from the ground or litter would be most effective by placing their webs near the litter.

Conclusion

The placement of spider webs seems to reflect prey specialization. Optimizing both height and surface area may allow many spiders to live in high densities without competing.

Table 1. Characteristics of Spider Webs Observed at La Selva.

Web Type	Orientation	Family	Insect Prey
Orb Weaver	Flat	Araneidae	Falling
Orb Weaver	Vertical	Araneidae cyclosa	Flying
Orb Weaver	Inclined	Uloboridae	Flying
Sheet-Webs	Dome	Pholcidae(1)	Jumping
Sheet-Webs	Domito	Pholcidae(1)	Jumping
Sheet-Webs	Flat	Pholcidae(2)	Falling
Sheet-Webs	Vertical		Falling
Funnel Web	Funnel	Tangelia radiata	Falling
Leaf Rollers	Rolled Leaves	Theriidae	

Figure 1. Average Height of Web Types.

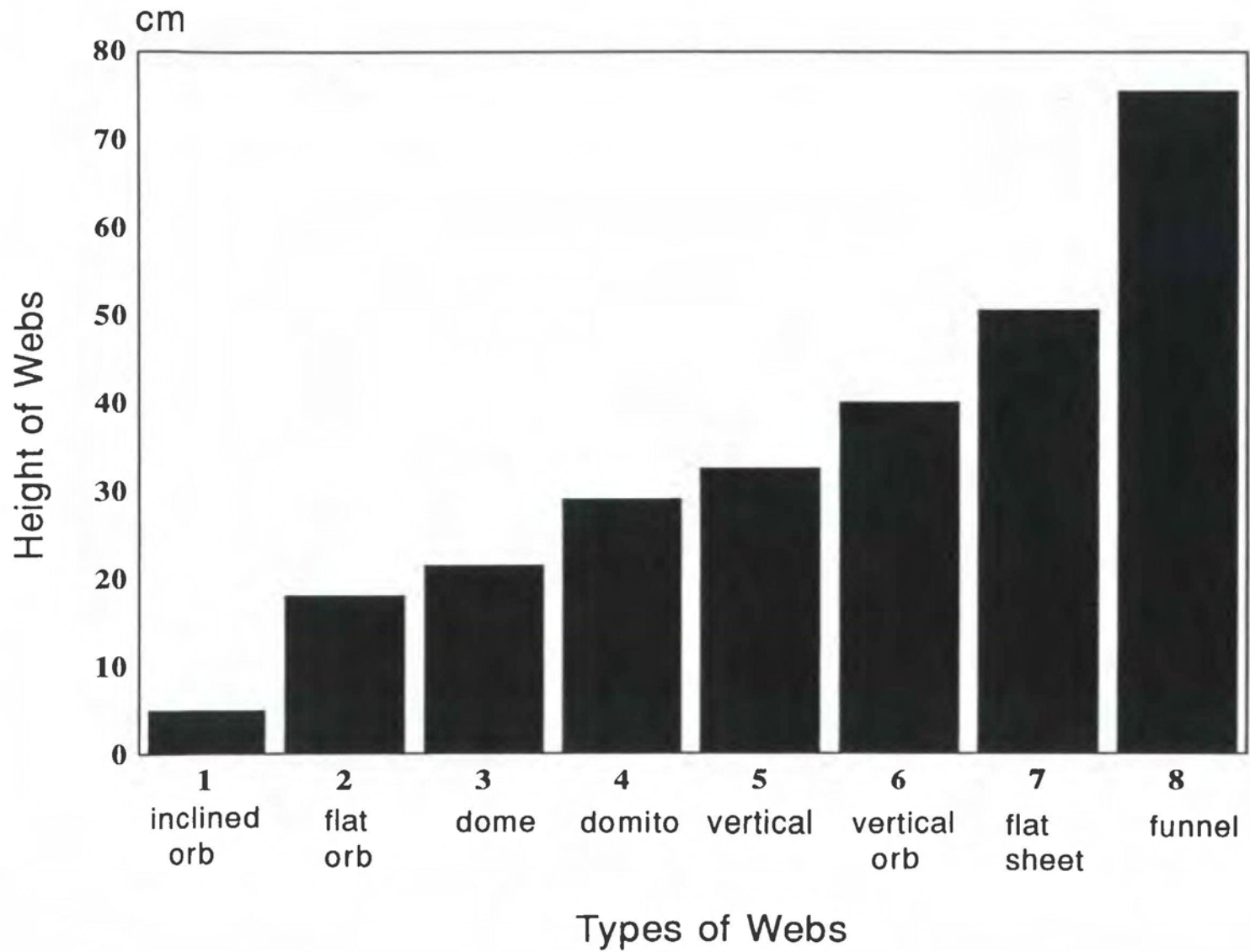


Figure 2. Size of Webs.

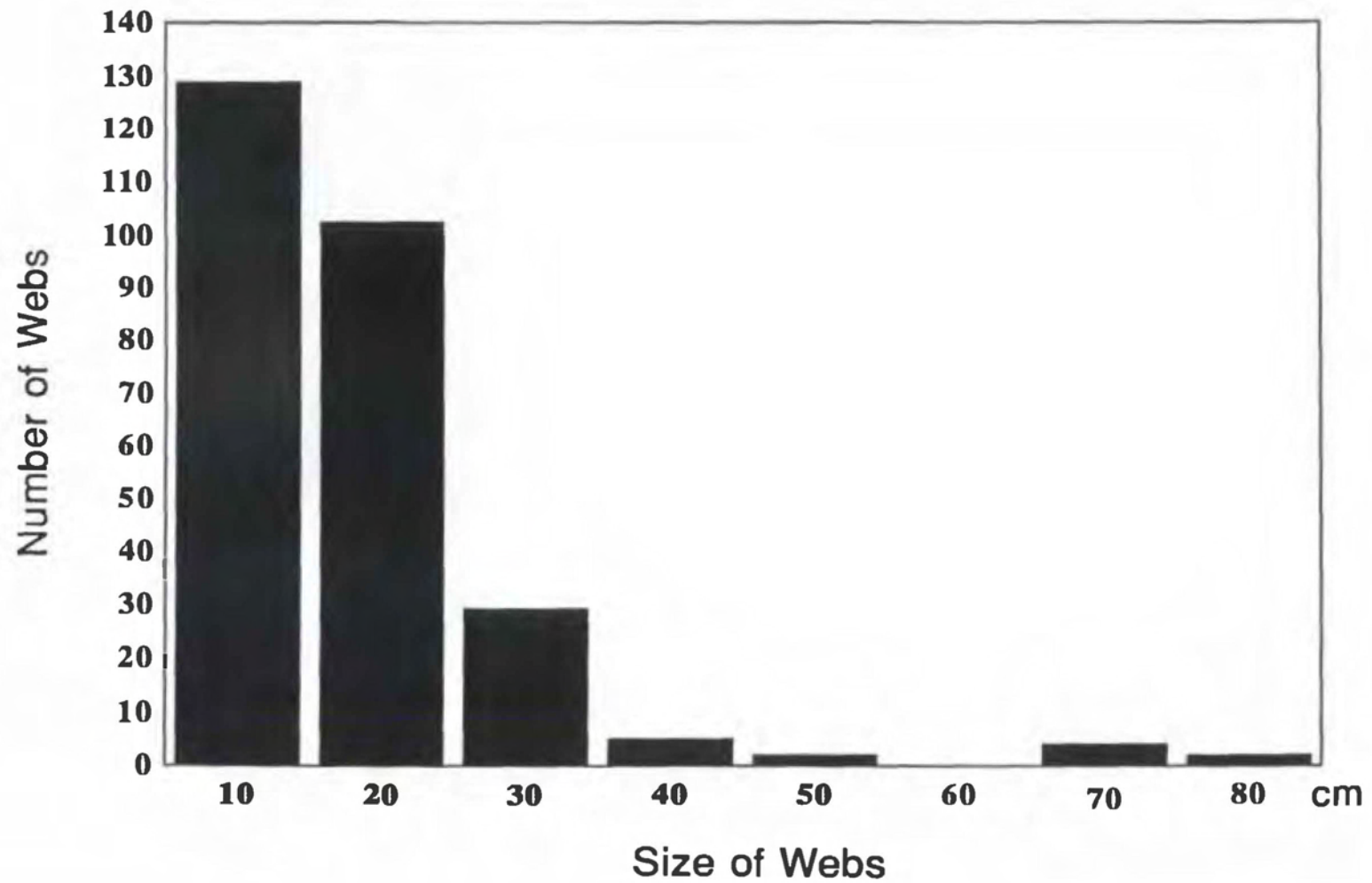


Figure 3. Frequency of Types of Webs.

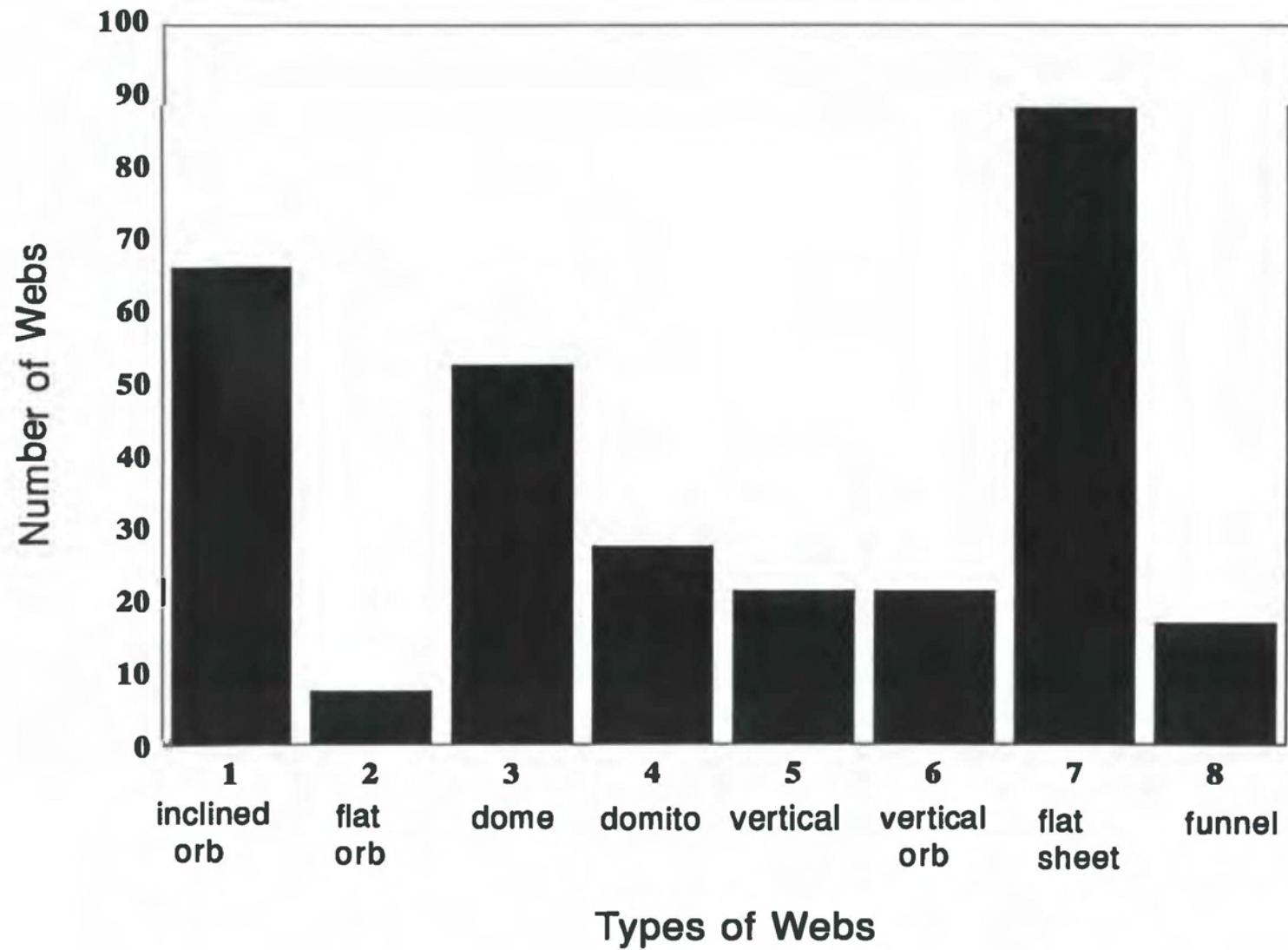
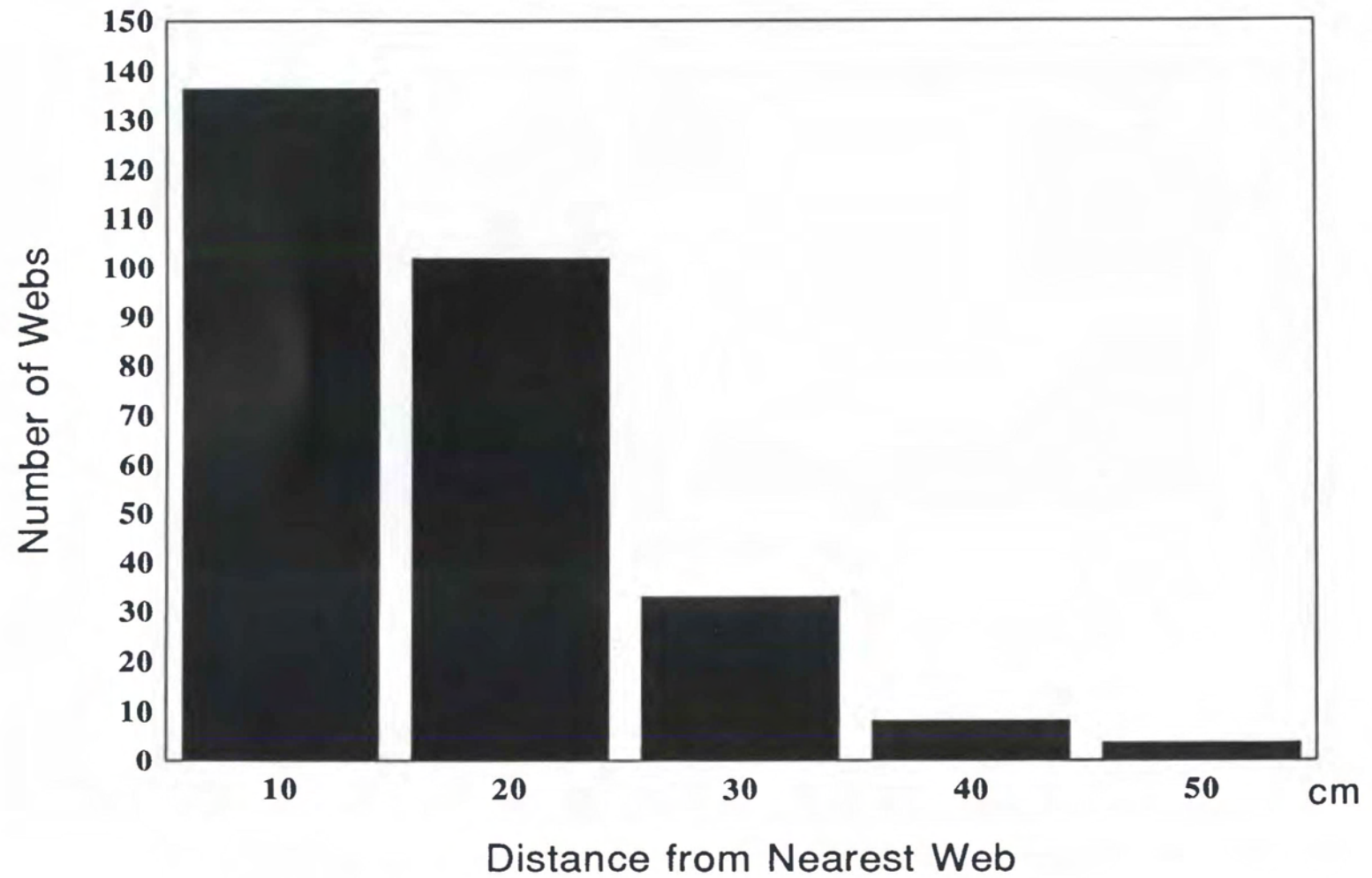


Figure 4. Density of Webs.



Guided Field Problem

EXPLORING A PASTURE FOR COW VITTLES

Author: Christopher Rosin
Faculty: Edzard Van Santen

Resumen

Se explora la ecología de un potrero cerca de la Estación Biológica La Selva. Las especies preferidas y no preferidas de forraje fueron identificados. Seis muestras de plantas del potrero fueron separados según evidencia de consumo preferencial. Después fueron correlacionados entre ellas y con condiciones del suelo para determinar la distribución y concentración espacial.

Abstract

Pasture ecology is explored in a pasture at a dairy farm near La Selva Biological Station. The preferred and non-preferred grazing species were identified. Six pasture plant samples were separated based on grazing preferences. These separations were correlated with each other and with soil pH and compactness readings to determine spatial distribution and concentration.

Introduction

The ecology of a pasture reflects the physical characteristics of the site as well as human and bovine influences. The combination of these factors is evident in the spatial distribution and local concentration of various pasture plants. This study examines the ecology of the pasture based on the determination of preferred and non-preferred forage plants -- i.e., those which exhibit evidence of bovine feeding compared to those left uneaten. Emphasis will be placed on the physical characteristics of the site in attempting to explain the described distributions.

Study Site

The pasture for the study is located just outside the boundaries of the La Selva Biological Station. It is situated on the flood plain of the Puerto Viejo River. This location contributes the site's wetness and its relatively level topography. These characteristics are also indicative of the Coastal Plain region of northeastern Costa Rica which is bounded to the west by the river. This situation helps explain the slightly acidic nature of the soils as well.

The pasture is approximately a two hectare (350 m x 63 m) rectangle following a northwest to southeast axis (see Figure 1). A slight slope to lower areas in the extreme northern corner and along the northeast edge of the field creates wetter areas which are characterized by large clumps of grasses. Such clumps appear sporadically throughout the "higher" areas. There is also a scattering of shade trees (southwest half of the pasture) on drier ground. These are areas of concentrated organic matter deposition, both from the leaf litter and the manure of cows which congregate in the trees' shade. The pasture appears to have been prepared in the past--cleared, grasses and trees planted, etc. -- but experiences little current management as evidenced by the encroachment of species which the cows do not eat.

Method

The study was conducted as a means of establishing baseline data for a single pasture. The initial assessment of the pasture included a rapid cursory appraisal of major represented plant species. Samples of those species which were preferentially grazed and those which appeared untouched were collected separately. These species were then identified to facilitate recognition.

The second phase of the study involved a detailed mapping of the pasture. The mapping was followed by stratified random sampling in which the pasture was divided into six sectors and actual sampling sites were selected utilizing an object flung by a blindfolded individual. Each sample consisted of the above-ground plant material within a 20 x 25 cm rectangle. The samples were sorted according to preferred grasses, preferred legumes, non-preferred species, and litter. Wet and dry weights were taken for each sample. Soil acidity and compaction were recorded from each sample site as well.

Results

The initial review of pasture plants revealed three major preferred (*Anoxopus compresus*, *Digitaria carialis*, and *Desmodium* sp.) and several non-preferred species (including *Paspalum fasciculatum*, two *Labiatae* spp, 3 *Cyperaceae* spp, and a *Mimosoidae* sp.). The preferred grasses appeared to be distributed throughout the pasture. The *Desmodium*, however, was not represented in the samples to the extent expected from the visual survey. Where these three species were predominant, the pasture maintained approximately 5 - 20 cm stand height. The other species were distributed throughout the pasture as well, although the *Paspalum f.* and the sedges formed concentrated clumps and the *Mimosoidae* covered a large section in the center of the pasture (see Figure 1). The presence of these obvious intrusions suggest the lack of pasture maintenance. The clumps were up to 80 cm in height and included uneaten preferred species. An unscientific sampling of the clumps suggested soils with lower pH and higher moisture content in these areas. The *Mimosoidae* tended to smother competitors and retained a height of approximately 20 - 30 cm. The cows avoided this area completely--except to cross it--due to the plant's thorns.

The results of the sampling reflected the selective grazing of the cows. Sites with high biomass exhibited non-preferred species and those with lower biomass, preferred species dominance. The respective species domination results from the partial removal of biomass by the cows.

The soil acidity and compactness of the samples contained no extreme value variations. The soil pH varied from 5.6 to 6.1 (Table 1) with a possible trend from the northwest to southeast. Compactness varied from 0.3-1.1 k/cm² responding largely to wetness and proximity to the cows' habitual paths.

The species in the sample were representative of the initial assessment. The *Mimosoidae* did not appear in any of the samples, however. As this plant is concentrated in a particular site, the data would indicate its recent invasion and limited dispersal range. The *Desmodium* sp. exhibited lower populations than expected after initial inspection. This may indicate selective grazing of *Desmodium* in comparison to other preferred species due to its higher protein concentration.

The analysis of species biomass suggests that the NE half of the pasture is more heavily grazed (Table 1). The respective sampling sites (1-4) also have the greatest amount of preferred vs. non-preferred species. The site furthest from the NE corner contained more non-preferred than preferred biomass.

Correlations (Pearson's) of the various data suggest several trends although the limited data set places their significance in question (see Table 2). Soil acidity (pH) exhibits a positive correlation (negative pH is a positive acidity correlation) with each of biomass indicators reflecting the NE to SW pH and grazing intensity trends. Thus, non-preferred species may be more competitive in more acidic soil and discourage the grazing of associated preferred species. This explanation seems particularly valid for the *Desmodium* which correlates well ($r^2=0.74/0.64$) with the non-preferred species. Litter is positively correlated with only the preferred grasses possibly due to torn material left behind by grazing cows.

Conclusion

The sampling of six plots within the pasture provided an overview of its ecology. The preferential grazing implied in the initial survey of the pasture proved largely valid, although some species' populations were over estimated. A relationship of soil pH to biomass was established. From the conclusions drawn, one would generally expect to find cows resting under the shade trees (as they sleep 16 hours a day) or grazing in the NE half of the field.

Recommendations

Based on the conclusions drawn from the study, further analysis of pasture ecology could be undertaken. Detailed information on management practices would be of particular interest as would be an evaluation of land manager perceptions of plant diversity within the pasture. Used as a baseline, this study could aid in the establishment of in-pasture experimentation such as response to fertilizers, varying cow densities, or selective weeding. On its own, the study reveals certain patterns in concentrations of preferred grazing species which may not appear obvious in visual observation of field conditions.

Table 1. Biomass of Sampling Sites.

		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Preferred Grass	W	49.30g	17.90g	69.00g	81.80g	55.50g	40.50g
	D	18.38g	10.45g	10.92g	20.75g	16.01g	12.62g
Preferred L Legume	W	0.70g	1.65g	0.00g	0.00g	0.00g	10.70g
	D	0.20g	0.25g	0.00g	0.00g	0.00g	1.83g
Not Preferred	W	4.40g	7.10g	0.00g	0.23g	59.90g	82.60g
	D	1.70g	1.36g	0.00g	0.06g	18.33g	20.38g
Litter	W	14.90g	3.10g	21.40g	30.9 g	7.20g	8.10g
	D	0.17g	1.51g	11.35g	12.26g	6.70g	1.01g

Table 2. Pearson Correlations of Sample Variables.

	pH	Compact	Grass	Legume	Non-prf
compact (wet)	.3310				
compact (dry)	.3310				
grass	-.4039	-.8371			
grass	-.5397	-.4808			
legume	-.0854	.1831	-.3921		
legume	-.0905	.1558	-.2968		
non-prf	-.0491	.1356	-.2656	.7399	
non-prf	-.6964	.1243	-.1186	.6372	
litter	-.0854	-.7477	.8981	-.3813	-.5420
litter	-.5144	-.2811	.6667	-.3805	-.0608

Figure 1. Map of Pasture Characteristics



shade tree



clump

1 = site of samples



sensitive plant

W = wet area

scale = 1:1,000



continuous area



N

Guided Field Problem

USE LEAVES OR LEAVE THEM

Group Members: Amelia Oliver and Jill Fischer
Resource Person: Orlando Vargas

Resumen

Se hizo un estudio de las especies de plantas indígenas que posean un uso particular para los seres humanos y que se encuentran en la estación biológica. Plantas que consideramos que tuvieran usos particulares cayeron en una o más de las siguientes categorías: la construcción, la comida, la caza, la artesanía, la medicina, la madera y el fuego. Cada categoría fue representada por muchos individuos y varias familias taxonómicas.

Abstract

A study of the native plant species found at La Selva, which possess qualities of a particular use to humans, was undertaken. Plants considered to have particular use fell into one or more of the following categories: construction, food, hunting, crafts, medicine, timber, and fire. Each of the categories was represented by numerous individuals and several families.

Introduction

La Selva's collection of primary and secondary forests offers unique and interesting native plant species. As social scientists in this natural environment, we were interested in the types of uses these plants may have to the local population. The idea for the project developed from the hope of encountering forest resources that because of their value, might encourage the protection of the forest.

Methodology

Three sites were visited, all of which were located in primary forest to obtain a certain degree of similarity in terms of soil type, vegetative cover, and historic land use. Care was taken to select sampling regions not within close proximity of the riverain area to avoid any influences produced by the river. To determine the location of the transects, we arbitrarily selected G.I.S. coordinates along two trails. From those coordinates, we selected a direction which would not lead us into the riverain area or toward another trail. This degree bearing was followed, marking a 70 m line with a tape measure. Only the last 50 m were utilized in the study to avoid any externalities that could result from close proximity to a trail. Each of the sample sites were transects 50 m long and 2 m wide.

The first transect was to the North of the G.I.S. coordinates: 1400, 400, along the "SSO" trail. The second transect was near the coordinates 1300, 300, of the "SSO" trail; a degree bearing of 160 was used to determine the initial point of this transect. The third transect was located 20 m from the 1100, 850 coordinates of the "CCC" trail, at a bearing of 30 degrees.

All vegetation along each transect was studied. Since only those plants that had a human usefulness were recorded, our extremely knowledgeable guide (Orlando) was consulted to provide the name and specific use of each selected species. Species were characterized into the following categories: construction, food, hunting, crafts, medicine, timber, and fire. Food, craft, and medicinal plant uses were more obvious to characterize. Plants used to build houses or household utensils were considered as construction plants. Timber trees held their primary value as prepared wood. Plants used to make bows or spears were for hunting. The interesting species, which were used to make matches or fire-starter fluid, were categorized as fire plants. Firewood was not included as a specific use, as any woody plant could be used. A single species could be characterized into all applicable categories.

Site description

The first transect had a slope (that was transversed) of approximately 15 degrees. An ant hill inhibiting vegetative growth was observed nearest to the trail, while the farther end of the transect was located within a gap (which was approximately five years old - a judgement based on the amount of sunlight that graced the area, as well as the density of the vegetation). At the second transect, we descended with a slope of approximately 20 degrees. Due to the thick understory growth, we classified the gap as being relatively old. The third transect was extremely flat; it had a slope of only 3 degrees. It also varied greatly in vegetative cover: while the 15 m closest to the trail had very dense vegetative cover (caused by a large gap - approximately 10 years old), the 20 m furthest from the trail consisted of relatively sparse understory.

Results

A total of 43 species in the three transects combined was discovered. The total number of individuals was 310. Appendix 1 shows the number of individuals found in each of the categories. Each of the categories is illustrated by a table, in which the number of individuals and their scientific and common name is given, as well as the particular use of each species and the portion used.

Construction

This category had the greatest number of individuals, 174, which represented ten families, dominated by palms (Table 1). The most common use was that of leaves for thatching. Other uses included the use of roots for tying, stems for furniture, and wood

for poles, tools, and fences. One tree species had a special water resistant wood which was used to build La Selva's trail network.

Food

A total of 104 individuals in the three transects combined were identified as having edible portions (Table 2). These individuals of varying stages of maturity represented nine distinct taxonomic families. Of the more interesting specimens, nineteen individual water-producing vines were identified, as were seventy-one palm individuals, including three *Euterpe*, five *Iriarte*, and twenty-four *Socratea*, all valued for their hearts-of-palm.

Hunting

Two different palm species (representing seventy-one individuals) were identified as being useful to humans in hunting (Table 4). Over 95% of the individuals belonged to the genus *Genonma* and possess stems that make good spears. The other species has stems that are used for bows.

Crafts

Six families were represented in this category, and fifty-nine individuals were identified (Table 3). The highest number of individuals found were of the genus *Asplundia*; the fruit of this plant was, in times past, used as a designed stamp with which one applied body paint. Other plants produced seeds and stems for jewelry, roots for wicker furniture, and wood for growing orchids.

Medicine

A total of fifty-five medicinal plant specimens were identified (Table 3). Nine families were represented. The uses of these individuals ranged from curing relatively common ailments such as stomach aches and anemia, to quite severe illnesses such as diabetes and malaria. The parts of the plants used for the medicinal purpose also varied.

Timber

In this category the greatest number of distinct taxonomic families were represented: 11 (Table 4). With the exception of Gavilán (*Pentaclethra macroloba*) which had twenty-four individuals, each family was represented by only 1-3 individuals. This trend appears to confirm the theory regarding the diversity of primary tropical rain forests: within a given area, there is great diversity of species, yet no one species is extremely dense.

Fire

Eleven individuals representing three families constitute the sub-category of fire (Table 4). The fire-related uses in this category include the use of wood for matches, and the use of oil from the fruits as fire-starting fluid.

Concluding Remarks

It is important to note that only the plants capable of providing a direct benefit to man were considered in this study. Numerous plants that indirectly benefit man were not investigated. Therefore, it was not possible to calculate the percentage of the number of species beneficial to man compared to total species.

Nonetheless, we encountered many valuable plants in the transects studied within the primary forest. This diversity of the plants was promising, as it encourages those who utilize forest products to protect such a valuable resource.

Table 1. Construction Species.

CONSTRUCTION

SCIENTIFIC NAME			COMMON NAME	#	PART	USE
Araceae	Philodendron	sp	Fierrillo	2	root	tying
Araceae	Philodendron	radiatum	Mano de Tigre	1	root	tying
Bignoniaceae	Mussatia	sp	Liana	2	stem	wicker frames
Bombacaceae	Matisia	bracteolosa	Molenillo	1	wood	
L-Papilionoideae	Pterocarpus	rohrii	Paleta	1	wood	tools
Melastomaceae	Miconia	elata	Lengua de Vaca	3	wood	
Olacaceae	Minquartia	guianensis	Manú	2	wood	water proof
Palmae	Asterogyne	martiana	Suita	12	leaves	thatch
Palmae	Astrocaryum	confertum	Pejibaye de Montana	2	trunk	
Palmae	Genoma	congesta	Caña de Danta	68	leaves	thatch
Palmae	Genoma	cuneata		14	leaves	thatch
Palmae	Iriarteia	gigantea	Palmito Dulce	3	leaves	thatch
Palmae	Socratea	durissima	Palmito Amargo	24	leaves	thatch
Palmae	Welfia	georgii	Corozo	28	leaves	thatch
Rhizophoraceae	Cassipourea	elliptica	Mangle de Monte	2	wood	poles
Rubiaceae	Faramea	parvibractea	Cafecillo	5	wood	roof
Rubiaceae	Warszewiczia	coccinea	Pastora de Montana	3	all	fence
Sapotaceae	Pouteria	standleyana	Sapotillo	1	wood	
TOTAL				174		

Table 2. Food Species.

FOOD					
SCIENTIFIC NAME			COMMON NAME	#	PART
Bombacaceae	Matisia	bracteolosa	Molenillo	1	fruit
Burseraceae	Protium	costaricense	Canfín	3	fruit
Burseraceae	Protium	glabrum	Canfín	2	fruit
Burseraceae	Protium	pittieri	Canfín	2	fruit
Convolvulaceae	Maripa	nicaraguensis	Conserva	1	fruit
Costaceae	Costus	sp	Caña Agria	8	water
Dilleniaceae	Doliocarpus	dentatus	Bejuco de Agua	11	water
Guttiferae	Garcinia	intermedia	Jorco	3	fruit
L-Mimosoideae	Inga	fagifolia	Guavo	2	fruit
Palmae	Asterogyne	martiana	Suita	12	heart fruit
Palmae	Euterpe	macrospadix	Palmito de Mantequilla	3	heart
Palmae	Iriarteia	gigantea	Palmito Dulce	3	heart
Palmae	Socratea	durissima	Palmito Amargo	24	heart
Palmae	Welfia	georgii	Corozo	28	fruit heart
Sapotaceae	Pouteria	standleyana	Sapotillo	1	fruit
TOTAL				104	

Table 3. Medicinal and Craft Species.

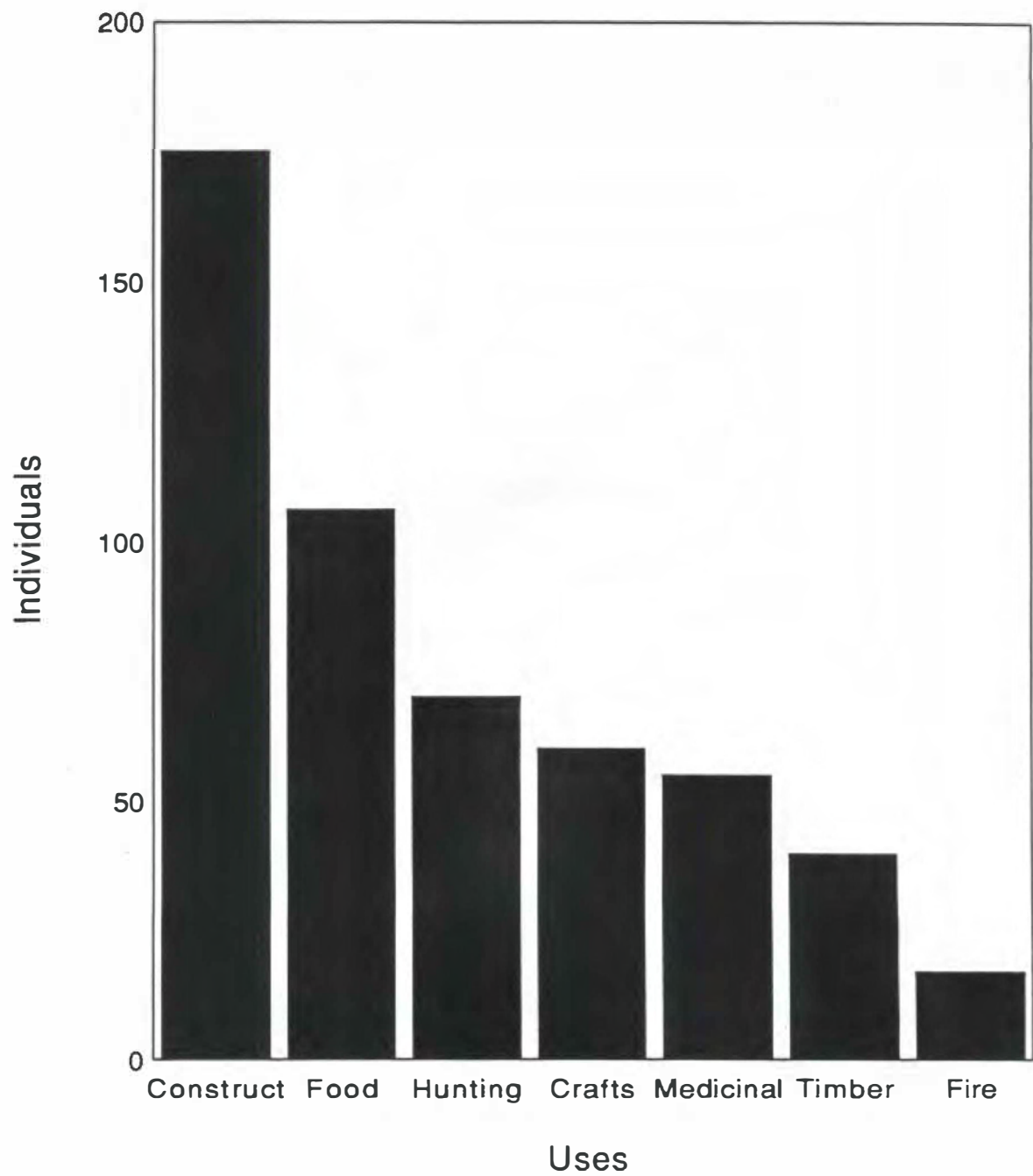
MEDICINAL						
SCIENTIFIC NAME			COMMON NAME	#	PART	USE
Costaceae	Costus	sp	Caña Agria	8	stem	kidney thirst
Dilleniaceae	Dolioscarpus	dentatus	Bejuco de Agua	11	sap	water kidney
L-Caesalpinioideae	Bauhinia	guianensis	Escalera de Mono	2	stem	diabetes
L-Mimosoideae	Pentaclethra	maculosa	Gavilán	24	wood	fungi
Moraceae	Naucleopsis	naga	Quina	2	sap	malaria fungi
Myristicaceae	Virola	sebifera	Frutilla Dorada	3	sap	drug fungi
Simaroubaceae	Simarouba	amara	Aceituno	2	bark	stomach
Smilacaceae	Smilax	sp	Sarzaparrilla	2	root	anemia
Tiliaceae	Apeiba	membranacea	Peine de Mico	1	fruit	shampoo
TOTAL				55		
ART						
Annonaceae	Unonopsis	pittieri	Hamburger	1	seed	jewelry
Araceae	Philodendron	rigidifolium	Mimbre	1	root	wicker
Cyatheaceae	Cyathea	sp	Helecho Arborescente	4	trunk	orchid
Cyclanthaceae	Asplundia	sp		47	fruit	body-paint
L-Caesalpinioideae	Bauhinia	guianensis	Escalera de Mono	2	stem	jewelry
Palmae	Iriarteia	gigantea	Palmito Dulce	3	seed	jewelry
Palmae	Synechanthus	warscewiczianus		1	seed	jewelry
Sapotaceae	Pouteria	standleyana	Sapotillo	1	seed	crafts
TOTAL				60		

Table 4. Timber, Fire, and Hunting Species.

TIMBER						
SCIENTIFIC NAME			COMMON NAME	#	PART	USE
Flacourtiaceae	Casearia	arborea	Manga Larga Blanca	1		
Flacourtiaceae	Laitia	procera	Manga Larga Colorada	2		
Guttiferae	Calophyllum	brasiliense	Cedro María	1		
Humiriaceae	Sacoglottis	trichogyna	Danto Plomillo	1		
L-Mimosoideae	Inga	fagifolia	Guavo	2		
L-Mimosoideae	Pentaclethra	macroloba	Gavilán	24		
L-Papilionoideae	Dussia	cuscatlantica	Targuayugo	1		
L-Papilionoideae	Pterocarpus	rohrii	Paleta	1		
Meliaceae	Guarea	bullata	Cocora	2		
Myristicaceae	Virola	sebifera	Frutilla Dorada	3		
Ochnaceae	Cespedesia	macrophylla	Tabacón	1		
Olasaseae	Minquartia	guianensis	Manú	2		
Verbenaceae	Vitex	cooperi	Cacho de Venado	1		
Sapotaceae	Pouteria	standleyana	Sapotillo	1		
TOTAL				42		
FIRE						
Araliaceae	Dendropanax	arboreus	Fosforillo	1	wood	matches
Burseraceae	Protium	costaricense	Canfin	3	oil	starter
Burseraceae	Protium	glabrum	Canfin	2	oil	starter
Burseraceae	Protium	pittieri	Canfin	2	oil	starter
Melastomaceae	Miconia	elata	Lengua de Vaca	3	wood	
TOTAL				11		
HUNTING						
Palmae	Genoma	congesta	Caña de Danta	68	stem	spears
Palmae	Iriarteia	gigantea	Palmito Dulce	3	stem	bows
TOTAL				71		

Appendix I

Uses of Native Species



SELVITA FOREST GROWTH SIMULATION

Group Members: Norm Bourg, Bruce Ferguson, Jill Fischer, Ankila Hiremath, Amelia Oliver, Ellen Pederson, and Pamela Stedman

Faculty: L. Simpson

In this exercise, we ran two different forest growth simulations over a fifty-year period, noting the data at ten-year intervals (Table 1). The first simulation was run as a control. It was defined by the following characteristics: an elevation of 20.0 m, a soil moisture capacity of 250.0 mm/m, 1.0 m depth of soil, 120.0 units of soil moisture, and a water table depth of 0.3 m. In the second simulation, the only difference was in the water table depth, which was changed to 15.0 m.

We found few differences in the number of individual trees and the total tree biomass when the depth of the water table was lowered (Table 1). These data can be interpreted in two ways. It is feasible that the depth of groundwater has little effect on the growth of trees, as the typically high rainfall of the region may provide the trees with the necessary water. It is also possible that this model is inadequate for determining the effects of changes in the depth of the water table on tropical rain forests.

Table 1

Simulation 1 (Control)			Simulation 2 (Dry)		
Year	# Trees/ 100 m sq.	Biomass kg/m sq.	Year	# Trees/ 100 m. sq.	Biomass kg/m sq.
1	0.0	0.0	1	2.4	0.0
10	103.2	5.5	10	88.4	16.3
20	127.0	18.7	20	111.2	15.4
30	24.8	33.1	30	40.0	33.3
40	10.6	44.8	40	11.2	44.7
50	8.0	52.1	50	7.0	55.3
60	5.8	63.8	60	4.8	59.1
70	3.4	68.4	70	3.8	63.3
80	3.0	64.8	80	6.2	72.4
90	4.4	70.4	90	16.2	56.3

Simulation Model

SELVITA SIMULATION OF THE ELIMINATION OF MAHOGANY COMPETITORS

Authors: Laura Howard and Chris Picone

Group Participants: Laura Howard, Chris Picone, Nabiha Megateli, Chris Rosin, Jagdish Swamy, Pantaleo Munishi, Alexander Njue and Nick Short

Faculty: Larry Simpson

The Selvita computer model was used to test the hypothesis that the removal of mahogany (*Swietenia*) competitors would increase the harvestable volume of Caoba and reduce plot biodiversity. In order to test this hypothesis we increased Coaba sapling numbers from 10 to 20 per plot. We would have preferred to implement the selective logging regimen, however, this parameter of the system was not functional. A sample of 10 Coaba saplings per plot was run for a 50 year period (Treatment #1: control) in order to establish baseline data. Subsequently, a trial using 20 Coaba saplings per plot was also run for a fifty year period (Treatment #2).

Results are summarized in the following table. Generally, in both the treatment and the control species diversity declined over time. However, after year 30 species diversity of treatment 2 declines to less than 1/2 of the control. The numbers of individuals per plot peaked at 20 years for both treatments, yet severely declined by year 30. Increasing the number of Caoba seedlings greatly improved the volume of wood per plot. The increase was highest at 10 years, declining to twice the control volume by year 50.

It appears that timber harvest is greatly improved by doubling sapling numbers per plot. However, without knowledge of tree diameters, it is impossible to determine how much of the volume increase is actually harvestable. Furthermore, the sustainability of such a regime is questionable when considering the loss of biodiversity.

Table 1. Tree Diversity of Selvita Simulation Trials.

Year	Common Name	Treatment	No. 1	Treatment	No. 2
		# of Ind.	Volume	# of Ind.	Volume
10	Gavilan	17	9.9	9	4.5
10	Caoba	28	5.0	51	28.5
10	Zopilote	12	0.0	4	0.0
10	Coloradit	13	0.0	5	0.0
10	Fruta Dor	8	0.0	8	0.0
10	Fruta	6	0.0	4	0.0
10	Guacimo Bl	6	12.9	1	15.2
10	Totals	111 (18sp)	50.7	102 (17sp)	48.3
20	Gavilan	22	566.3	9	265.4
20	Caoba	33	165.6	70	656.9
20	Zopilote	13	20.8	1	0.0
20	Coloradit	26	0.0	7	0.0
20	Fruta	8	0.0	4	0.0
20	Fruta Dor	9	0.0	7	0.0
20	Guacimo Bl	4	12750.5	1	720.5
20	Guarumo	4	2.4	5	4.0
20	Molenillo	5	0.0	1	0.0
20	Totals	130 (17sp)	1430.1	106 (15sp)	1646.8
30	Gavilan	8	1508.3	2	1018.9
30	Caoba	13	396.4	11	1761.3
30	Cirri Col	1	12.4	1	36.1
30	Guacimo	1	88.2	0	0.0
30	Zopilote	4	40.8	0	0.0
30	Guacimo Bl	1	1039.5	0	0.0
30	Totals	33 (17sp)	3087.1	15 (4sp)	2818.0
40	Gavilan	7	3373.5	2	2362.0
40	Caoba	5	742.9	4	2627.0
40	Cirri Col	1	35.4	1	140.3
40	Zapilote	1	24.0	0	0.0
40	Guacimo Bl	1	2529.1	0	0.0
40	Totals	15 (5sp)	6704.8	7 (3sp)	5129.3

Table 1 continued.

50	Gavilan	6	5537.2	1	3195.0
50	Caoba	4	1284.3	2	3141.6
50	Cirri Col	0	0.0	1	319.8
50	Zapilote	1	38.5	0	0.0
50	Totals	11 (3sp)	5690.0	4 (3sp)	6656.4

Key for Simulation Table 1:

Common Name:

Coaba
Gavilan
Guacimo
Molenillo
Fruta Dorado
Fruta de Mono
Guacimo
Molenillo

Scientific Name:

Sweitenia
Pentaclethera
Guazuma
Luenea
Virola sebifera
Posoqueria latifolia
Guazuma ulmifolia
Luehea candida

SELVITA FORESTRY MODEL: GROUP 3

Authors: Don Mee, Keith Taulbee, Lucy Buchan, Liz Marshall, Brent Blair, and Jeff Zimpfer

For this project we used the Selvita model (a modified version of the Jabowa forest simulation model) to examine forest dynamics in representative stands belonging to the Portico Corporation. The goal of this exercise was to compare stand composition with and without one of the two dominant tree species, *Carapa guianensis*. The model ran fifty iterations over a period of 90 years. The following describes the model results.

When all individuals of *Carapa guianensis* were eliminated from the stands, the population of *Pentaclethra macroloba* (the other dominant tree species) doubled. Basal area for the *Pentaclethra macroloba* increased by 60%. At the end of the 90-year period, 7 species were represented in the undisturbed stands. In the stand where Carapa was removed, three additional species were represented. Therefore, it appears that alpha diversity increased. The number of stems per plot doubled in the scenario where Carapa was removed. However, time did not permit us to analyze beta diversity.

Results of this experiment suggest that if Carapa is eliminated from these forests, Pentaclethra will replace it and become even more dominant in the community than it is presently.

Guided Field Problem

EFFECTS OF NITROGEN FIXATION IN THE TRAILS PROJECT

Authors: Bruce Ferguson, Ankila Hiremath, and Chris Picone

The Trials Project at La Selva examines the potential of native tree species for use in agroforestry, reforestation and restoration of degraded soils. As part of the project, long term plots were established in 1988 to determine effects on soil of plantations of eleven tree species. These soils experiments are being performed on abandoned pastures in the Peje annex. Square, quarter ha. monocultures of five nitrogen fixing trees, six non-nitrogen fixers and a control are arranged randomly in a three ha. block. There are four replicate blocks. Trees are spaced three meters apart and there has been some mortality. We did two studies within Block I (see Figure 1). The first surveys groundcover diversity beneath four different overstory species, while the second examines the effect of a nitrogen fixing tree on growth of two non-nitrogen fixing neighbors.

Groundcover Diversity

Introduction

Growth and diversity of plants found under different canopy trees are important considerations for choosing which trees are best suited for different objectives. For example, both the farmer with intercropped annuals in a tree plantation, as well as the restoration ecologist, want to encourage diverse plant growth under the tree canopy. The amount of light reaching the soil, as well as chemical changes to the soil, are two factors affected by canopy trees that are critical to the establishment and growth of groundcover and understory. Therefore, in this study we tested the relationship between species of overstory tree and groundcover plant diversity. Unfortunately, soil differences could not be determined due to time constraints.

Methods

We examined groundcover plants under four different tree species: two nitrogen-fixing members of the Mimosaceae, *Pentaclethra macroloba* and *Inga edulis*; and two non-nitrogen fixers, *Hyeronima oblonga* (Euphorbiaceae) and *Vochysia ferruginea* (Vochysiaceae). All vegetation under the canopy trees had been cleared by machete approximately 1-1.5 years prior to the study.

Four 1x1 m sample plots of groundcover vegetation were examined for each canopy tree species. We spaced the plots four meters apart in the center of each tree stand, following a line parallel to the slope of each 0.25 ha parcel. Percent groundcover was approximated visually. Canopy density was determined by averaging densiometer

readings from 2-3 different locations for each canopy tree species. We measured leaf litter thickness of *Pentaclethra* and *Vochysia* by pushing a ruler through to mineral soil. Several litter measurements at each plot were averaged.

Results and Discussion

Table 1 summarizes the data listed in Appendix 1. Canopy trees seem to affect several factors that control the diversity of groundcover plants, especially shading. For example, when the two nitrogen-fixers are compared, the groundcover amount and diversity was considerably higher under *Inga* than under *Pentaclethra*. Differences in soil properties alone are unlikely to account for the drastic change, because both trees contribute nitrogen and their parcels were adjacent on top of the slope. Rather, the relatively high light levels reaching the forest floor under *Inga* probably account for the improved growth and diversity.

Yet light is not the only factor, since groundcover diversity also differs between *Pentaclethra* and *Vochysia*. Both permit little light to pass through the canopy, but *Pentaclethra* has somewhat higher plant growth beneath. This is probably a result of higher soil nitrogen. In addition, leaf litter under *Vochysia* formed a solid carpet of leaves about 8-12 cm thick, much higher than any of the other three tree species. In contrast, the extremely rapid decomposition of the nitrogen-rich *Pentaclethra* leaves left the soil surface almost bare, with less than 1 cm of litter. Thick leaf litter under *Vochysia* probably discouraged establishment of seedlings because their roots dry out faster in a solid leaf mat than in mineral soil.

Neither increased light nor nitrogen-fixation could explain the high diversity under the canopy of *Hyeronima*, because it lacks both of these benefits to groundcover plants. Perhaps the soil is improved by the high content of phosphorous in *Hyeronima*'s leaves (La Selva Researcher). Also, the soil may receive nitrogen inputs from the *Inga* stand, which was uphill and adjacent to the *Hyeronima* stand. Another series of groundcover samples should be taken from a *Hyeronima* parcel in a location that is unaffected by adjacent nitrogen-fixing trees.

On the other hand, if it turns out that these data describe typical groundcover under *Hyeronima*, then it seems this species is the best choice among the four tested. Both *Inga* and *Hyeronima* can apparently be planted in high densities without shading out the plants beneath them. However, a farmer can sell *Hyeronima* for lumber, a benefit *Inga* lacks. On the other hand, *Inga* may contribute to long-term soil changes that compensate for its lack of marketable wood. Such soil interactions are the focus of current research of the Trials Project at this study site in the Peje Annex.

Effect of Nitrogen-Fixing Neighbors

Introduction

Due to the tight spacing of plots of different species within the blocks, we hypothesized that there may be interference between plots due to nutrient flows and shading, specifically that a nitrogen fixing species may enhance growth of its non-nitrogen fixing neighbors. We sought to quantify the effect of *Inga edulis*, a nitrogen fixing tree often used for shade, fruit and firewood, on growth of neighboring plots of *Vochysia guatemalensis* and *Hyeronima oblonga*, both non-nitrogen fixers valued for their timber.

Methods

We measured dbh of every individual of *Vochysia* and *Hyeronima* and calculated average dbh for rows running parallel to the edge of the *Inga* plot. We performed a regression to assess the significance of the results.

Results and Discussion

Figures 2 and 3 are plots of the average dbh of the two non-nitrogen fixing trees as a function of distance from *Inga*. Proximity to *Inga* has no discernable effect on mean dbh of *Vochysia*. Unexpectedly, dbh of *Hyeronima* increases with distance from *Inga* ($r^2=0.1891$, $p<0.00005$, $n=112$). Retarded growth of *Hyeronima* near the *Inga* plot is likely a result of topography. The block slopes downward from *Inga* to *Hyeronima* and then levels out at the bottom of the *Hyeronima* plot. It seems likely that the *Inga* are shading the *Hyeronima* growing immediately down hill from them. Furthermore, nutrients, including nitrogen fixed by the *Inga*, may accumulate at the bottom of the slope, enhancing *Hyeronima* growth farther from the *Inga* plot. Thus, there may be interference between the plots, though not in the pattern we predicted.

Acknowledgements

We would like to thank José Manuel for introducing us to the Trials Project, and Orlando Vargas for guiding us in plant identification.

Figure 1. Arrangement of Quarter Ha. Plots in Block I of the Trials Project Long-Term Soil Study Plots. "N" Indicates Nitrogen-Fixing Trees.

<i>Gmelina arboria</i> (Melina)	<i>Hyeronima oblonga</i> (Pilon)	<i>Virola koschnyi</i> (Fruta dorada)	<i>Acacia mangium</i> (Acacia) N
<i>Pithecellobium</i> sp. N	<i>Inga edulis</i> (Guabo chulillo) N	<i>Vochysia guatemalensis</i> (Chancho)	<i>Vochysia ferruginea</i> (Botarama)
<i>Stryphnodendron excelsum</i> (Vainillo) N	<i>Pentaclethra macroloba</i> (Gavilan) N	<i>Pinus caribea</i> (Pino)	Control

Table 1. Groundcover Light Levels and Coverage Under Four Canopy Tree Species.

Canopy Tree Species	Avg. % Light	Avg. % Groundcover	Avg. # Sp./ Plot
Nitrogen-Fixing			
<i>Pentaclethra macroloba</i>	12	6	3.5
<i>Inga edulis</i>	24	99	7.0
Non-Nitrogen-Fixing			
<i>Vochysia ferruginea</i>	14	15	1.8
<i>Hyeronima oblonga</i>	14	83	7.5*

* Note high variation under *Hyeronima* in Appendix.

Figure 2. Mean ddb of rows of *Vochysia guatemalensis* as a function of distance from a plot of *Inga edulis*.

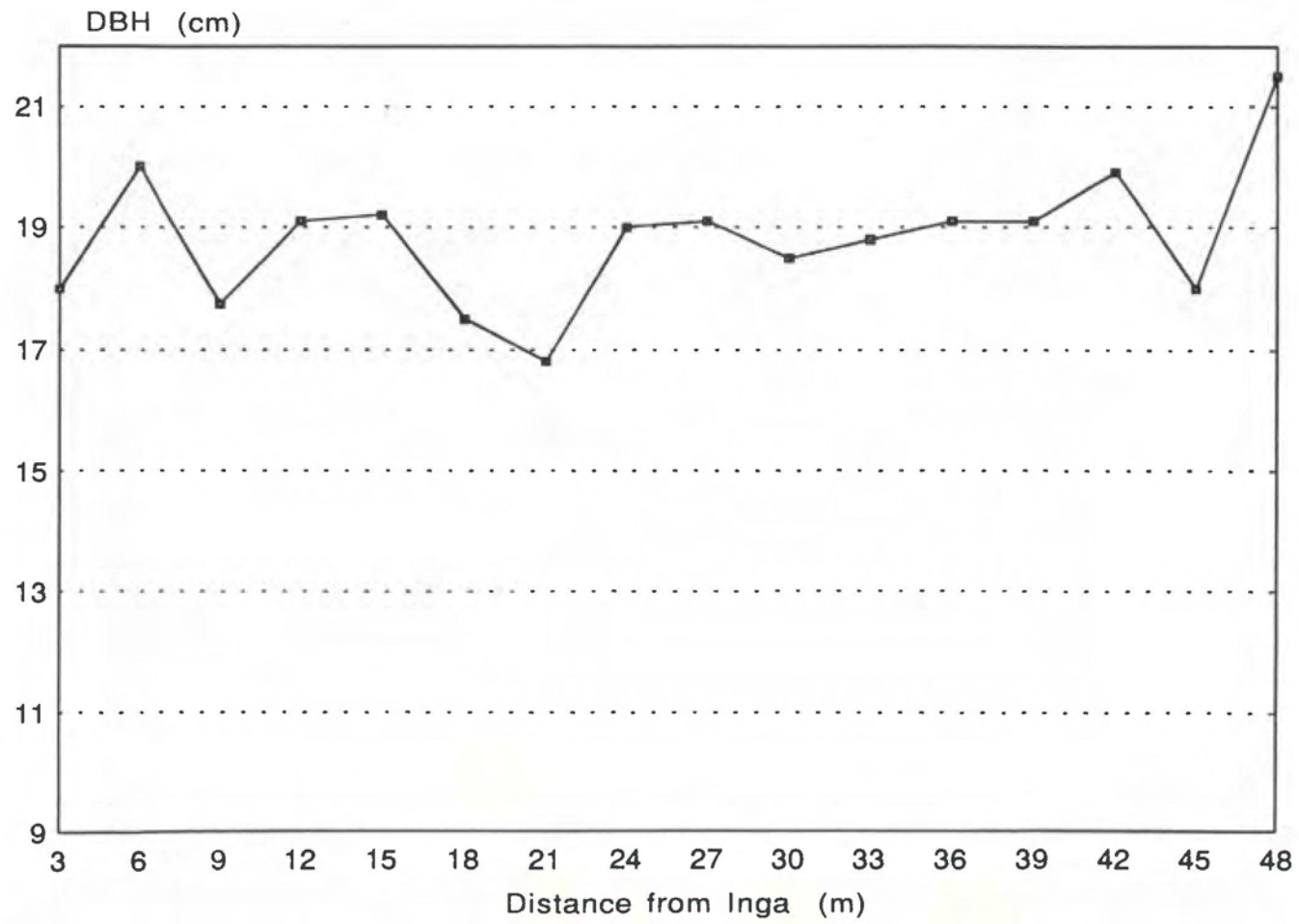
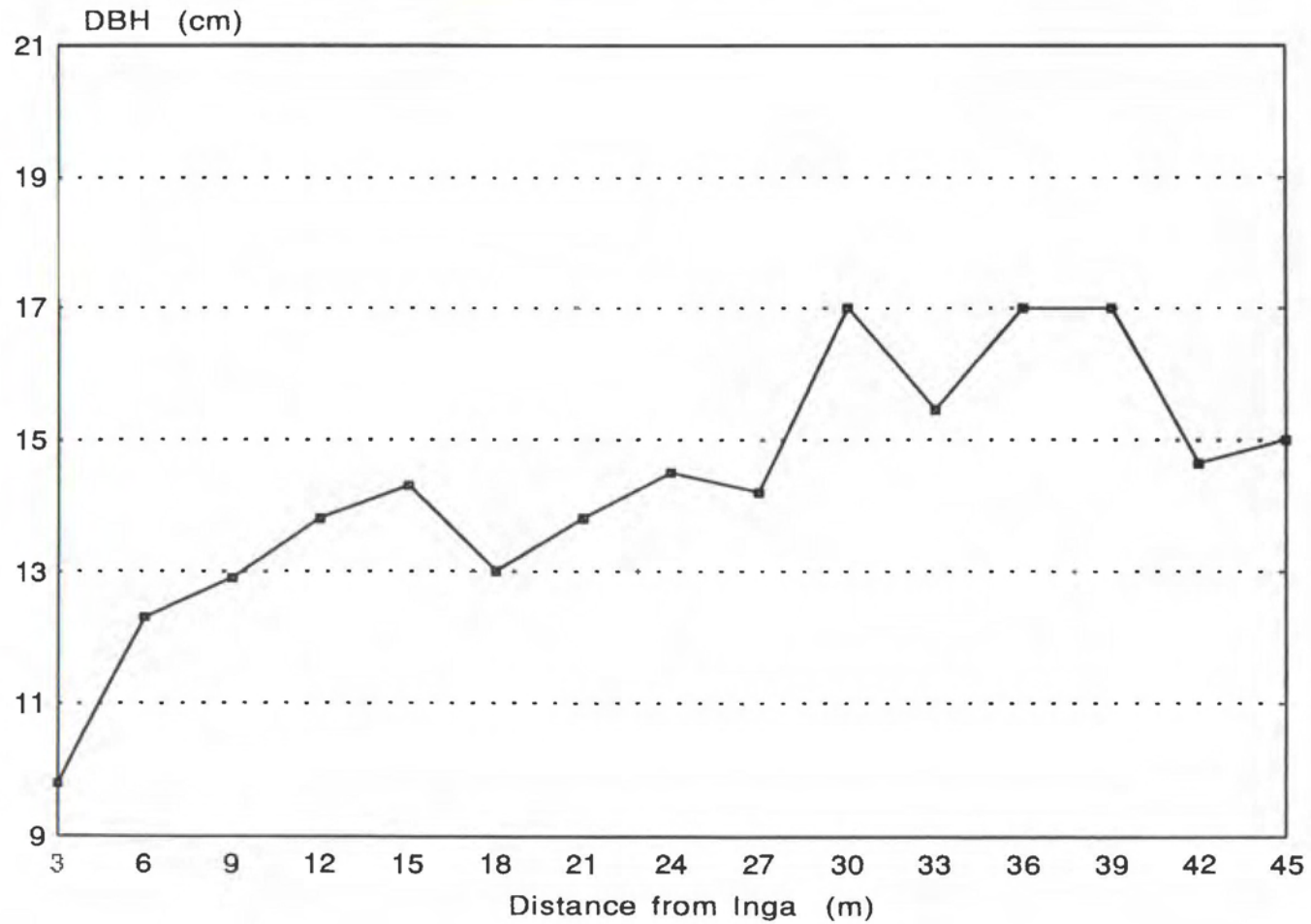


Figure 3. Mean ddb of rows of *Hyeronima oblonga* as a function of distance from a plot of *Inga edulis*.



Appendix 1. Groundcover Plant Diversity Per Plot.

Canopy Species		% Groundcover	Family	Genus	#
Pentaclethra macroloba					
	Plot 1	2-3	Melastomataceae	-	5
			Piperaceae	Piper A	2
			Euphorb ?	-	1
			Papillionoid	-	1
	Plot 2	4-5	(Pteridophyta)	-	5
			Melastome	-	2
			Piperaceae	Piper B	1
			(Unknown)	-	1
	Plot 3	7-8	(Pteridophyta)	-	5
			Melastome	-	4
	Plot 4	8-10	(Pteridophyta)	-	10
			Piperaceae	Piper B	5
			Melastome	-	3
			Smilacaceae ?	Smilax ?	1
Inga edulis					
	Plot 1	98-99	Poaceae	Panicum	100's
			Araceae	-	6
			Cyperaceae	-	6
			Rubiaceae	Psychotria	2
	Plot 2	99	Poaceae	Panicum	100's
			Poaceae	Brachiaria	100's
			Cyperaceae	-	6
			Melastome	Conostegia subcrustulata	5
			Rubiaceae	(creeper)	3
			Convolvulaceae?	-	2
			Mimosoid	Inga edulis	1
			Nyctaginaceae	Neea psychotrioides	1
	Plot 3	99-100	Rubiaceae	(creeper)	15
			Melastome	C. subcrustulata	10

Appendix 1 continued.

			Cyperaceae		10
			Poaceae	Brachiaria	10
			Poaceae	Panicum	3
			Mimosoid	Inga edulis	1
	Plot 4	98-99	Poaceae	Brachiaria	30-50
			Poaceae	Panicum	20-30
			Rubiaceae	(creeper)	20
			Cyperaceae		2
			Rubiaceae	Palecouria	1
			Rubiaceae	Psychotria	1
			Mimosoid	Inga edulis	1
			Rubiaceae		1
			Melastome		1
			Unknown		1
Vochysia ferruginea					
	Plot 1	1-2	Marantaceae		1
	Plot 2	15	Unknown	(creeper)	1
	Plot 3	25	Papillionoid		2
			Araceae	Dieffenbachia	1
			Papillionoid	Mocuna	1
			Unknown	(creeper)	1
	Plot 4	2-3	Papillionoid	Mocuna	1
Hyeronima oblonga					
	Plot 1	98-99	Poaceae	Panicum	30-40
			Poaceae	Brachiaria	30-40
			Melastome	C. subcrustulata	19
			Rubiaceae	Psychotria	7
			Piperaceae	Piper A	5
			(Pteridophyta)		5
			Rubiaceae	(creeper)	3
			Araceae	(creeper)	3
			Piperaceae	Piper B	2
			Cyperaceae		2
			Araceae	Monstera ?	2
			Papillionoid	Mocuna ?	2

Appendix 1 continued.

		Melastome	Miconia	1
		Poaceae	Panicum ?	1
		Unknown	(creeper)	1
		Unknown	(creeper)	1
Plot 2	97-98	Poaceae	Panicum	40-50
		Poaceae	Brachiaria	10-20
		Papillionoid	Mocuna ?	10
		Melastome	(square stem)	3
		Rubiaceae	Psychotria	1
Plot 3	95	Melastome	C. subcrustulata	28
		Papillionoid	Mocuna ?	7
		Costaceae	Costus	3
		Rubiaceae	Psychotria	1
		Cyperaceae		1
		(Pteridophyta)		1
Plot 4	40	Poaceae	Panicum	12-13
		Papillionoid	Mocuna ?	2
		Araceae	(creeper)	1

FRUITING BEHAVIOR OF *SOCRATEA EXORIZA*

Author: Liz Marshall

Resumen

Este estudio mide la palma *Socratea exoriza* para determinar la altura en que esta especie empieza a fructificar. Las palmeras menores de 10.5 metros nunca tenían fruto, las de más de 14.4 metros siempre tenían fruto, y las que estaban dentro de 10.5 y 14.4 metros tenían fruto el 44% de las veces.

Abstract

This study measures *Socratea exoriza* in order to determine at what height this palm species produces fruit. Palms below 10.5 meters were never found to fruit, palms above 14.4 meters were always found fruiting, and palms in the interval 10.5 - 14.4 meters fruited 44% of the time.

Introduction

Palms are an integral part of the structure and dynamics of neotropical rainforests. They are a valuable food source for birds and mammals, and in many forests palm species are prominent among the forest's dominant tree species. Palm species are also used by human beings for construction material, food, and other miscellaneous purposes such as the making of bows and arrows. Human use of these products, however, often involves extraction of the palm, which can significantly alter the rainforest ecosystem.

Different areas within La Selva Biological Research Station have been subject to various degrees of harvesting pressure for the heart of palm, or palmito. Certain species in the forest have been extracted for palmito -- *Euterpe macrospadic*, *Iriarte gigantea*, and *Socratea exoriza*. Recent studies indicate that this harvesting pressure has caused a shift in the relative frequency of edible vs. non-edible palms in the areas that were more heavily impacted (Blair et al., 1993). Unfortunately, very little life history information is available for most palm species, so it is difficult to predict what effects this shift will have on forest structure and dynamics in the future.

Due to past harvesting pressure, more heavily impacted areas in La Selva are also depauperate in large size classes of palm. This loss of reproducing adults may have enormous future consequences for the species and the forest as a whole. It is, however, difficult to estimate such long-term effects without an understanding of the palm's basic life history. This study examines one of the edible palm species in La Selva--*Socratea exoriza*--to estimate at what height it begins to reproduce. This information should help

model the current and future effects of past harvesting impacts on the *Socratea* population.

Lieberman et al., (1988) report that *Welfia georgii*, the dominant palm in La Selva, begins to reproduce at 6 meters of height. *Welfia* is unique among La Selva's palms, however, in that it forms its entire crown before it begins to extend its stem. As a result, *Welfia* may be relatively more mature at 6 meters than other palm species at the same height. I would therefore expect that *Socratea* palms will begin to produce fruit at a height greater than 6 meters.

Methods

Socratea palms were identified and measured along two sampling transects. The first transect was the 1200 South grid line between points 600 East and 450 East on La Selva's grid system. The second sampling line was the Sendero Sura trail between the beginning of the trail and the 750 meter point. All *Socratea* palms visible from those lines were measured, categorized as either fruiting or non-fruiting, and assigned a light category of either full shade, partial sun, or full sun. Palm height was measured with either a range finder from the base of the tree or a dendrometer from some distance away from the tree, depending on which method was more appropriate given the topography or presence of obscuring vegetation. Trees below 6.6 meters were not recorded; no trees below that height were observed to be fruiting.

Results

A total of 50 palms were recorded. Of these, 27 were not fruiting. Non-fruiting palms reached a maximum height of 14.4 meters. Fruiting palms ranged in height from 10.5 - 29.8 meters. In the interval of observed overlap from 10.5 - 14.4 meters, 44% of the recorded palms were fruiting. All palms below 10.5 meters were not fruiting, while all palms above 14.4 meters were fruiting.

Twenty percent of the palms recorded were in full shade, 66% were in partial shade, and 14% were in full sun. There does not appear to be any correlation between degree of sun and either height or fruiting status.

Conclusions

Because this study is a cross-sectional observation of palms at one specific point in time, it is difficult to make generalizations about reproductive behavior of palms throughout the year. My results do, however, allow a few generalizations about physiological ability to reproduce as it relates to height. Many *Socratea* palms are able to reproduce by the time they reach 10.5 meters, and they are likely to all be reproducing by the time they reach 14.4 meters.

In order to determine that palms cannot reproduce below 10.5 meters, one would have to conduct a longitudinal study examining palms throughout the year; it is possible, for instance, that smaller palms reproduce earlier than larger palms. Similarly, in order to determine what is happening within the overlap period, one would have to have results from a longitudinal study; it is again possible that some of those palms that I observed as non-fruiting are fruiting at some other time of year. It is interesting to note, however, that all palms above 14.4 meters were reproducing. This suggests that larger *Socratea* palms do not fruit at staggered times throughout the year but that there are definite fruiting seasons.

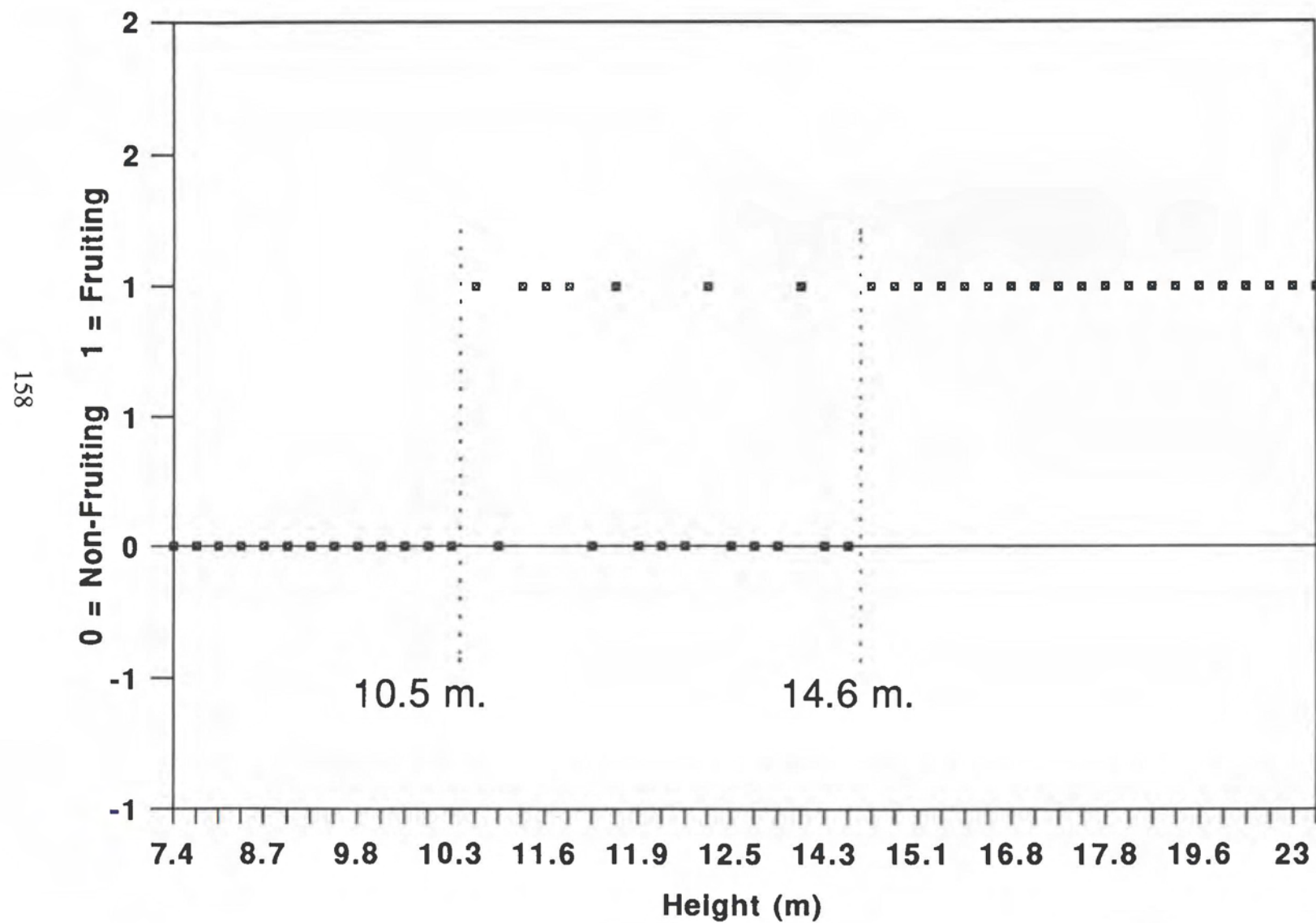
If longitudinal studies find that palms below 10 meters do not reproduce at any time during the year, this would have interesting implications for palm populations subjected to harvesting pressures. Previous studies indicate that most palms harvested for palmito are smaller than 10 meters, and that in La Selva's more heavily impacted areas, this harvesting has led to a paucity of palms in the 10 - 15 meter size class. There is also evidence that there are fewer palms in the greater than 15 meters size class (Blair et al., 1993). These findings may indicate that a large proportion of the *Socratea* palms that should currently be reproducing did not have a chance to mature and are not available to provide seed. There is, therefore, the possibility that areas within La Selva that were heavily harvested for *Socratea* may currently be suffering from a lack of seeds for natural regeneration. This decrease in available seeds may result in even greater alterations of *Socratea* populations in the future.

Corroborating such theories would require extensive research into the life history of palms, including more thorough studies of reproductive behavior, life span, etc. The importance of palm species in the forest ecosystem, as well as the continuing impact on palm populations from disturbances suffered in the past, makes this research vital to a long-term understanding of forest dynamics and to effective forest management.

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**Figure 1. Heights of Fruiting and Non-Fruiting Socratea Palms,
La Selva, Costa Rica.**



Independent Field Problem

STRANGER - NEIGHBOR RECOGNITION IN THE STRAWBERRY POISON DART FROG *DENDROBATES PUMILIO*

Author: Keith Taulbee

Faculty: Lori Wollerman

Resumen

El reconocimiento entre ranas conocidas y las vecinas fue investigado en una población de una especie de ranas *Dendrobates pumilio* en la estación biológica La Selva, cerca de Puerto Viejo, Costa Rica. Las ranas reaccionaron más fuerte a las grabaciones de cantos producidos por ranas lejanas que a las de cantos producidos por ranas vecinas. La capacidad de distinguir entre conocidas y las no conocidas es común en las especies de ranas territoriales, porque es más eficiente en términos de energía reaccionar menos fuerte a una rana vecina que ya ha establecido territorio que a una rana no conocida que tal vez está intentando de tomar el territorio.

Abstract

Stranger-neighbor recognition was tested among males of the strawberry poison dart frog, *Dendrobates pumilio*, at La Selva Biological Research Station near Puerto Viejo, Costa Rica. Frogs reacted more strongly to the playbacks of distant frog calls than to the playbacks of neighboring frog calls. The ability to differentiate between strangers and neighbors is common in many species of territorial frogs, as it is energetically efficient to react less strongly to a neighbor that already has an established territory than to a stranger that is possibly trying to take over the territory.

Introduction

The strawberry poison dart frog, *Dendrobates pumilio*, is a small, terrestrial, diurnal frog commonly found in lowland tropical rain forests of Central and South America. Named for the use of its poisonous dendrobatid skin-glands for the blowdarts of the Choco Indians of Columbia, the poison dart frog's conspicuous red head and torso with blue legs is an excellent example of aposematic coloration to deter predators (Janzen, 1983). This is necessary due to its diurnal feeding habits, and its need to expend a great deal of energy in hunting ants and termites (Janzen, 1983).

Poison dart males are also very territorial. Territoriality is very common among the Anurans in general, having been described in 60 species and across nine genera (Donnelly, 1987). Male poison dart frogs position themselves every 2-3 meters across all available territory, usually at the base of a tree which has nearby bromeliads (Donnelly, 1987). Males position themselves at a height of 0.1 - 2.0 m from the ground and emit a

rapid series of "insect like chirps" (Donnelly, 1987) during both the early morning and afternoon.

Protecting a high-quality territory is crucial to the male's success in attracting a mate. Eggs are deposited in bromeliads and nourished with the frog's bodily fluids, as well as from non-fertilized nutritive eggs from the female (Donnelly, 1987). Recognition of neighbors is a valuable strategy for energy conservation of many species. A frog's neighbor is less likely to move into its territory than a stranger, as immigration into prime nest sites is a common practice of many juvenile male poison dart frogs (Donnelly, 1987).

The purpose of this study is to determine whether male poison dart frogs can recognize the calls of their neighbors. It is expected that they can recognize neighbors, and will react more strongly to the recorded call of a frog from a distant territory.

Study Site

This study was performed at La Selva Biological Research Station in northeastern Costa Rica. One pair of frogs was located in a large tree in front of the new laboratory building, and the other pair was located on the outskirts of the Arboretum within La Selva.

Materials And Methods

Territories were mapped by visually locating the frogs, and calls of all four frogs, two per territory, were recorded during a calling period with a Marantz audiocassette recorder and a Sennheiser directional microphone. The vocalizations were recorded onto four playback cassettes, and each call was limited to two minutes.

Once in the morning and once in the afternoon, a series of playbacks was performed for each of the frogs (Table 1) for a total of thirty playbacks. Behaviors of the frogs to the playbacks (Table 2) were manually recorded, and the relative reactions of frogs to the calls of neighbors and strangers were rated, using an index of importance from 1 - 4 (Table 3) based on Donnelly's (1987) information of poison dart frog reactions to previous playback experiments.

Results

All four frogs reacted more strongly to the playbacks of distant frogs than to neighboring frogs (Table 4). The greatest difference occurred in frogs C and D, neighboring frogs in the same territory. The only time a frog jumped towards the recorder was when it was presented with the playback of a distant frog. Also, frogs were more likely to climb higher on their perch, and slightly more likely to chirp, when presented with a neighboring frog's playback.

The reactions of the four frogs to both neighboring and distant playbacks were analyzed using the Mann-Whitney U Test. The difference was found to be significant at $Z > 0.10$, and were almost significant at $Z > 0.05$.

Discussion

Despite the small sample size, the results strongly suggest that male poison dart frogs are able to differentiate between the calls of another male from a nearby territory from that of a male from a distant territory. The only reason the particular statistical test did not yield significance at $Z > 0.05$ was due to a missing data point from frog B. Even a moderate reaction to the stranger's call would have placed the rank of frog B to the stranger call above that of frog C's reaction to the neighbor call (Table 4).

The fact that the frogs only approached the recorder when presented with a stranger's call is also a strong indication that the frogs can distinguish between neighboring and distant males. Furthermore, the tendency of the frogs to climb higher and chirp more loudly when presented with a neighbor's playback are also what one should expect. Since a frog already knows that his neighbor is not trying to invade his territory, but it also knows that females are more likely to approach the frog that is singing the loudest, its most sensible move when hearing a neighbor calling would be to move higher, and thus reduce ground attenuation, and to begin calling with the hope of exceeding the neighbor's call.

Conclusion

Dendrobates pumilio males were found to be able to differentiate between the calls of neighboring and distant males. This ability would be strongly selected for evolutionarily in the sense that protecting and maintaining a high quality territory is the primary determining factor in mate acquisition for males. In the future, an increase in sample size and duration of the experiment would serve to further strengthen the results of this study.

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Table 1. System of Playbacks Among the Poison Dart Frogs.

Time/Date	Neighbor				
	Stranger	Pairing	1	Pairing	2
AM/19-7-93	Neighbor	A to B	B to A	C to D	D to C
	Stranger	C to B	C to A	A to D	A to C
PM/19-7-93	Neighbor	A to B	B to A	C to D	D to C
	Stranger	D to B	D to A	B to D	B to C
AM/20-7-93	Neighbor	A to B	B to A	C to D	D to C
	Stranger	D to B	D to A	B to D	B to C
PM/20-7-93	Neighbor	A to B	B to A	C to D	D to C
	Stranger	C to B	C to A	A to D	A to C

Table 2. Reactions of Frogs to Playbacks.

Level of	
Aggressiveness	Description of Behavior
High	Jump towards recorder
Middle	Jump in circle; first away from, and then towards recorder
Less	Chirp during playback
Less	Chirp following playback
Less	Climb to a higher perch
Less	Assume erect posture

Table 3. Rating System of Frog Reactions.

Score	Criteria (Please Refer to Table 2)
1	Any combination of 1 or 2 less aggressive behaviors.
2	Three or more less aggressive, or one intermediately aggressive behaviors.
3	Moves toward the recorder.
4	Moves toward the recorder and chirps both during and after playback.

Table 4. Level of Reaction of Frogs to Playbacks.

Time/Date	A		B		C		D	
	Str	Nei	Str	Nei	Str	Nei	Str	Nei
AM/19-7	2	1	2	1	3	2	2	2
PM/19-7	1	1	3	2	3	3	4	2
AM/20-7	3	2	-	-	3	1	3	1
PM/20-7	3	1	2	2	4	2	2	1
Total	9	5	7	5	13	8	11	6

**THE SIGNIFICANCE OF MOISTURE STORAGE BY BRYOPHYTE
COMMUNITIES IN A TROPICAL LOWLAND RAIN
FOREST AT LA SELVA, COSTA RICA**

Author: Pantaleo K. T. Munishi

Abstract

This study was done in a lowland tropical rain forest at La Selva Biological Station. The objectives of the study were to quantify the water storage capacity of bryophyte communities in a lowland rain forest, and to explain the significance of this water storage characteristic to the ecosystem. Results of this study indicate that the percentage moisture storage by bryophytes ranged from 83% - 89%. Bryophytes can store 4 - 8 times their own weight of water. On average the moisture content (%) of bryophyte plants is 87% (sd=1.7), and they can store 7.3 times their own weight of moisture. These moisture storage characteristics (capacity) have diverse significance and implications on the hydrologic cycle (water interception, storage and release), as well as on other epiphytic communities of a forest ecosystem.

Introduction

One of the very obvious and striking features observed in tropical rain forests is the widespread amounts of epiphytes, especially bryophyte communities, occurring on many forest trees, leaves, trunks, and branches. Probably higher relative humidity and moisture allow bryophyte communities (mosses and liverworts) to exist in these forest microhabitats. In any other ecosystems, the condition might be too arid for their survival. Bryophytes have been observed in different tree species with no difference in abundance between species. However, epiphytic communities were observed to be more abundant on slow growing shade tolerant trees than on fast growing shade intolerant trees (Manning et al., 1983; Bush, 1984).

Crown epiphytes include many orchids, ericaceae, and bryophytes and they range in their degree of adaptation to cool and dark conditions (Whitemore, 1984). Epiphytes grow attached to trunks and branches of rain forest trees, shrubs, and lianas, some even on the surface of living leaves (Richards, 1981).

Epiphytes are important in many aspects. They are important in some cases as the only chief habitat of certain animals, some of which play an important role in rain forest ecosystems. For example, the roots of epiphytic flowering plants and ferns are the chief nesting places for arboreal ants. Others are important as humus accumulating/producing plants (Richards, 1981).

Epiphytic vegetation of the tropical rain forest includes lichens, algae, mosses, and liverworts. Mosses and liverworts form one division of the non-vascular epiphytes - the bryophyta. Some of these non-vascular epiphytes grow in close association with ferns and flowering plants, and may be regarded as forming part of the same synusia. Bryophyte and many families (Mosses, Legeuneaceae, Plagiochila spp., etc.) dominate the shade community of epiphytes. Many epiphyllous bryophytes are not parasites and there is no evidence that they obtain organic food from the plant on which they grow. At the same time many of them show structural modifications which appear to assist them in adhering to their substratum. Most of them are constructed to hold large quantities of water by capillarity either between their leaves and the substratum, or in "water sacs".

The importance of bryophyte communities in tropical rain forest, especially their contribution to water storage and impact on the hydrologic cycle, is yet to be fully quantified. The significance of bryophytes in moisture storage in montane and submontane forests including fog condensation have been documented (Poc's, 1988; Vilchez, 1989). It is very possible that in tropical rain forest ecosystems, bryophyte communities greatly modify the hydrologic cycle of the forest ecosystem in one way or another, through interference with stem flow and through fall. On the other hand, the water storage capacity of the bryophytes may be of prime importance to the survival and existence of other epiphytes, as well as microclimate modification.

This study attempts to quantify the moisture interception and storage by bryophytes and discusses the contribution of this storage to the forest ecosystem.

Materials and Methods

Study Site

The study was conducted in the tropical lowland rain forest at La Selva Biological Station in Costa Rica. The area is situated in the Atlantic lowlands of Costa Rica, at the confluence of rivers Sarapiquí and Puerto Viejo. With an area of about 1508 ha, it ranges from 35 meters above sea level at the river to 150 meters above sea level along parts of the southern boundary. The mean annual temperature is 24° C (75° F) and the mean annual rainfall is 4 meters (157 inches).

Methods

Twelve samples of bryophytes (mosses) were collected from random sites in the La Selva lowland rain forest. The samples included moss plants growing on both tree trunks, branches and leaves. Collection was confined to the understorey trees, shrubs, and lower parts of tree trunks. Upper tree parts were not considered due to inaccessibility. The fresh weight of each sample was measured after allowing for the free draining water to drain out. The samples were dried and allowed to cool to room temperature, then

weighed for dry weight. The moisture storage percent and capacity was calculated using standard method for moisture calculations.

Results

The percentage moisture content of the mosses ranged from 83% - 89%, and their moisture storage capacity was 4 - 8 (400% - 800%) times their own weight (Table 1). On average, moisture content of the plants is 87% (sd=1.7), while moisture storage capacity of the plants is 7.3 (sd=1.1) times their own weight (Table 2).

Discussion

The implications of moisture storage by bryophyte communities in both lowland and upland (montane) tropical rain forests are diverse. The significance of this may be considered from the perspectives of the hydrologic cycle, and the interrelationships between the bryophyte communities and other epiphytic communities which live in close association with them.

From the hydrologic cycle point of view, the bryophyte communities may contribute to water interception, especially from stem flow. When the water intercepted is stored and released into the ecosystem evenly and time, it will be an advantage to the system. This situation will tend to lengthen the periods of high moisture conditions in the forest ensuring relatively constant water yield from the forest and hence survival of various organisms dependent on such an ecosystem.

On the other hand, much of the intercepted water may evaporate back into the atmosphere without entering the system. This will then add to crown interception losses, reducing water storage and yield from the forest. With catchment forests in which water distribution in space and time is of prime importance, this will be a serious drawback. This latter impact/situation may be negligible given that the spongy nature of bryophytes and their capacity to store large amounts of water will tend to resist excessive water losses by evaporation. At the same time, many bryophyte species live on shade tolerant understorey species (Bush, 1984) which are normally shaded from direct sunshine thus reducing the chances of excessive evaporation.

Periodic water shortage is one of the two major limiting factors faced by most epiphytes, and their ability to resist periodic droughts is important (Whitmore, 1984). The capacity of moss plants to store large amounts of water is important not only to themselves but also to other epiphytic communities in association with them. This ability therefore ensures their survival as well as the survival of the associated epiphytic communities, thus maintaining the structure, processes, and the diversity of the particular forest ecosystem.

Conclusion and Recommendations

Although not fully quantified, bryophyte communities play an important role in water interception, storage and release within tropical lowland rain forest ecosystems. They are therefore of prime importance in regulating water yield in space and time from such ecosystems of which water yield is their prime function. More intensive and extensive study of water interception, storage, and release by bryophyte communities, assessment of bryophyte loading on different tree species, the interrelationships and associations between bryophyte communities and other epiphytes is needed. These studies will give insight into the real interaction and role played by bryophyte communities in the hydrologic cycle and the forest ecosystem as a whole.

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Table 1. Water Interception and Storage by Bryophytes in a Lowland Tropical Rain Forest, La Selva, Costa Rica, Central America.

	Fresh wt. (g)	Dry wt. (g)	Water wt. (g)	M.S.G. %	M.S.C.
	28.5	4.2	24.3	85	5.8
	29.0	3.2	25.8	89	8.0
	29.8	3.5	26.3	88	7.5
	28.0	2.8	25.2	87	9.0
	29.9	3.5	26.4	88	7.5
	29.8	3.2	26.6	89	8.3
	29.7	3.9	25.8	87	6.6
	29.3	3.3	26.0	89	7.9
	29.9	3.6	26.3	88	7.3
	31.2	5.4	25.8	83	4.5
	30.1	3.6	26.5	88	7.4
	29.5	3.7	25.8	87	6.9
Mean	29.6	3.7	25.9	87	7.3

Table 2. The Average Water Storage by Bryophytes in Lowland Tropical Rain Forest, La Selva, Costa Rica, Central America.

Parameter	Mean (g)	SD	CV %	Description
Green weight	29.6	0.8	23	
Dry weight	3.7	0.7	19	
Water weight	25.9	0.6	18	
% M.S.	87.0	1.7	49	water wt/fresh wt*100
M.S.C.	7.3	1.1	32	water wt/dry wt

Note: Fresh weight = weight of the sample after free water has drained out.

Dry weight = weight of the sample under normal atmospheric conditions.

% M. S. = percent moisture storage based on fresh weight.

M. S. C. = moisture storage capacity.

Independent Field Problem

LEAF CUTTER ANT (ATTA SP) HERBIVORY ON VIROLA KOSCHNYI AND HIERONYMA LAXIFLORA SEEDLINGS IN SECONDARY FOREST AND DEGRADED PASTURE AT LA SELVA BIOLOGICAL RESERVE

Authors: Lucy Buchan, Brent Blair, and Nabiha Megateli

Abstract

Leaf cutter ants cause a large amount of herbivory in tropical regions. Our study looked at their impact on two tree seedling species, *Virola koschnyi* and *Hieronyma laxiflora*. We tried to discover: the distribution of ant mounds, trails, and entryways, if shade and light regimes affect herbivory, and if the two species tested had the same level of herbivory. The areas we used were plots set up in La Selva's biological reserve for a study examining insect herbivory rates, in general, of different tree species in light (pasture) and shade (secondary forest) regimes. We found that in the pasture there was no statistical difference between the two species. However, in the shade the herbivory rate was found to be statistically greater in *Hieronyma*. There was no difference in herbivory of *Virola* in the light and shade regimes, but *Hieronyma* had greater herbivory in the shaded plots. Although trails tended to be everywhere in the plots, it was evident that most mounds and entrances were located on or near the plot edges. Generally edges were characterized by denser vegetation and shade.

Introduction

The initial goal of this study was to examine the impact of leaf cutter ant (*Atta sp.*) herbivory on tree seedlings *Virola koschnyi* (Myristacaceae) and *Hieronyma laxiflora* (Euphorbiaceae) planted as part of the PLAGAS project. The PLAGAS project, located in the northwestern corner of the La Selva Reserve, was established as a long term study on insect herbivory and plant pathogens effecting native tree species. The objective of the project is to build upon the base of information about native tree species growth already established by the TRIALS project. The experimental design of PLAGAS incorporates several additional factors to those used in TRIALS: mixed species plots, and different light regimes in several habitat types (pasture, secondary, and primary forest). The design is random block with 8 replicates. Field conditions and experimental design were also critically examined.

Leaf cutter ants are notable for their intensive and large scale herbivory and resultant effect on soil structure. The cut vegetation is used by worker ants to create a mulch to feed fungal colonies within the ant mounds. The fungi are the sole source of sustenance for the ant larvae. Leaf cutter ants are generalist herbivores with no forage preference unless forced to limit their territory due to encroachment by other colonies. They do, however, exhibit a preference for new forages when introduced, for example,

newly planted seedlings. They avoid leaf matter rich in secondary compounds that are harmful to the associated fungi. The "signature" of leaf cutter ant herbivory is relatively easy to identify in the field. It appears as a smoothly cut arc, usually found on the leaf edges, and can be confused sometimes with herbivory by a wasp species (personal communication with Alex, Beth Braker's field assistant). We chose to examine *Virola* and *Hieronyma* because their leaf size was relatively large compared to other species in the plot and this facilitated identification of herbivory.

Our study was designed to test three null hypotheses: 1.) Leaf cutter ant mounds and trails are randomly distributed among the plots; 2.) No difference exists in the amount of leaf cutter ant herbivory for a single tree species between the different shade regimes - secondary forest and pasture; 3.) No difference exists in leaf cutter herbivory levels between the two species in either the secondary forest or the pasture plots.

Methods

We developed our sampling methodology heuristically, based on initial observations in the quarter hectare plots, each of which was planted with 60 individuals in March, 1993. As shown in Map 1, eleven plots were studied: four secondary forest *Virola* plots, four secondary forest plots of *Hieronyma*, one pasture plot of *Virola*, and two pasture plots of *Hieronyma*. Fewer plots were located in the pasture due to high levels of seedling mortality (50 - 100%) that limited the number of plots from which we could obtain representative samples.

In each plot, we recorded the total number of living and dead seedlings. The living seedlings were then classified into seedling condition categories. Levels of herbivory by leaf cutter ants were assessed using low damage, high damage, and complete defoliation categories based on rough visual estimation of percent of leaf area damage. Leafless individuals with possible but not positive indication of ant damage were recorded, as were individuals with vines. Ant trails, entrances to mounds, and mounds themselves were located by looking for ants in each plot, and following their trails. This information was then mapped (see Map 1).

Results and Discussion

After surveying all the plots and sampling eleven of them intensively, it became clear to us that it was difficult to establish experimental control using this design in this particular setting. The following is a brief discussion of the problems related to our specific focus on leaf cutter ant herbivory that may arise from the experimental design based on our field observations. The plot design retained understory vegetation between each of the plots on all sides. It is unclear why this was done. Presumably the large amounts of woody and leafy debris were results of plot preparation and subsequent weeding for plot maintenance. These edge environments appeared to provide the preferred conditions for leaf cutter ant mounds. Our partial survey of the sampled plots

and several others revealed that virtually all the leaf cutter ant mounds were located in these edge areas. It may be that the shaded conditions provide the soil temperature necessary for the ants to maintain the fungal colonies in their mounds. In addition, both standing and fallen tree trunks on plot edges appeared to serve as important conduits of leaf cutter movement and herbivory. Therefore, the physical plot design and strategy for maintaining the plots appeared to be contributing to leaf cutter ant herbivory.

Implementing the light regimes called for in the experimental design also appeared to be difficult at this site. Secondary growth forest was highly manipulated in an attempt to provide a shaded environment with an open understory to facilitate seedling growth, yet the results of such management created light regimes that provided anywhere from 10 - 95% shade. A similar range for the light regimes was found in the pasture plots, yet the intent had been to create non-shaded conditions. Thus, it appeared to be very difficult to obtain controlled light regimes, and it was unclear how all of the plots could be managed to establish better control for this factor. The manner in which pasture plots were cleared and planted also created problems for the experiment. After plots were prepared, an unexpected voracious growth of grasses occurred that severely outcompeted the seedlings. The seedling planting date - during the dry season - also contributed to their high mortality rate. It is important to note that these complications in experimental design are partially a result of contracting the work for plot preparation and not having project-related people on-site during this time to monitor progress.

The number of *Virola* and *Hieronyma* seedlings per plot characterized by the three ant herbivory levels and other conditions in both the pasture and secondary forest light regimes are summarized in Table 1. The Statistix software package was then used to process this raw data.

Table 2, with associated Figures 1 and 2, shows the median characteristics of the typical secondary forest and pasture plots. The percentages of leaf cutter ant herbivory levels sampled were comparable in both light regimes: 20 - 25% low, 5 - 15% high. Seedlings completely defoliated by ants were only observed in the secondary forest. However, numerous leafless, yet living seedlings (around 12%) without recognizable ant damage probably confound this result. Vines appeared to impair the growth of 2 - 5% of the seedlings. Ten percent of seedlings were dead, cause unknown.

The results from monitoring leaf cutter ant herbivory were aggregated based on herbivory level and light regime for *Virola* and *Hieronyma*, as shown in Table 3. These data were then used to perform chi-squared contingency tests. Two 2 x 2 contingency tables were made of all ant-damaged (summing low, high and complete)/non-ant damaged versus pasture/secondary forest light regimes. Table 4 indicates that in the case of *Virola*, we found no statistical difference in total leaf cutter damage between the secondary forest and pasture light regimes ($p=0.122$). However, in the case of *Hieronyma*, significantly more total ant herbivory was observed in the secondary forest than in the pasture ($p=0.005$, 93/212 vs 13/53, respectively).

Table 5 shows the results of six contingency tables made for ant herbivory levels/non-levels versus *Virola*/*Hieronyma* in pasture or secondary forest. In the pasture light regime, we found no statistical difference between *Virola* and *Hieronyma* in low, high or summed total herbivory levels ($p=0.645$, 0.239 , 0.252 , respectively). However, in the secondary forest plots, significantly more low, high and summed total ant herbivory was noted in *Hieronyma* than in *Virola* ($p=0.045$: 60/212 vs 45/224, $p=0.001$: 28/212 vs 9/224, $p=0.000$: 93/212 vs 55/224, respectively). The difference between ant herbivory on *Hieronyma* and *Virola* in secondary forest was most notable in the high herbivory level.

These results cannot necessarily be interpreted to mean that *Hieronyma* is suffering more from herbivory damage than *Virola*. Ant population spatial distributions and activity vary in time. Thus, from these snapshot observations we cannot infer that *Virola* withstands leaf cutter ant herbivory better than *Hieronyma*. Due to the brief period in which this study was conducted, we were unable to research the life history of either of the plants, therefore, the relative ability of the plants to recuperate from such damage is unknown. One could speculate that despite higher herbivory levels, the larger leaf area and apparent faster growth rates for *Hieronyma* seedlings relative to those for *Virola* seedlings means that *Hieronyma* seedlings are well-adapted to withstand leaf cutter ant herbivory.

Conclusion

In this study we only considered herbivory by a single insect species on a limited sample of two tree species, however, this data indicates that under these experimental conditions, our first hypothesis was disproved (qualitatively), our second hypothesis was disproved for one species (*Hieronyma*), and our third hypothesis was disproved under the shade regime (secondary growth forest). Our observations on implementation of experimental designs that attempt to manipulate several environmental factors increased our appreciation of the difficulty of designing field experiments in the wet tropics and stimulated us to think about opportunities for variation in experimental design.

Acknowledgements

We extend our gratitude to Beth Braker for allowing us to traipse through her plots, and for her interest and enthusiasm for our project. We also thank her field assistant, Alex, whose knowledge and on-site field experience was very helpful in our sampling methodology and analysis.

Table 1. Plot Seedling Leaf Cutter Ant Herbivory Levels and Conditions on *Virola* and *Hieronyma* in Pasture and 2° Forest (# seedlings per plot).

Plot	Genus	Habitat	Total #	LowH	HighH	CompH	Vine	Noleaf	Dead
Ai	<i>Viro.</i>	Pasture	32	6	3	0	2	7	28
Aj	<i>Viro.</i>	Pasture	26	7	4	0	1	0	34
Ea	<i>Viro.</i>	2° Forest	55	10	0	0	1	2	5
Ba	<i>Viro.</i>	2° Forest	56	18	4	0	0	8	4
Db	<i>Viro.</i>	2° Forest	54	7	1	1	1	10	6
Dd	<i>Viro.</i>	2° Forest	59	10	4	0	4	7	1
Gl	<i>Hier.</i>	Pasture	53	10	3	0	1	11	7
Bb	<i>Hier.</i>	2° Forest	45	23	12	1	5	0	15
Dc	<i>Hier.</i>	2° Forest	53	14	10	2	4	2	7
Fc	<i>Hier.</i>	2° Forest	58	8	2	1	1	10	2
Ha	<i>Hier.</i>	2° Forest	56	15	4	1	1	13	4

Table 2. Median Plot Seedling Leaf Cutter Ant Herbivory Levels and Conditions on *Virola* and *Hieronyma* in Pasture and 2° Forest (top: median # seedlings/plot, bottom: % of total).

Genus	Habitat	Total #	LowH	HighH	CompH	Dead	Vine	NoLeaf
<i>Viro.</i>	Pasture	29.0	6.5	3.5	0.0	31.0	1.5	3.5
			22.4	12.1	0.0	44.8	5.2	12.1
<i>Viro.</i>	2°Forest	55.5	10.0	2.5	0.0	4.5	1.0	7.5
			18.0	4.5	0.0	7.5	1.8	13.5
<i>Hier.</i>	Pasture	53.0	10.0	3.0	0.0	7.0	1.0	11.0
			18.9	5.7	0.0	11.7	2.4	12.1
<i>Hier.</i>	2°Forest	54.5	14.5	7.0	1.0	5.5	2.5	6.0
			26.6	12.8	1.8	9.1	4.6	11.0

Table 3. Aggregated Leaf Cutter Ant Herbivory Levels on *Virola* and *Hieronyma* Seedlings in Pasture and 2° Forest (total # seedlings grouped by genus, habitat, herbivory).

Genus	Habitat	Total #	LowH	HighH	CompH	All H
<i>Virola</i>	Pasture	58	13	7	0	20
<i>Virola</i>	2° Forest	224	45	9	1	55
<i>Hieronyma</i>	Pasture	53	10	3	0	13
<i>Hieronyma</i>	2° Forest	212	60	28	5	93

Table 4. Two 2 x 2 Contingency Table P Values for Pasture/2° Forest versus Total Leaf Cutter Ant Herbivory/Non-Herbivory for *Virola* and *Hieronyma*.

Genus	P Value
<i>Virola</i>	0.122
<i>Hieronyma</i>	0.005

Table 5. Six 2 x 2 Contingency Table p Values for *Virola*/*Hieronyma* Versus Leaf Cutter Ant Herbivory Levels/Non-Levels in Pasture and 2° Forest.

Ant Herbivory Level	Pasture	2° Forest
LowH	0.645	0.045
HighH	0.239	0.001
All H= Low+High+Full	0.252	0.000

**Figure 1. Secondary Forest Median Plot.
Seedling Condition/Ant Herbivory**

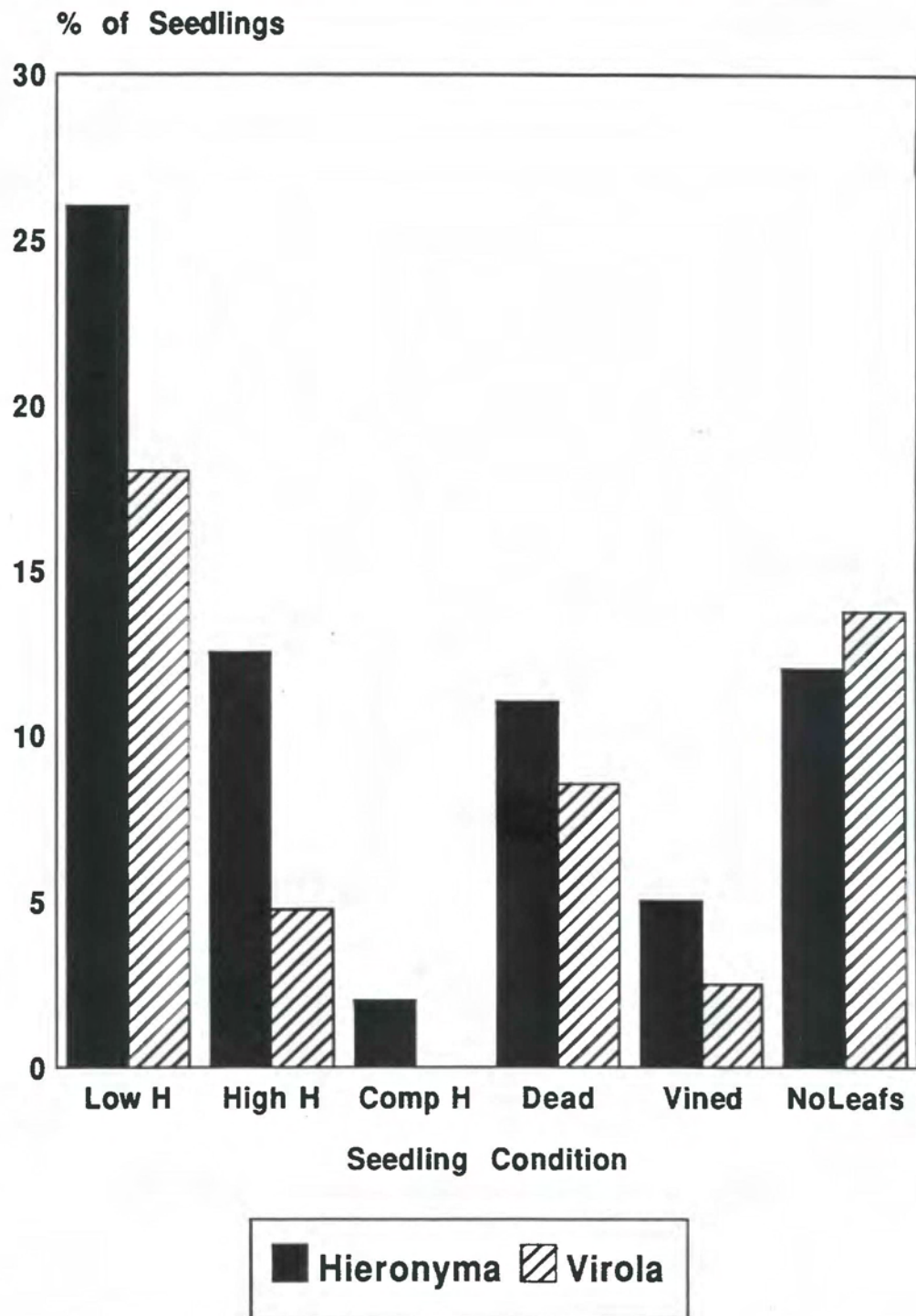
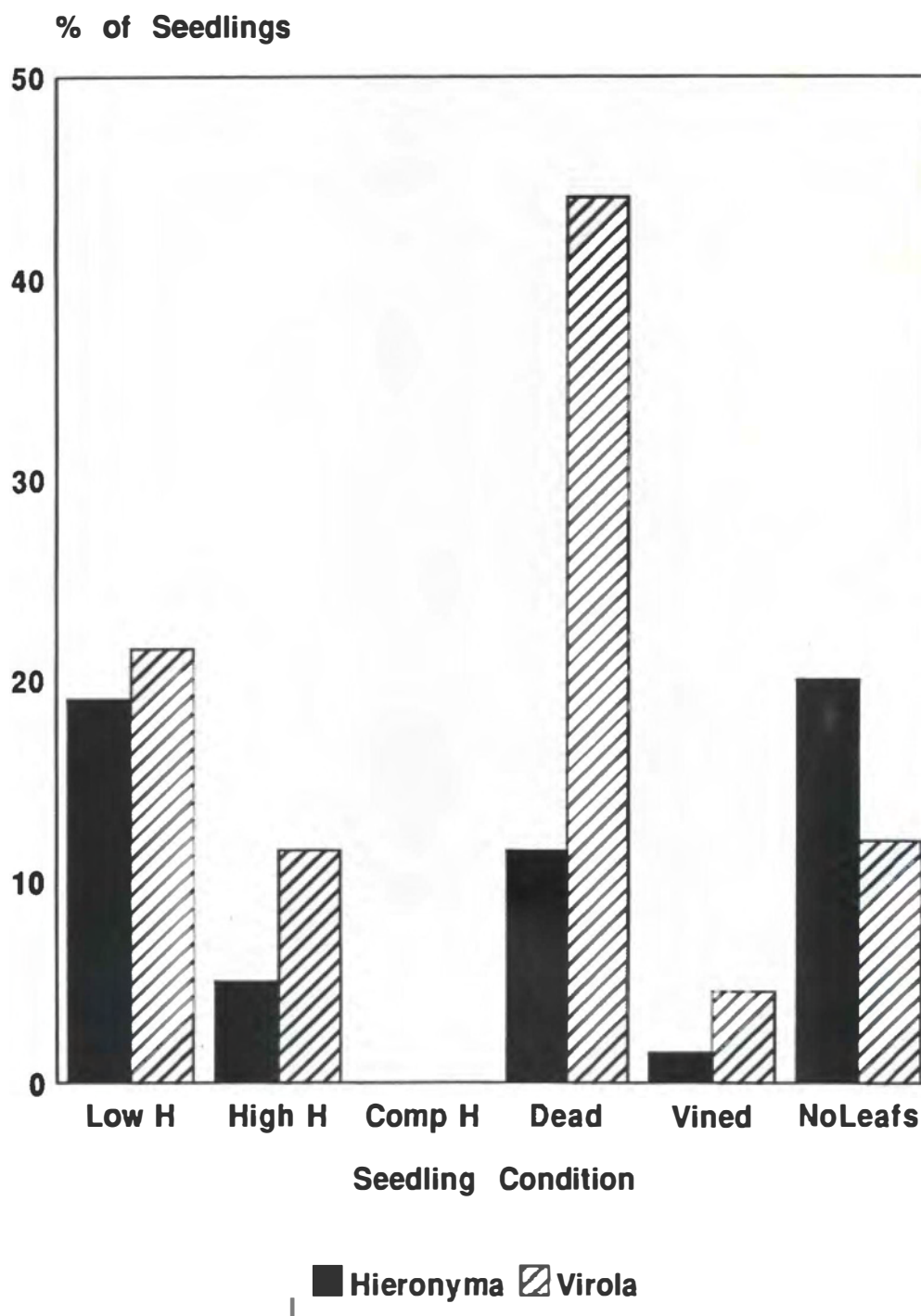
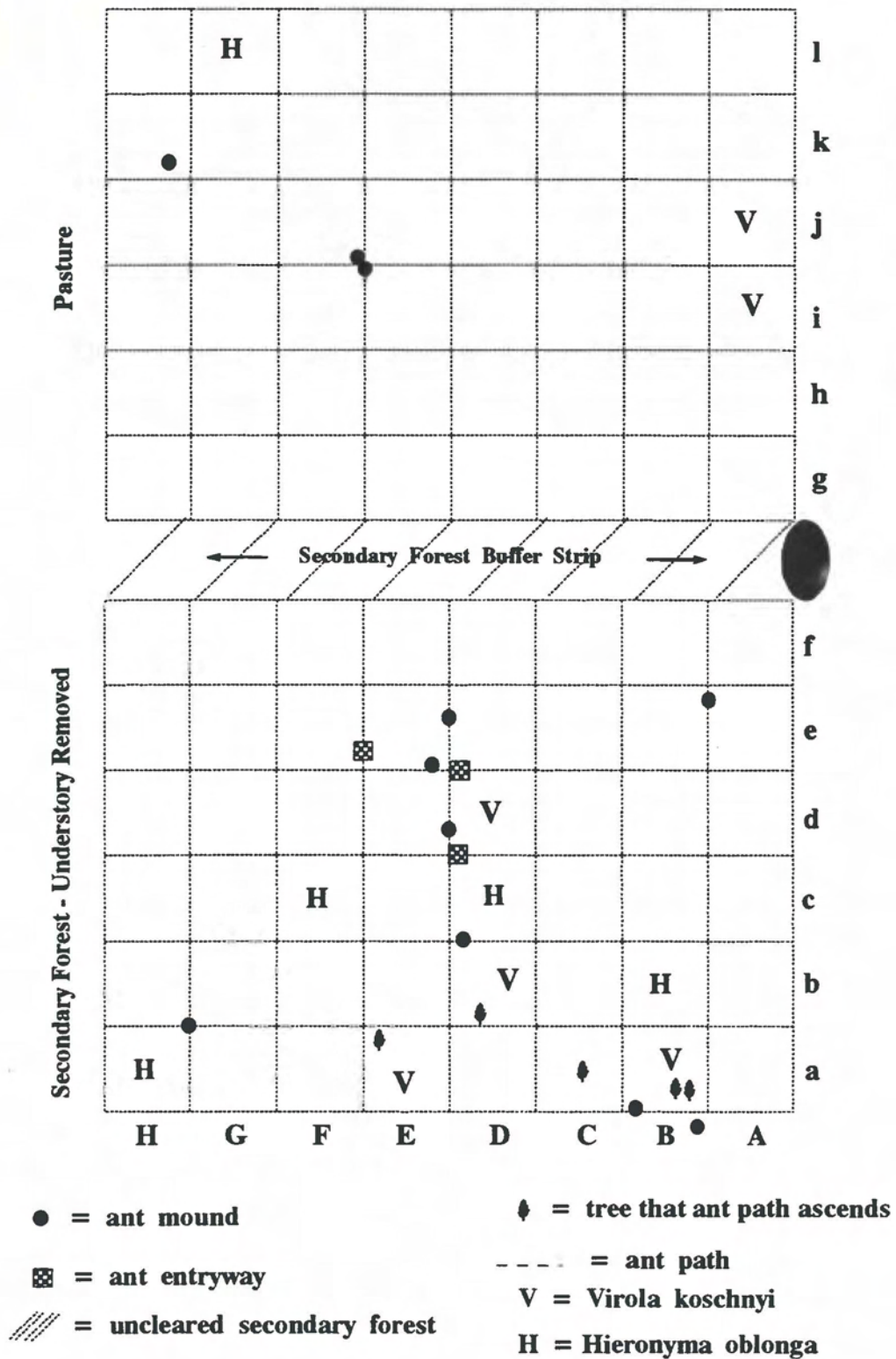


**Figure 2. Pasture Median Plot.
Seedling Condition/Ant Herbivory**



Map 1. Map of the PLAGAS Project.



AN EXAMINATION OF REGENERATION IN AN ACTIVE PASTURE

Authors: Bruce Ferguson, Jagdish Krishnaswamy, and Nick Shorr

Resumen

Para estudiar la regeneración de arboles en pasto, dos transecto eran hechos desde el margen del bosque hacia el centro de dos campos en una finca adyacente a La Selva. La posición y especie de cada vástago y árbol eran apuntados. Enrtevisamos al fincero sobre sus técnicos de manejo del pasto y los usos de árboles creciendo en el pasto. Datos de los transectos y información desde el entrevista están analizados en terminos de un modelo "tamiz ambiental" de regeneración.

Abstract

To study the regeneration of trees in pasture, transects were run from forest edge into the center of two fields on a farm adjacent to La Selva. The position and species of all saplings and trees in the transects were recorded. We interviewed the farmer regarding his pasture management practices and uses of trees growing in the pasture. Transect data and information from the interview are analyzed in terms of an "environmental sieve" model of regeneration.

Introduction

Regeneration of tropical forests following disturbance varies with the duration and intensity of the disturbance (Uhl et al., 1991). If use has been light and brief, the seedling bank and resprouting of primary forest trees afford direct regeneration of primary forest. Where use has been intense enough to kill trees, the soil seed bank becomes the primary source of regeneration. The seed bank is dominated by pioneer species, so return to closed forest follows a successional pattern. If repeated burning, herbicide applications, bulldozing and/or grazing have killed or removed roots, stems, and seeds of woody species, seed dispersal is the only remaining route for regeneration. Any seeds that are dispersed into pasture, generally by frugivorous birds, bats or wind, face a harsh microhabitat. Seeds and seedlings undergo intense predation and must compete with dense pasture vegetation for light, nutrients and water. In active pastures, regeneration faces not only grazing and trampling pressure, but may be deliberately or unintentionally eliminated by the farmer. The purpose of this study is to examine regeneration in an active pasture to determine which tree species survive this series of environmental filters.

Our study site was the farm closest to the gates of the La Selva Biological Reserve. The site was used most intensively in the 1960s as a mechanized rice farm. In

1976 the farm was converted to pasture and bananal. It was sold to IDA in 1985 and is now owned by Rafael Angel and his brothers. Of ten ha., eight are now in pasture. The pasture is dominated by the tall grass *Paspalum fasciculatum* (gamilote), which is too rough as a mature plant to be eaten by cattle. This species is especially dominant in wetter portions of the pasture. The more desirable *Ischaemum indicum* (rotana) is the next most common species, and the inedible *Desmodium* sp. (dormilona) is an important weed. The pasture is divided into two fields by a stream running through the property (we will refer to the side farthest from the La Selva gate as field 1 and the site closest to the gate as field 2). There is a fairly rich strip of secondary forest sloping down from field 1 about 15 m to the river. Field 1 has been burned almost annually since 1965, while field 2 has been burned very infrequently due to regular warnings from La Selva staff: field 2 abuts La Selva property. The brothers also use a weed whacker to clear undesirable ingrowth. They move their twenty cattle from one section to the other each week. The milk produced is consumed mostly by the brothers and their families. Their jobs at the banana plantations are their primary source of income.

Methods

In both fields, we randomly selected a point on the forest edge and laid a 100 m transect perpendicular to the edge, starting 10 m into the forest and extending into the pasture. The edge was defined rather arbitrarily since there was a transition from forest to pasture over the space of a few meters. The position along the transect of all saplings within 1 m, and all trees within 5 m of the center of the transect was recorded. We defined sapling as any tree species individual of at least 1 m in height and less than 10 cm dbh. Any individual greater than 10 cm dbh was considered a tree. Saplings and trees were rapidly identified by Orlando Vargas from samples brought from the field. We interviewed Rafael Angel regarding past and present land use as well as names and uses of trees left standing in the pasture. We obtained additional land use history from Isaías, a long-term local resident and station employee.

Results and Discussion

Figures 1 and 2 show the distribution of trees and saplings along the two transects. What is most striking is the concentration of individuals in the forest edge zone. In fact, 19 of the 25 trees in transect 1 and 14 of the 21 trees in transect 2 grew between 8 and 12 m from the origin of the transects. This edge clustering is probably due to a combination of greater light availability in the edge zone than deeper in the forest and reduction in management intensity near the pasture edge.

Table 1 shows the tree and sapling species composition of our transects, differentiating between the forest and forest edge (0 - 15 m from transect origin) and the pasture proper (15 - 100 m). Though transect 2 shows far greater mature tree population and diversity, it is devoid of saplings. The farmer explained this anomaly: just a few

weeks earlier he had macheted down all regrowth there, after about five years without extensive cutting.

Field 1 is adjacent to a rich forest patch, while field 2 is bordered by a more disturbed patch composed almost entirely of *Heliconia* and *Piper*, typical of light gaps and secondary growth. One might therefore expect greater seed dispersal into field 1. However, the nearby La Selva reserve may, for both fields, be a more important seed source than the immediately adjacent forest edge. With two interesting exceptions, all the tree species we could find information on were bird- or bird- and bat-dispersed. The wind-dispersed *Acalypha diversiflora* was the most abundant sapling in both transects, dominating the edge zone from 6.5 to 12.7 m. Finally *Psidium guajaba* (guava) is dispersed by cattle themselves, explaining its presence deep into transect 2.

Seedling establishment is likely affected by soil quality, burning regimes and competition with herbaceous species. On visual and tactile examination, we found field 1's soil considerably rockier and more compacted than field 2's. Perhaps equally important was the difference in fire regimes. Frequent burning in field 1 for weed control has probably greatly reduced regeneration there. *Bursera simaruba*, the only tree species present in field 1 beyond 13.5 m, was one of the few species Isaias and Joel (a La Selva staff botanist) identified as fire-tolerant. In addition to the direct effects of fire on tree regeneration, fire may indirectly affect pasture tree composition through its effects on pasture grass composition. The overwhelmingly dominant grass throughout the heart of field 1, *Paspalum fasciculatum*, resprouts vigorously after burning (thus use of fire to clear unpalatable grasses results in a vicious cycle). It seems likely that both above- and below-ground competition with such tall, thick grass may be an important environmental sieve for tree regeneration.

On a walk through his pastures, the farmer told us of at least one use for every tree that we passed. The most common use mentioned was timber (for both home-use and sale), followed by fruit (for both cattle and humans), firewood, post-making, medicine, and water-proofing (the native rubber tree). With the sole exception of two *Cecropia* individuals, we were given specific uses for all trees found beyond 12 m in both transects. Beyond specific uses, he said that all trees were good to have in pastures to provide some shade for the cattle. It is likely that managers of this farm have, over the past 25 years, recognized useful trees as saplings and tolerated and/or encouraged their growth. This may be the final and most important "environmental sieve" of all.

References

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Table 1. Tree and Sapling Species in Transects in Forest and Edge (0 - 15 m from Transects Origin) and in Pasture Proper (15 - 100 m).

Transect Zone	Species	# of Trees	# of Saplings
Transect 1			
0 - 15 m	<i>Acalypha diversifolia</i>		11
	<i>Acalypha machrostachya</i>		1
	<i>Alchornea costaricensis</i>	2	
	<i>Bravaisia integerina</i>		3
	<i>Casearia corymbosa</i>		1
	<i>Castilla elastica</i>	1	
	<i>Guarea guidonia</i>	1	
	<i>Inga spectabilis</i>		1
	<i>Nectandra membranacea</i>		1
	<i>Nectandra reticulata</i>	11	
	<i>Piper aduncum</i>	1	
	<i>Piper sancifelicis</i>		4
	<i>Psychotria macrostachya</i>		1
	<i>Rollinia microcephala</i>	3	
	<i>Bursera simaruba</i>	2	
15 - 100 m	<i>Solanum spp.</i>		2
	<i>Vernonia putens</i>		2
Transect 2			
0 - 15 m	<i>Alchornea costaricensis</i>	2	
	<i>Bravaisia integerina</i>		3
	<i>Casearia corymbosa</i>	1	
	<i>Castilla elastica</i>	1	
	<i>Cedrella mexicana</i>	2	
	<i>Hyeronima oblonga</i>	1	
	<i>Nectandra membranacea</i>	1	
	<i>Nectandra reticulata</i>	7	
15 - 100 m	<i>Bursera simaruba</i>	2	
	<i>Cecropia obtusifolia</i>	2	
	<i>Inga oerstediana</i>	3	
	<i>Psidium guajaba</i>	3	
	<i>Hyeronima oblonga</i>	1	
	<i>Alchornea costaricensis</i>	1	

Figure 1. Distribution of Trees and Saplings in Transect 1.

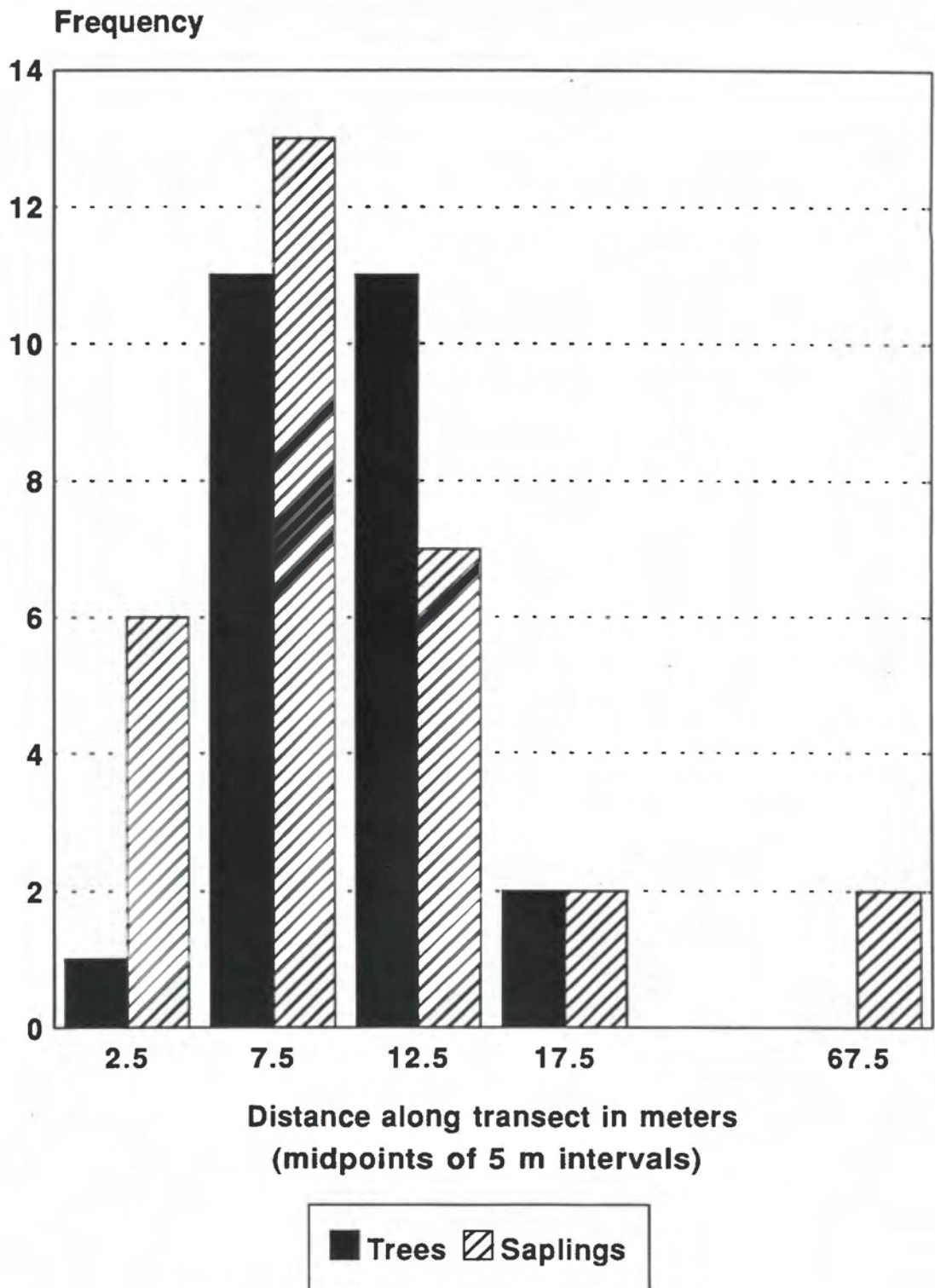
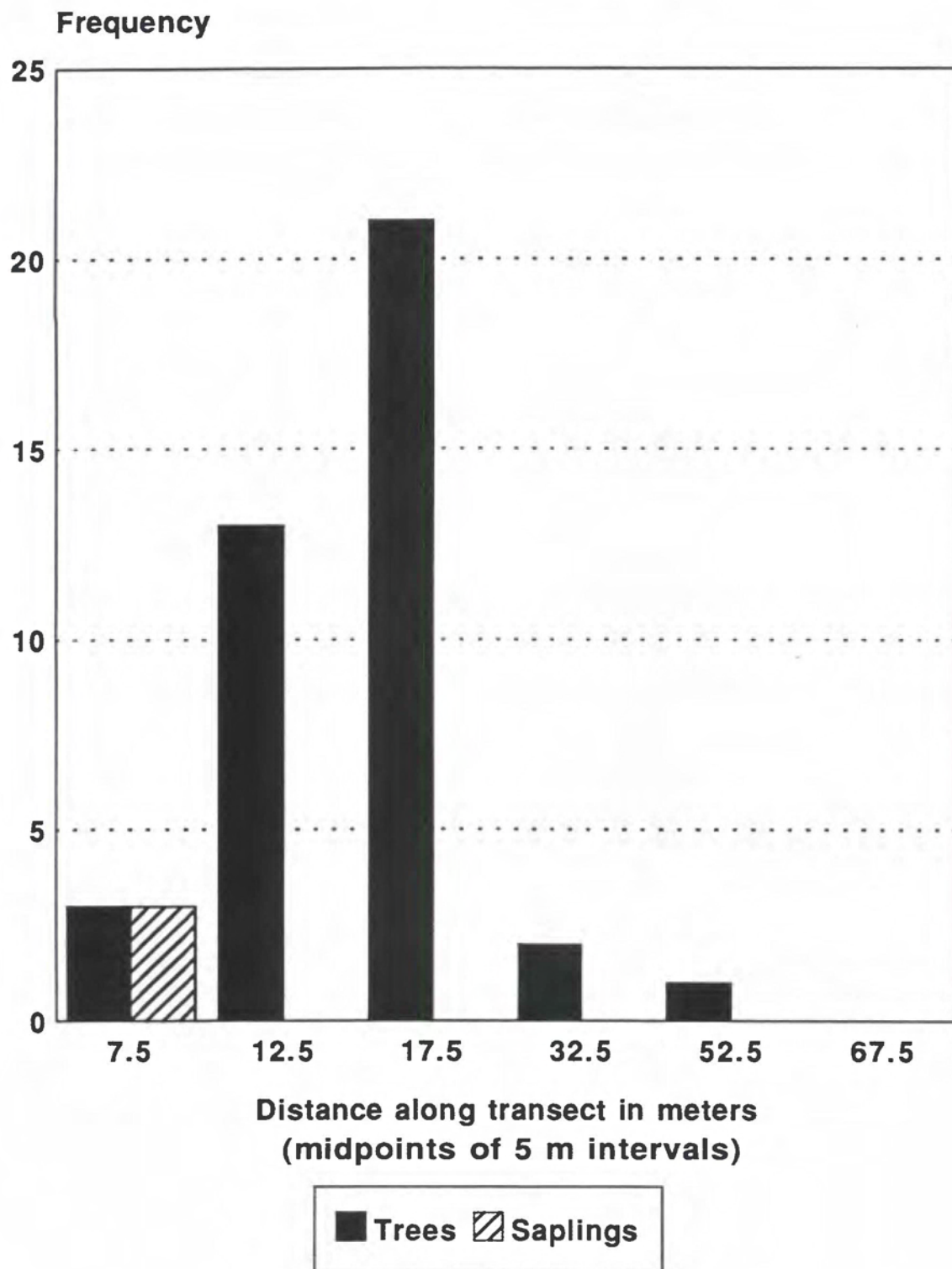


Figure 2. Distribution of Trees and Saplings in Transect 2.



TWO SOCIAL SCIENTISTS TAKE A WALK ON THE WILD SIDE

Authors: Pamela Stedman and Amelia Oliver

Resource Person: Orlando Vargas

Resumen

Bosques primarios y secundarios de La Selva fueron recorridos en busca de plantas ornamentales apropiados para su cultivo y exportación. Mas de treinta especies fueron encontradas e identificadas.

Abstract

Primary and secondary forests of La Selva were surveyed for ornamental plants suitable for cultivation for export. Over thirty species were found and identified.

Objective

The objective of this field project was, first, to make a rough estimate of the varieties of accessible plants in the forest of La Selva suitable for use as houseplants and ornamentals; and second, to enjoy the forest of La Selva.

Methods

Samples of plants suitable for cultivation as houseplants were taken from both primary and secondary forests of La Selva. Selection was based primarily on appearance. Plants with thick foliage, shiny or colorful leaves, and with no 'nasty' characteristics (smell, sting, etc.) were chosen. Easily accessible areas were chosen to ensure that all the plants could be easily collected from a managed forest, without getting lost or risking snake bites. Moreover, all plants selected are easily recognized and could be collected by someone with no training in botany (even by two social scientists). Approximately 5 hours were spent collecting samples.

The 35 samples selected were identified with much help from the local botanist (Orlando Vargas). Information was gathered on the collection sites (such as light levels and moisture levels), which is important for cultivation. Plant size and foliage density data were also collected using measurements between leaves and the length of each leaf stem.

Results

The 35 plants are listed in Appendix I. Most of the plants discovered thrived in much greater density in the secondary forest. Each of the plants appears to be suitable for cultivation as an ornamental with the exception of *Dieffenbachia longivaginata* which smells like peccaries and is caustic when contacted, and *Pentagonia donnell-smithii* which grows into a woody tree. The desirable characteristics in an ornamental are shade tolerance, dense foliage, attractive plant shape, and attractive leaf coloration. The plants collected range from a delicate ground cover to small ornamental trees, such as heliconia. The most commonly sampled plants were those which already enjoy great success as houseplants, namely *Philodendrons* and *Dieffenbachias*. Several ferns, palms, and other monocots were also found which appear to have potential as ornamentals. Given the wide range of situations in which ornamentals are used, a wide range of shapes and sizes of plants should be able to find a market.

Discussion

The varieties of plants sampled may be suitable for cultivation in agroforestry systems or for extraction from managed forests. In either case, the export of ornamentals would enhance the value of these systems and perhaps contribute to a reduction in deforestation by giving added value to forests and reducing the need for income from timber and clearcutting. This ornamental market could also create incentives for agroforestry or reforestation projects by providing short-run benefits.

APPENDIX I

ARACEAE	<i>Philodendron hastatum</i>
	<i>Philodendron grandipes</i>
	<i>Philodendron rigidifolium</i>
	<i>Philodendron</i> (6 other sp)
	<i>Dieffenbachia longispatha</i>
	* <i>Dieffenbachia longivaginata</i>
	<i>Spathiphyllum fulvovirens</i>
	<i>Syngonium</i> sp
CYATHACEAE	<i>Metaxya rostrata</i>
POLYPODIACEAE	<i>Diplazium</i> sp
	<i>Polybotrya</i> sp
	<i>Thelypteris</i> sp
OTHER FERNS	<i>Pellea rotundifolia</i>
	<i>Selaginella selvestris</i>
PALMAE	<i>Iriarteia gigantea</i>
	<i>Asterogyne martiana</i>
	<i>Geonoma cuneata</i>
	<i>Geonoma congesta</i>
	<i>Welfia georgii</i>
CYCLANTHACEAE	<i>Asplundia</i> sp
	<i>Bipartitus</i> sp
MARANTACEAE	<i>Calanthe</i> sp
	<i>Calanthe micon</i>
BROMELIACEAE	<i>Vriesea</i> sp
BEGONIACEAE	<i>Begonia</i> sp
RUBIACEAE	* <i>Pentagonia donnell-smithii</i>
	<i>Psychotria panamensis</i>
SMILACACEAE	<i>Smilax</i> sp
COSTACEAE	<i>Costus</i> (3 sp)
HELICONIACEAE	<i>Heliconia</i> sp
GRAMINEAE	<i>Pariana/Cryptochloa</i>

* Unsuitable as an ornamental

Independent Field Problem

JUST A SPOONFUL OF SUGAR HELPS THE MEDICINAL PLANTS GO DOWN

Author: Jill Fischer

Resumen

Se hizo un estudio del conocimiento del uso de plantas medicinales en y cerca de Puerto Viejo. El análisis se enfocó en la preferencia de plantas y no en las medicinas químicas.

Abstract

A study of the knowledge of the use of medicinal plants in and around Puerto Viejo was undertaken. The analysis centered on the preference for plants, as opposed to chemicals.

Methodology

A series of informal interviews was conducted at nine different sites, some bordering La Selva, and others in La Muelle. From this sample, ten people offered information and two declined the interview.

The limitations to a study of this sort dealt primarily with the time available for the interview process; such a study would produce more reliable results if sufficient time were allocated so that a large enough sample size could be obtained. Furthermore, the interviews tended to be quite time consuming, thus, a previously made appointment with the interviewees would have been ideal to not interrupt the daily activities, as well as to facilitate their recollection of a wider array of medicinal plants.

Another limitation of the study was based on the terminology: medicinal and native plants. The term medicinal was problematic, as the idea of using plants as medicine was not shared by all; rather, some interviewees viewed all plants as medicinal because they are very nutritive. The word native caused other conflicts, again because of differing definitions. Instead of deeming native plants as those that originated in a specific world region or country, plants were often referred to as native by the interviewees when examples of wild plants were found in Costa Rica. The plants were also considered native if the plant had been in the area for several generations.

Discussion

Most people interviewed knew of at least a few plants and their curative properties. (Most interviewees had similar knowledge of and uses for the more common plants). Interestingly enough, these widely-used plants were of the Old World (such as oregano,

manzanilla, and mint), and are not considered to be endemic to Costa Rica. The people who seemed to know more about the use of plants with medicinal properties occasionally knew of several uses for the well-known plants, however, all were familiar with the same, more common uses.

The more common ailments had medicinal plant cures (e.g., manzanilla tea relieves stomach ache and menstrual cramps; mint tea also is a good remedy for general stomach problems; tilo tea is used as a relaxant; and oregano tea stops coughing). Whereas only those people with a great deal of knowledge of medicinal plants were able to inform me of plant-based medicines capable of curing more serious conditions and illnesses. It was also this group that gave me more detailed recipes (for lack of a better word).

Most of the plants possessing curative properties could be (and were) cultivated. No one spoke of collecting from areas other than the roadside and tree-filled areas along the sides and back of their houses.

The seeds for these cultivated plants could often be obtained from family or friends. Those that were not readily available could be bought from local sources.

The interviewees' knowledge of medicinal plants came from several sources: parents, friends, other relatives, acquaintances, books, and radio/television programs.

The reasons for using plants as medicine varied greatly. The most common response was that there was often no easy access to a doctor or medicine. Another of the more common reasons for using medicinal plants was that of cost: several believed that plants work better and cost less than medicine from a doctor. Some felt that it was extremely convenient to have an entire pharmacy surrounding the house, while others spoke of having a preference for natural cures.

AILMENT	COMMON NAME	PREPARATION
Anemia	Cocolmecca	Boil root in 1C milk. Drink tea.
	Culantro coyote	Boil small portion of root in water or milk. Drink tea.
	Hombre grande	Boil small portion of stem in water. Drink tea.
	Sarsaparilla	Dry and grind roots. Boil in water. Drink tea.
Cancer	Flor de maravilla Frailecillo* *(preventative)	
Cough	Oregano	Boil 8 cm of stem (with leaves) in 1 c. milk. Drink tea.
	Mango	Boil leaves with water. Add honey. Drink tea.
Ear Pain	Ajo	Fry garlic. Soak cotton in pan. Place cotton in ears.
	Albajaca Romero	Boil small branch in water. Rinse ears with liquid.
Fever	Borraja	Boil small branch (spines and all) in water. Drink tea.
	Sacate de Limón	Boil leaves in water. Drink tea.
Fungal Infection of Nails	Achiote	Apply paste made of seeds to affected areas.
Gastritis/Ulcer	Malba	Boil leaves with water. Drink tea.
	Mosote	Peel branch, crush bark. Boil bark in water until foamy. Drink tea.
	Sorosí	Boil vine. Drink water.

AILMENT	COMMON NAME	PREPARATION
Headache	Achiote	Boil a few leaves in water. Soak towels in water and place on head.
	Naranjo Agrio	Boil leaves in milk or water. Drink tea.
Menstrual Cramps	Manzanilla	Boil a few leaves in water. Drink tea.
Nerves/Insomnia	Naranjo Agrio	Boil leaves in milk or water. Drink tea.
	Tilo	Boil 2 small stems with leaves (8cm/ea.) in 1 c. milk or water. Drink tea.
Recover after child birth	Limón Agrio	Boil small stem with leaves, in water. Drink tea.
	Manzanilla	Drink tea.
Rheumatism	Iliotropo	Crush root. Boil in water. Bathe affected part.
	Mosote	Peel branch, crush bark. Boil bark in water until foamy. Drink tea.
Sinusitis	Manzanilla, Romero	Boil Romero and Manzanilla in water. Bathe affected area.
Skin Infection	Salbia	Boil leaves in water. Soak towels in water, and place on affected areas.
	Cerocantil	Boil leaves in water. Drink tea.
Sore Throat/Swollen Glands	Menta	Boil stem with leaves in water. Drink tea. Or chew leaves.

AILMENT	COMMON NAME	PREPARATION
Stomach Ache	Hombre Grande Llantén	Boil 1 leaf with water. Drink tea.
	Mosote	Peel branch, crush bark. Boil in water until foamy. Drink tea.
	Guanábana (poor digestion)	Boil a few leaves in water. Drink tea.
Vomiting	Canela	Boil 2 small sticks (8cm) in 1 c. water or milk. Drink tea.
Worms	Ajo	Crush garlic and mix with alcohol. Rub over child's body-always massaging away from heart.

Independent Field Problem

BEE INTERACTIONS AND GENE-FLOW IN THE POLLINATION OF *SPATHIPHYLLUM FRIEDRICHSTHALII* (ARACEAE)

Author: Cecelia Smith
Faculty: Carlos Valerio

Resumen

Los modelos de abeja forrajando y interacciones fueron observados en una población de *Spathiphyllum friedrichsthali* (Araceae) por un día. Abejas Euglossa (Hymenoptera; Euglossinae) fueron establecidas para forrajear la mayoría pesadamente en las horas de la mañana. El medio tiempo de forraje por las abejas Euglossa fue mucho más que el de las cuatro especies de abejas Meliponas (Hymenoptera; Meliponae) observadas forrajando en la mañana y tarde. Interspecifica y intraspecifica interacciones disminuyen el medio tiempo de forraje a flores individuales por todas las especies de abejas y son potencialmente importantes por flujo de genética en *S. friedrichsthali*. Este estudio sugiere que Euglossans pueden ser más importantes por entre población flujo de genética y Meliponas por dentro de población flujo de genética.

Abstract

Bee foraging patterns and interactions were observed on a population of *Spathiphyllum friedrichsthali* (Araceae) for 1 day. Euglossa bees (Hymenoptera; Euglossinae) were found to forage most heavily in the morning hours. Average foraging time of Euglossa bees was much greater than that of the four Melipona bee species (Hymenoptera; Meliponae) observed foraging both in the morning and afternoon. Interspecific and intraspecific interactions were found to decrease mean foraging time spent on individual flowers for all bee species and are potentially important for gene-flow in *S. friedrichsthali*. This study suggests that Euglossans could be more important for between population gene-flow and Meliponas for within population gene-flow.

Introduction

Pollinator behavior is often taken for granted in population models and studies looking at gene-flow between and within populations. This one day study of bee foraging patterns on *Spathiphyllum friedrichsthali* (Araceae) in Cantarana pond in La Selva is a glimpse at the possible implications of pollinator behavior and interactions for gene-flow in metapopulations.

Euglossa bees have been assumed to be the primary pollinator for Araceae because the chemical compound that Euglossa require to attract females is produced by the inflorescence of plants in this family and was thought to be closely co-evolved (Janzen

1988). However, several other bee species (*Melipona*) were observed foraging on *S. friedrichsthalii* and could have a significant effect on the gene-flow between and within populations.

Methods

Observations were made of bee foraging activities on 19 *S. friedrichsthalii* plants in 4 contiguous patches at Cantarana Marsh, La Selva Biological Reserve. Observations were made from 10 - 12 a.m. and 1 - 3 p.m. July 20, 1993. Each patch had 4 - 5 recently opened, apparently receptive inflorescences. The duration of each bee visitation, and interaction between bees was noted as well as movement between receptive inflorescences in each patch. Each of the four patches was observed for 20 - 25 minutes in the morning and again in the afternoon.

Results

Of the 19 plants chosen for observation in the four patches, 6 individual inflorescences (32%) received over 75% of bee visitation. Of these, only 3 inflorescences received visitation from *Euglossa* bees, and of that, 2 received the bulk of visitation (80%). This suggests that the number of acceptable receptive inflorescences is much smaller than indicated by the mere presence of open, fragrant inflorescence. As summarized in Table 1, *Euglossa* bees foraged the longest (mean 7:32) on individual inflorescences.

Four species of *Melipona* bees were observed foraging on *S. friedrichsthalii* flowers, but the two larger species (1 black and 1 yellow) were by far the most abundant and active. Mean foraging times of the black and yellow *Melipona* were not significantly different (2:19 and 2:22, respectively). The yellow *Melipona* was most sensitive to the presence of other bees, particularly of its own kind. When other bees were present, mean foraging time was reduced from 4:33 (no interaction) to only 1 minute in the presence of its own kind, and 1:81 in the presence of another *Melipona* species. The black *Melipona* was less sensitive to the presence of other bees and actually increased its mean foraging time in the presence of other species of *Melipona* (2:40 no interaction, 2:50 presence of own species). Foraging time was shortest for the black *Melipona* in the presence of other *Melipona* bees (2:00). Unfortunately, sample sizes were insufficient to perform statistical analysis.

Conclusion

Euglossa bees foraged on individual *S. friedrichsthalii* flowers for a much longer time than did *Melipona* bees, which is consistent with the ecological lore that because they rely on *S. friedrichsthalii* for pheromone chemicals, *Euglossa* are the most effective pollinator. However, *Euglossa* bees observed foraging only in the morning, were far rarer than *Melipona*, and were highly selective in which flowers they visited. *Euglossa* are thought to be "trap-liner" foragers (Valerio, pers. comm.), which indicates that they are

best for facilitating gene-flow between habitat "islands". Since *S. friedrichsthalii* is confined to ponds, this sort of gene transfer is probably very important for maintaining genetic diversity of populations.

The limited foraging range of *Euglossa* within a patch leaves the problem of within population pollination unsolved. Although *Melipona* are probably less efficient and more promiscuous foragers than *Euglossa*, this study suggests that their abundance, longer foraging day, and lack of selectivity could be important for general pollination and within population gene-flow.

In all cases, interactions between bees decreased the mean foraging time and increased the movement of bees between individual plants. This suggests that bee interactions are an additional factor to consider when looking at gene-flow between and within populations.

Further studies to determine the relative efficiency of pollen transfer of *Euglossa* and *Melipona* bees are needed to resolve these questions - especially given that these bees are foraging for different resources (*Euglossa* for chemicals, *Melipona* for pollen). The confinement of *S. friedrichsthalii* to isolated pond "islands" makes this a particularly interesting study in gene-flow dynamics.

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Table 1. Mean Time Spent Foraging (minutes:seconds) Under Different Interaction Regimes. N = Number of Observations.

	Euglossa	Yellow M	Black M	N
All	7:32	2:19	2:22	3/16/18
No interaction	9:45	4:33	2:40	1/3/5
Intra-species	---	1:00	2:50	0/2/2
Inter-species	5:03	1:81	2:00	2/11/11

Independent Field Problem

LEADING ANTS DOWN THE WRONG PATH: LEAF-CUTTER ANT (*ATTA CEPHALOTES*) RESPONSE TO NEST SOIL AND PHEROMONES

Authors: Ellen Pedersen, Norm Bourg, and Laura Howard

Resumen

Se estudió el efecto de feromonas y de tierra excavada por la hormiga cortadora de hojas como repelente para proteger los cultivos. Ambas sustancias se colocaron sobre los caminos de las hormigas y se estudio el efecto sobre el movimiento de ellas. La tierra excavada no tuvo ningún efecto, mientras que algunas concentraciones de feromona dieron resultados significativos.

Abstract

Leaf cutter ants pheromones and soil excavates from mounds were used to determine the effectiveness as ant repellent to protect crops. Both substances were placed across ant paths and their effect on ant movement rate measured. Soil excavates proved ineffective, whereas some pheromone concentrations yielded significant differences.

Introduction

Leaf-cutter ants (*Atta cephalotes*) are one of the most conspicuous insect herbivores in tropical forests below approximately 2,000 m in Costa Rica. These ants have been known to cut leaves from more than eighty species of plants (Hubbell et al., 1979) and their colonies function as major nutrient cyclers in forests (Lugo et al., 1973). Due to their effectiveness as herbivores, leaf-cutter ant colonies can also be important pests of agricultural crops in the tropics.

Bentley (1993, pers. comm.) has reported that small farmers use discarded fungus garden material and/or excavated soil from ant nests to repel leaf-cutters from their crops. Leaf cutter ants occurring in humid areas, such as La Selva, only produce soil piles. These soil piles were used in the present experiment to examine its effect as repellent against leaf cutter ants. The potential use of these huge soil piles as a repellent is important due to their accessibility and abundance. These ants, particularly the foraging worker caste, are also known to produce trail pheromones in addition to alarm pheromones.

The objective of this study was to examine potential biological control methods for leaf-cutter ant herbivory. Two methods to divert ants from their trails were studied: 1.) placement of excavated nest soil across trails; and 2.) the use of pheromones to lead ants along an alternate path. The null hypotheses for both methods were as follows:

Ho: Movement rates along the trunk trail will not be affected by the presence of soil excavates or pheromone extract.

Methods - Soil

A leaf-cutter ant colony was selected in the Arboretum and another behind the classroom at La Selva Biological Station. The highways were flagged and monitored for activity. Strings crossing the highways perpendicularly at 1 and 5 m from the mound were placed across the paths to count the number of ants crossing the line. Each experiment started by counting the number of ants crossing the line each 10 seconds during 5 minutes. After this number was known, a barrier of 10 cm or 30 cm long was placed either at 1 or 5 m from the mound using one of the 3 soil types. Soil from an unrelated colony, from the forest, and from their own colony was collected and placed in a plastic bag until the moment of the experiment. Both lengths of barriers were tested with the 3 types of soil. After 10 minutes the number of ants were counted again to determine the duration of the repellent effect. Once a highway had been used for one of the experiments, it was not used again for at least one hour.

Methods - Pheromones

Three leaf-cutter ant colonies were studied at the La Selva Biological Station. Two colonies were located in the lawn area surrounding the large laboratory building of the station. These colonies were used for the pheromone experiments. A third colony was found next to the trail leading to the arboretum.

Data of three types were collected for each trunk trail pheromone experiment. First, baseline data were recorded on normal ant movement rates by tallying ants moving across a point during 1 minute periods for a total of 10 minutes. Next, a control cotton string (30 cm) soaked only in methylene chloride and olive oil was used to measure for any effect of string placement on the ants over the same time intervals. Finally, trail pheromone experimental treatments were prepared. Pheromones were extracted from ants to test for their diversionary ability. Foraging ants carrying leaves were collected from a colony located in front of the lab building. These foragers were separated into groups of large and small foragers. Each sample was frozen immediately after collection. The heads were separated from the abdomens in order to isolate the alarm pheromone (located in the head) from the trail pheromone (located in the abdomen). Four concentrations of trail pheromones were created using the following protocol:

Treatment 1 (Large Ants/High Concentration):

2 ml methylene chloride (MCl), 5 drops olive oil (OO), crush 25 large forager abdomens into solution

Treatment 2 (Small Ants/High Concentration):

2 ml MCl, 5 drops OO

60 small abdomens

Treatment 3 (Large Ants/Low Concentration):

Solution #1: 1 ml MCl, 2.5 drops OO

crush 12 large forager abdomens into solution #1

Add one drop of solution #1 to:

1 ml MCl, 3 drops OO

Treatment 4 (Small Ants/Low Concentration):

Solution #1: 1 ml MCl, 2.5 drops OO

24 small ant abdomens

Add one drop of solution #1 to:

1 ml MCl, 3 drops OO

A Cotton string (30 cm) was soaked in each extract and allowed to air dry so that the methylene chloride residue was eliminated. Each string was laid diagonally across the trunk trails, and the behavioral responses of the ants were recorded for time periods identical to those mentioned above.

Treatments 1 and 2 were applied to both the ant colony behind the laboratory and to the same colony (front of laboratory) from which the pheromone was extracted. Treatments 3 and 4 were only given to the front lab colony.

Results - Pheromones

Table 1 presents the results and statistical analyses of the experiments. Two-sample t-tests were used to determine whether mean movement rates of controls and treatments differed significantly from the baseline movement rates. In only one case (same colony/large forager/high concentration) did control movement rates differ significantly from the baseline, implying little or no effect of the methylene chloride/olive oil-soaked string on the ants. However, 3 of the 6 treatment means were significantly less than the mean baseline movement rates, showing that the presence of trail pheromones could divert or distract ants from their trails regardless of whether the pheromones came from the same ant colony or a different one. Although neither of the low pheromone concentration treatments gave significant results, the same colony/small forager/low concentration treatment approached significance.

Results - Soil

In all cases the ants were confused immediately after the alien material had been placed on their paths. This was manifested by sudden stop, backtrack, and accumulation of ants on both sides of the barrier. However, after a few minutes some ants from both

sides started entering the barrier, going back, followed by others, and finally crossing the barrier. When the ants were counted after 10 minutes, all ants had overcome the barrier and circulation was back to previous levels.

Discussion - Pheromones

Heavy rain followed by clear, sunny skies during the control sampling period could have caused the significantly different result in the same colony/large forager/high concentration case. Also, the pheromone levels used in the low concentration treatments may have been too dilute to affect the ants. In general, ant reactions to the trail pheromone treatments could be characterized in two ways: 1.) apparent confusion and disorientation; and 2.) some ants following the treated string and others diverting their route around one end of the string. In any case, the pheromone treatments did seem to alter normal *Atta* movements.

The initial results of the pheromone trials call for further investigation into their potential use for diverting foraging ants from their food plants. Pertinent studies would include more replications of various treatments and determination of effective pheromone levels. The ultimate goal should be to provide small farmers with an inexpensive, easy-to-manufacture and use, and environmentally benign means for protecting crops from leaf-cutter ants.

Discussion - Soil

Since the aim of this experiment was to find an easy, cheap, and non-toxic protection of crops against leaf-cutter ants, common sense indicates that statistical analysis of the data is not necessary, since the only effect of any of the experiments was the confusion of the ants due to a physical more than chemical barrier. In the hypothetical case that the soil excavated from the colonies would have acted as repellent for 8 hours, an easy application method could have been developed to facilitate biological control of leaf cutter ants.

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Table 1. Leaf-cutter Ant Response to Trail Pheromones.

Treatment 1				Treatment 1		
Different colony/large forager/HI				Same colony/large forager/HI		
	B	C	T	B	C	T
average	39.9	36.3	10.7	64.7	80.2	75.4
var.	47.3	36.5	32.8	144.2	153.2	182.2
t-value		1.032	4.281		-2.84	-1.87

Critical t (0.05,6)= 2.447

Critical t (0.05,9)= 2.262

Treatment 2				Treatment 2		
Different colony/small forager/HI				Same colony/small forager/HI		
	B	C	T	B	C	T
average	22.7	20.0	6.1	27.0	20.7	14.8
var.	22.2	46.0	5.3	31.4	69.8	65.8
t-value		0.869	8.365		1.980	3.913

Critical t (0.05,6)= 2.447

Critical t (0.05,9)= 2.262

Treatment 3			
Same colony/large forager/LO			
	B	C	T
average	64.7	52.9	77.4
var.	144.2	131.9	507.6
t-value		2.245	-1.57

Critical t (0.05,9)= 2.262

Treatment 4

Same colony/small forager/LO

	B	C	T
average	24.2	16.7	16.0
variance	83.2	33.6	52.6
t-value		1.815	2.225

Critical t (0.05,9)= 2.262

B = Baseline

C = Control

T = Treatment

Independent Field Problem

NODULATION AT LA SELVA

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Problem # 1

Actinorhizal plants, those plants that form a symbiotic relationship with *Frankia*, are rare in the neotropics. The few exceptions being a few species of *Myrica* and *Alnus*, which occur in Central and South American highlands. *Frankia* in the root nodules of actinorhizal plant are able to fix atmospheric nitrogen which is made available to plants. In return, the plant receives carbohydrates. This ability to fix atmospheric nitrogen gives plants a competitive advantage in environments where nitrogen is limited. There are no known actinorhizal plants in the lowland neotropics where woody legumes usually fill the niche of nitrogen fixation. However, Paschke (1992) found infective and effective *Frankia* in soil samples collected at La Selva Biological Research Station. This suggests either a non-symbiotic population of soil *Frankia*, the presence of unknown actinorhizal plant species, or the ability of *Frankia* to be dispersed long distances.

The purpose of this study was to investigate the possibility of new actinorhizal plant species. *Frankia* are known to form an association with 8 dictyodermous plant families. I hypothesize that if there are previously unknown actinorhizal plant species at La Selva, the species would be in one of the 8 known actinorhizal plant families.

Methods

A list of plant species occurring at La Selva was consulted to find species that are in families that are known to be actinorhizal. Two families known to be actinorhizal with genera at La Selva were identified. In Rhamnaceae *Colubrina spinosa* is present at La Selva and in Chrysobalanaceae, a family that includes Roseaceae in the plant list of La Selva, *Hirtella lemsii* and *Maranthes panamensis* is also present. Three individuals of each species were examined for the presence of root nodules by digging around the root collar with a trowel and examining the roots for nodules. Where possible, species near the sites where Paschke took soil samples were examined.

Results and Conclusions

No root nodules were found on any of the individuals examined. This could indicate that either the sample size was too small or that these species are not actinorhizal. Future investigations might sample a larger number of individuals per species and examine other genera in the two families that are more rare at La Selva.

Problem # 2

We chose to determine if there was a correlation between the number of nodules and nodule weight and the dbh of nitrogen fixing trees. In order to investigate this we measured the dbh of 8 *Hymenolobium* sp. trees and took soil cores 3 cm deep and 6 cm in diameter. Soil cores were taken 10 cm and 40 cm from the trees. From the samples, the number of nodules and the dry weight was determined. Bulk density was also determined.

Results and Discussion

There was no correlation between the number of nodules or dry weight of nodules per tree and dbh (see Table 1). There was, however, a significant difference ($P > .05$) in bulk density of soil samples taken at 10 cm and 40 cm from the base of the tree (see Figure 1). This suggests that these trees are able to improve soil structure near the base of the tree.

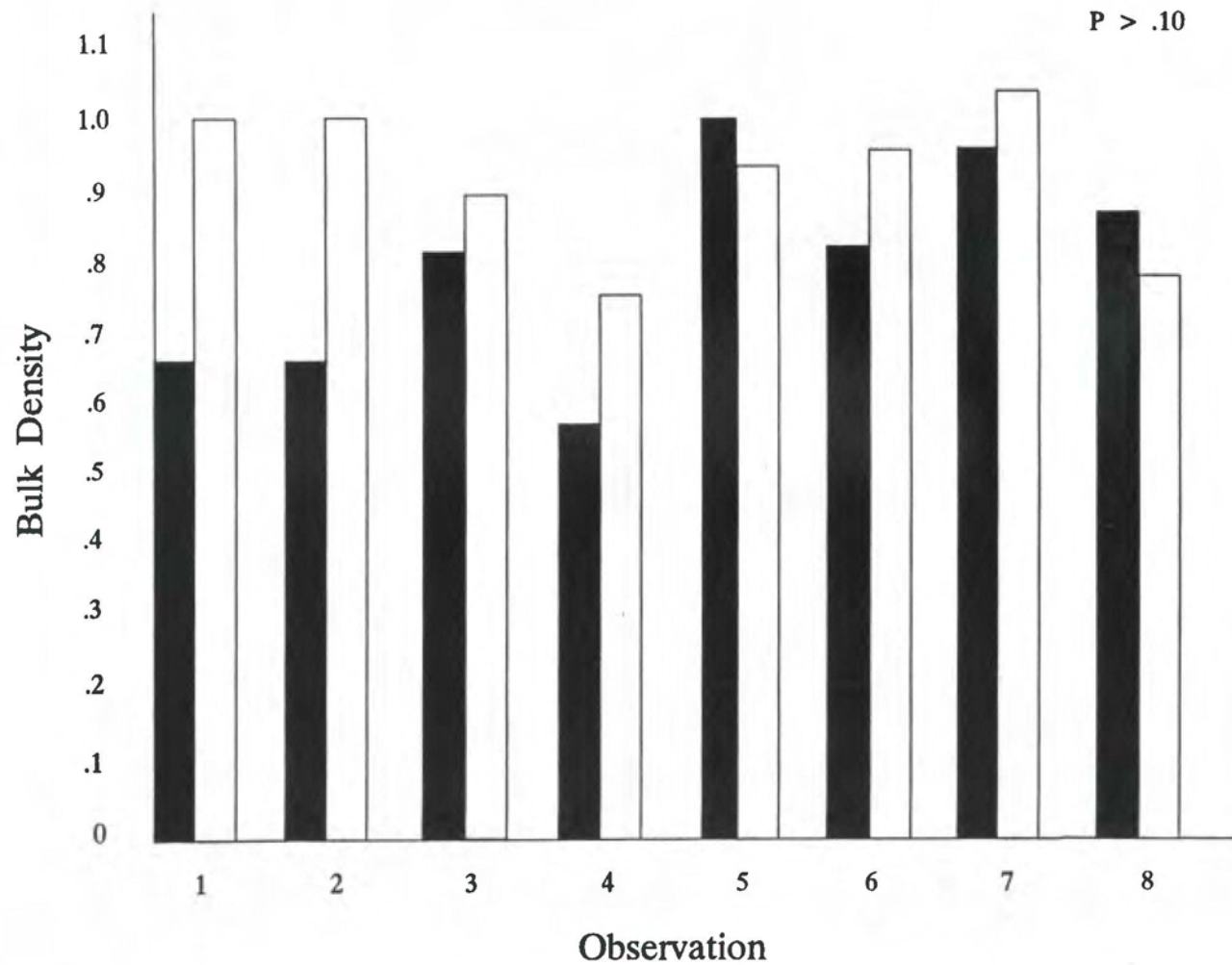
Literature Cited

Paschke, M. W. and J. O. Dawson. The occurrence of *Frankia* in tropical forest soils of Costa Rica. Plant and Soil. 142:63-67.

Table 1. Root Nodules Under *Hymenolobium*.

Tree #	DBH	Dry Wt. of Nodules	# of Nodules	
			10 cm	40 cm
1	31	.51	2	0
2	49	5.17	34	0
3	54	.98	19	0
4	72	.19	12	5
5	58	.06	3	0
6	37	.71	7	0
7	48	.24	7	0
8	61	1.29	14	0

Figure 1. Bulk Density of Soil Under *Hymenolobium*.



BOSCOSA
COSTA RICA

Guided Field Problem

A TALE OF THREE TROPHIC LEVELS: PIPER-ANT-SPIDER MUTUALISM

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Group Members: Brent Blair, Laura Howard, Lucy Buchan, Ellen Pedersen, and Keith Taulbee

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Introduction

Many plant species are known to have mutualistic relationships with ants. Generally, the plant provides food bodies while the ant helps to protect the plant against predators and competitors. These plants include species within the genera *Acacia*, *Cecropia*, and *Piper*.

The present study focuses on the mutualistic relationship of *Piperaceae finbriolatum* with *Phediole* ants. The plant produces nectaries inside the petiole and on young leaves. In return, the ant defends the plant against herbivore by removing egg masses of other insects. In addition to the plant-ant mutualism, *Theridiid* (*Dipenidae*) spider builds its web on the *Piper* and may prey solely upon the *Phediole*.

Objectives

The purpose of this study was to examine the relationships among the *Pipers*, *Phedioles*, and *Dipenids*. Our first objective was to determine the herbivore rate of newer leaves of plants in the presence/absence of ants and/or spiders. The second objective was to describe predation rates, movement patterns, and spatial arrangements of the ants and the spiders living on the *Pipers*.

Methods

Pipers were located along streams in the forest surrounding the BOSCOA Research Station. The following data were recorded: height of the plant, presence/absence of spider, location of spider-webs, and percentage of herbivore of the 5 youngest leaves.

A subset of seven plants from the original sample were revisited. The number of ants were counted separately for new leaves, mature leaves, and other parts of the plant. A leaf was classified as new if it had a yellow-green color, as opposed to dark green, and it had not yet unfolded.

Behavioral observations involved recording ant and spider locations and activity patterns on seven piper individuals. Data was recorded regularly at 4 minute intervals, for a minimum of 20 minutes. Leaf locations were classified L1=youngest to L10=oldest to include all leaves present on the plant.

Results

Of the 26 plants observed in our survey, 12 contained at least one *Pheidole* ant (Table 1). Other species of ants were very rare, and spiders were found on only six plants. A strong positive correlation existed between height of the *Piper* plants and presence of *Pheidole* ants. Of the 15 plants without ants, only one was taller than 100 cm. *Dipenid* spiders were found both in the presence and the absence of the *Pheidole* ants.

Although low levels of herbivore were evident in all the plants, the highest levels of herbivore were found in plants without *Pheidole* ants.

Within the subsample of the original survey (Table 2), more ants were found on the twelve new leaves than on the 136 mature leaves. Furthermore, an average of 5.67 ants were on each new leaf, compared to 0.45 ants for each mature leaf.

Appendix 1 summarizes behavioral data, which includes 303 ants and 11 spiders observations taken from 7 *Piper* plants. The *Pheidole* ants were found on the youngest and the second youngest leaves (L1 and L2) 66% of the time, whereas the total remaining 8 leaves (L3 to L10) accounted for the remaining 33%. Similarly, L1 and L2 accounted for 64% of all the web locations. Female *Dipenid* spiders built webs at the base of leaves 63% of the time, while 66% of the males built webs on the underside of leaves. These spiders caught only *Pheidole* ants, even though 2 other species of ants were occasionally seen on the *Piper*. Female spiders accounted for 80% of all the *Pheidole* captures.

Discussion

Pheidole ants appear to be providing protection to the *Piper* plants by removing the eggs of herbivorous insects from the plant's leaves, especially the vulnerable young leaves. This was evidenced from the much higher concentration of ants on young leaves than on any other part of the plant. The much higher levels of herbivore in the plants, which lack *Pheidole* ants, further support this hypothesis.

The lack of *Pheidole* ants on more than half of our sample population plants, and the presence of spiders on plants lacking *Pheidole* ants, are somewhat anomalous. The literature suggests that virtually every plant over 20 cm high, with at least two hollow petioles, is occupied by *Pheidole* ants (Risch et al., 1977). The presence of spiders and webs on plants without *Pheidole* ants contradicts Risch's observation that the spider feeds exclusively on *Pheidole* (Risch et al., 1977).

In contrast, the behavioral data supports the hypothesis that *Dipenids* feed primarily on *Pheidole* ants. Although other ant species were occasionally present on the *Piper* plants, during behavioral observations the spiders fed exclusively on the *Pheidole* ants. Furthermore, the larger female spiders, with webs on younger leaves, captured more prey. Since the youngest leaves are the sites of highest *Pheidole* activity, one might anticipate that the spiders would build their webs close to their primary prey.

Finally, the relationship between size and occupancy can be explained by the fact that a larger plant contains more hollow petioles in which the ants can reside. Furthermore, in order for a plant to reach a large size, it would likely require the protection of the ants. As a result, the larger plants would be more likely to have a colony of ants living within them.

Conclusion

The *Piper-Pheidole-Dipenidae* spider relationship is a classic example of the diversity present in the tropics. If either the *Piper* or the *Pheidole* were eliminated, all three species would be driven to extinction. Instead of the traditional mutualistic system of aggressive defense, the *Piper-Pheidole* system is a more subtle, non-aggressive mutualism. *Piper* plants only produce extra-floral food bodies in the presence of ants and discontinue food body production when the ants are removed. This phenomenon provides the best evidence that the plant benefits from ant presence, and is willing to incur a metabolic cost, by producing food bodies to maintain a colony of ants.

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Table 1. General Characteristics of Piper Plants.

ht	loc	Phe	gb	spi	web	pb	ps	lf 1	lf 2	lf 3	lf 4	lf5
200	2	17	0	1	2	1	0	3	2	3	4	3
15	4	20	0	0	0	0	0	4	1	0	0	0
20	4	1	0	0	0	0	0	2	2	2	0	0
15	6	0	0	0	0	0	0	3	5	8	0	0
10	6	0	0	0	0	0	0	4	2	4	1	0
165	2	26	0	0	1	0	1	1	2	2	2	2
130	2	16	0	0	1	0	1	2	3	3	3	2
160	4	29	0	2	3	1	2	2	3	3	4	4
130	4	18	0	0	0	0	0	3	2	2	4	4
30	6	0	0	0	0	0	0	10	3	5	5	0
50	6	0	0	0	0	0	0	2	3	9	9	10
50	6	0	0	0	0	0	0	6	5	5	5	6
120	10	4	0	2	0	0	0	2	1	2	2	2
30	10	0	0	1	1	0	1	2	2	3	3	3
20	10	0	0	1	1	0	1	0	2	2	0	0
40	11	2	0	0	0	0	0	1	2	1	2	3
40	11	0	0	0	0	0	0	4	2	3	3	3
20	11	0	0	0	0	0	0	2	1	4	10	9
30	11	0	0	0	0	0	0	2	2	2	5	0
70	11	0	0	0	0	0	0	2	3	2	2	2
140	5	42	0	0	0	0	0	2	1	3	2	2
40	5	0	0	1	1	1	0	3	2	2	2	2
60	6	31	0	0	0	0	0	1	2	2	3	5
15	7	0	0	0	0	0	0	2	3	2	2	3
125	5	0	0	0	0	0	0	3	2	5	0	0
30	3	0	1	0	0	0	0	2	3	2	2	4

Table 1 Key:

ht: height

loc: location

Phe: Pheidole

gb: gold butt ant

Spi: number of spiders present

Web: Number of spiderwebs

pb: petiole-based location of the web

ps: Petiole-stem location of the web

lf 1 to 5: leaf number. 1 is the first leaf starting from the apex of the plant

Code for classification of herbivore referred to in lf 1-5: 0: non existing leaf, 1: <5%, 2: 5-10%, 3: 10-20%, 4: 20-30%, 5: 30-40%, 6: 40-50%, 7: 50-60%, 8: 60-70%, 9: 70-80%, and 10: >80%.

Table 2. Ant Distribution By Leaf Class.

Time	Ht.	NL (#)	ML (#)	S/P	Ants/NL	Ants/ML
8:24	160	4 (1)	4 (18)	3	4.0	0.22
8:35	165	6 (3)	7 (27)	5	2.0	0.26
8:40	200	7 (2)	10 (33)	15	3.5	0.30
8:55	140	14 (2)	20 (30)	22	7.0	0.67
9:00	130	11 (2)	10 (13)	12	5.5	0.77
9:14	120	12 (1)	3 (7)	7	12.0	0.43
13:54	140	14 (1)	7 (8)	9	14.0	0.88
Total		68 (12)	61 (136)	73	5.67	0.45

Key:

Time= Time of day

Ht.= Plant height (cm)

NL= Ants on new leaves (#)=Number of new leaves

ML= Ants on mature leaves (#)=Number of mature leaves

Appendix 1. Behavioral Observations of *Pheidole* Ants and *Dipenid* Spiders.

Time/ Plant	Leaf (L)	Behavioral Observations
7/26 8:40	5	male spider, base of leaf
Piper#89	1	female spider, underside of leaf 3 chromatogasters on patrol
	4	female spider, base of petiole
8:45	1	3 chromatogasters patrolling spider caught Pheidoli, eating
	1,2,4	L1=8, L2=4, L2=2
9:00	1,4,5	Pheidolis running past all spiders
	1,2,3	L1=6, L2=2, L3=5
9:04	1,2,3	L1=5, L2=3, L3=2
9:08	1,2,3	L1=8, L2=5, L3=3 L4spider caught 2 Pheidolis, tied up
9:12	4	L4spider caught 2 more, far from web (13cm) on stem
	2	ant mimic
	1,2,3	L1=6, l2=6, L3=3
7/26 9:30 Piper#82	2,3	10 gold butts roaming
7/26 9:35 Piper#77	1,2	L1=male spider, underside L2=female spider, basal area
9:40	1	male caught Pheidoli, tied up 10 Ph. roaming
9:45	1	male spider eating ph
	2	guard and 3 workers outside entrance, clustered at petiole and stem
9:50	1	spider gets another ph, tethered guard hanging out at entrance
	2	L2=5
9:55	1	L1=10

Appendix 1 continued.

Time/ Plant	Leaf(L)	Behavioral Observations
7/26 11:30	3	female spider, base of leaf, 1 ph in web
pob#63	1,2	L1=7, L2=5
11:35	1,2	L1=5, L2=3, increased activity at petiole 1 and 3
11:39	3	spider out of web, caught 1ph l1=8, l2=1
11:43	3 1,2,3	spider wrapping ant in web L1=7, L2=2
11:47	1,2	L1=10, L2=1
11:51	3 1	spider eating ant in web L1=9
7/27 14:02#120	1	female spider base of L1, male spider on underside of L1
	2	male at base L2
14:06-14:20		Pheidoli not active, perhaps due to rain
7/27 14:32#119	2	female spider underside of L2, one pheidoli present L1=18, web/no spider petiole 1
	1	female spider at base of leaf, no web present
	3	
14:36	1,2	L1=10, l2=2
14:40	1,2	l1=10, L2=3
14:44	1,2	l1=9, L2=2
14:49	1,2	L1=6, L2=1
14:53	1	L1=5, female on L1 caught/tethered ph
14:57	1	4 ph watching tethered ant struggle
7/27#116	4	female under L4
15:00	3,4,5,6,7,8,9	L3=4, L4=2, L5=6, 4 on stem, clustering at petiole 7, L6=5, L7=10, L8=3, L9=9, jumping spider L1
15:04	7,8,9	L7=7, L8=4, L9=3, jumper on L1
15:10	2,5,7,8,9,11	clustering at base of L4, jumping spider on L1, L2=3,L5=2,L7=7,L8=5,L9=9,L11=1
15:14	2,7,9,2	jumping spider on L1, L2=2,L7=8,L9=9,L10=2
15:18	2,4,5,6,7,8,9,10	L1=2,L4=1,L5=1,L6=3,L7=6,L8=2,L9=3,L10=1 Ants clustering at L1,L7,L9

Guided Field Problem

LEONARD NIMOY'S IN SEARCH OF ... THE ELUSIVE GUANABANA MARKET - STARRING DON, JILL AND CHRIS WITH SPECIAL GUEST APPEARANCE BY UPTON HATCH

Authors: Jill Fischer, Donald Mee, and Christopher Rosin
Faculty: Upton Hatch

Resumen

La viabilidad económica de la producción de la Guanábana en la Península de Osa fue estudiado. La potencial económica y los problemas verdaderos de mercadeo y la cultivación fueron analizados. Fue determinado que la producción de la guanábana podría ser muy lucrativa; sin embargo, los productores de la guanábana están limitados por la disponibilidad de capital y un mercado débil. Problemas en la cultivación de la guanábana surgieron que continuen las dificultades para los agricultores.

Abstract

The economic viability of guanabana production in the Osa Peninsula was studied. Economic potential and actual marketing and cultivation problems were analyzed. It was determined that guanabana production could be very lucrative; however, guanabana producers are limited by capital availability and a weak market. Problems in guanabana cultivation suggest continued difficulties for the farmers.

Introduction

The Osa Peninsula provides an excellent environment for the production of guanabana. Several farmers around Cañaza have exploited the region's soil and climate characteristics to cultivate the fruit tree. The fruit is widely accepted and produces relatively heavily on the trees. However, the farmers have recently united to form Guasosa (Guanabaneros Asociados de Osa) in order to work with the BOSCOSA project. BOSCOSA was expected to provide organized groups farmers with technical and commercialization assistance and to improve the profitability of guanabana production.

The field study attempted to evaluate the actual economic viability of guanabana production. An analysis of guanabana market potential was performed with the assistance of Upton Hatch. Later, the realities of the market are addressed and the marketing limitations examined. Finally, long term impediments related to cultivation practices are discussed. The study allows for conclusions concerning future guanabana production in the region.

The Region

The Cañaza region of the Osa Peninsula is an area of broken hills and flatlands stretching into the coastal plain and Golfo Dulce. The area's soils are principally Franco Arenoso. These present a typically well drained upper layer (approximately 30-40 cm at the site) grading to higher clay content and poorer drainage with depth. They are red soils of slightly acidic nature (pH of 5 - 6). The area experiences high annual rainfall (up to 4,000 mm) with a relatively dry season from November to March. From the viewpoint of guanabana, these characteristics are limited, depending on the ability of roots to enter the more clayey subsoil, the addition of nutrients, and irrigation during the dry season.

The Cañaza farmers are all recent settlers. A number were resettled from national park land with the cooperation of IDA. Some land was purchased outright, as well. The farmers originally attempted cacao, maize, and beans as cash crops. Due to poor markets for the crops, they adopted guanabana and, eventually, plantain and root crops. Maize and bean production have been reduced to consumption crops.

The farmers admit not having previous fruiticulture experience. They began planting guanabana four to five years ago on the basis of a recommendation. Seed was obtained from established plantations with little selection involved. The trees were started in seed beds and planted in the field after six months. Currently, only one of the farmers interviewed maintained a nursery and was actively replacing older trees. The first marketable fruits were harvested three years later. Since the first harvest, the plantations have experienced increasing problems with anthracnose (a fungal disease attacking, and eventually killing, trees and fruit) and declining yields. The farmers are, thus, faced with greater labor and capital demands and reduced market returns.

Guanabana Market Potential

The estimated economic potential for guanabana production is presented in Table 1. (More exact figures were not available from interviews as the farmers were currently reducing inputs due to marketing problems.) Trees were planted at seven meter spacings, resulting in 225 trees per hectare. Each tree was expected to produce approximately 20 fruits with an average weight of four kilograms. The current price for fresh guanabana was 50 Colones per kilogram. Thus, estimated gross receipts were 900,000 Colones per hectare per year. The figure for estimated cost of inputs is the result of a 1991 study and includes the costs of initial investment, pesticide application, labor, and marketing. The study suggested costs for moderate input levels. The figure is estimated to be 400,000 Colones per hectare per year. Thus, the approximate net annual receipts for a hectare guanabana plantation equals 500,000 Colones.

Obstacles to Guanabana Profitability

There are several obstacles preventing guanabana cultivation from becoming a lucrative means of income generation for Guasosa. The fact that the fruit, once ripe, has a two day shelf-life forces the farmer to pick the guanabana well before maturation. Harvesting is further complicated by difficulties in determining the stage of fruit maturation. The transport of guanabana is also problematic. A recent problem faced by the members of the association was the failure of a large shipment of guanabana to ripen. The farmers attributed this to a change in the fruits' sugar concentration induced by the movement between two radically different climates. Irrelevant of the cause, the distributors were disappointed, and thus, no longer accept fresh fruit from the farmers.

With no market for their fresh fruit, the association began to look for other markets. They invested in a truck in which they hoped to transport semi-processed fruit (i.e., peeled, cored and bagged), as well as fruit pulp. Unfortunately, the project was undertaken without first locating a market for the product and large quantities remain in storage in Puerto Jimenez. (The members now recognize the importance of finding a market first, as was the case with the root crops now being grown for export.)

Farmers Reaction to Obstacles

The guanabana farmers would not be able to continue producing the fruit without the support of the association. Not only does the organization allow the farmers to decrease input costs through bulk purchases, but also to market the produce more effectively. The farmers achieve access to BOSCOA services only by means of the association. This access includes technical (such as an INA -- Instituto Nacional de Apredizaje--agronomist) and marketing assistance.

Without the added income expected from guanabana cultivation, these farmers rely on subsistence and cash crops planted in adjacent fields. In one case, a farmer intercropped his plantation with fruit trees and root crops. These crops include maize, beans, rice, yuca, and several tubers such as yams, tequisque, and chamol. With a greater diversity of crops, the farmers are able to decrease their risk, as they are no longer dependent on the success of a few crops.

One farmer has decreased his guanabana acreage by 66% in an attempt to minimize losses. Another farmer chooses to prune diseased or insect ridden branches and occasionally pulls out entire trees. The reasoning behind this approach is that the diseased trees can be cured, but only through constant applications of costly pesticides. Therefore, for the individual with limited cash flow or available time (the new tuber crops also require a good deal of attention), this may be a worthwhile strategy as the unaffected portions of the tree will still produce marketable fruit. Although some production is lost in pruning, capital not invested in inputs is saved -- as is valuable time.

Despite the current less than lucrative market for guanabana, the farmers in the association continued to cultivate the fruit. The members of the association were enticed into guanabana production because of the potentially high economic returns. They have already dedicated five years to its cultivation, as well as the capital invested over that period. Furthermore, the guanabana cultivators enjoy their work. One interviewee shared his interest in pruning--it appeared as if he viewed the act as an art form. Another farmer explained how he communicated with and looked to the trees to tell him how to care for them. Thus, it is the perception of the researchers that the agriculturalists prefer to continue nurturing the trees until they reach a healthy, productive and profitable stage. They do not perceive the trees as entities assessed solely on their economic profitability.

Long Term Cultivation Impediments

Noncommercial guanabana production in Costa Rica is usually a low input undertaking. However, the small commercial guanabana farms we visited appeared to be managed much more intensively than homegarden guanabana trees seen in other parts of the country. The farmers we visited were also applying agrochemicals to their trees regularly. Though, because of the problems they are experiencing with marketing their produce, it is doubtful that they can continue with such an expensive undertaking.

Farmers started their own seedlings in containers in small home nurseries. Previously, no consideration was given to seed selection. Now, they select seed from trees that have good form, have even fruiting, and produce big fruit. A problem still exists with cross-pollination. It is possible that this may be overcome through hand pollination.

About three months after germination, trees are ready for planting. A large hole is dug and backfilled with top soil from the excavation. Fruits are removed during the first couple of years to encourage tree growth.

Shoot bores, ants and sucking insects (aphids and/or mealy bugs) are the major insects that farmers were concerned about. Previously, these pests were treated by spraying the entire tree with insecticides, which unfortunately eradicated all insects detrimental to the tree and its fruit, as well as the pollinators of the guanabana flower. Now, due to the present problems with pollination, the trees are spot treated around the trunk and on branches with maturing fruit. Insecticide is injected into entry sites to control shoot bores. Birds are also a perceived problem. Some farmers are experimenting with insecticide-impregnated bags to protect maturing fruits from bird and insect damage.

Antractnose was the major disease reported by farmers. It infects both branches and fruits. Farmers said they could control this disease with fungicides. However, we seen several infected trees that appeared to be in terminal decline.

Farmers reported using fertilizer every three months. It is applied as a band around the dripline of the trees, either placed in a shallow trench or broadcasted on the surface. They also spoke of using lime in the form of burnt lime, probably to increase the pH. They were aware of the problem of applying lime and fertilizer at the same time, and as a result, would stagger their applications by a couple of weeks. Many farmers expressed the desire to have their soils tested, however, the trees that we saw did not appear to be nutrient deficient.

Clean cultivation is not necessary to control weeds. The majority of farmers cut weeds down around trees prior to pesticide and fertilizer applications. Some herbicides were also used, but not to any great extent.

The trees we saw were heavily pruned. Farmers said that they pruned to increase light and air penetration into the crown of the trees, as well as to make harvesting easier. Though this practice has a sound basis, excessive pruning may be traumatic to the plant and provide numerous sites of entry for diseases and insects. Also, the possibility of transmitting diseases among trees via pruning tools appears high. Farmers were somewhat aware of the importance of disinfecting tools, but were not using this practice.

As stated previously, pollination was a problem, probably due to excessive insecticide use. Farmers were concerned about this problem. On one day, we helped farmers collect beetles from another guanabana plantation to be released on their own farms. Farmers were also interested in learning more about hand pollination.

Overall, the guanabana farms appear in very good condition. The major cultural problems were a vascular disease, probably antractnose, and incomplete pollination. These conditions may be a consequence of the intense care the trees receive. The problem farmers are facing with the market may cause them to decrease the pesticides and labor being put into their orchards, possibly helping to alleviate these cultural problems. The farmers we talked to were still very interested in guanabana culture. They appeared to be receptive to suggestions, and were actively seeking more information concerning this crop. Specific areas that may be of benefit to them are hand pollination and sanitation.

Table 1. Economic Potential of Guanabana.

Trees/hectare	225
Fruit/tree/year	20
Average Weight of Fruit (kg)	4
Price Received (colones/kg)	50
Gross Receipts (colones/ha/yr)	900,000
Estimated Input Costs (colones/ha/yr)	400,000**
Net Receipts (colones/ha/yr)	500,000

* Source: INA Representative Victor Julio, Agronomist.

** Input cost figure from 1991 study and does not include inflation.

Guided Field Problem

WHERE ARE THE TRAIL MARKERS?

Authors: Amelia Oliver, Elizabeth Marshall, and Pamela Stedman

Resource Persons: Gabriela Soto and Aracelly Gomez

Resumen

El propuesto proyecto de ecoturismo de ADESCAB fue investigado. Se ofrecen sugerencias acerca de los senderos, servicios turisticos, potenciales economicos e impactos medio ambientales.

Abstract

The proposed ecotourism project of ADESCAB was explored. Suggestions are offered regarding trails, tourist facilities, economic potentials, and environmental impacts.

Introduction

The Osa peninsula is one of Costa Rica's most biologically diverse areas, containing much of its original natural forest. Nevertheless, the forests of Corcovado National Park and the surrounding buffer zone face continuous pressure from loggers, farmers, and gold-miners. The Fundacion Neotropica established its BOSCOA program in the area to encourage sustainable development efforts in the buffer zone.

The Asociacion de Desarrollo Sostenable y Conservacion de la Cuenca de Agua Buena (ADESCAB), a local cooperative, was established in 1992 as part of the BOSCOA initiative to promote forest conservation through local development programs that increase the value of standing forests. The total landholding of ADESCAB members is comprised of approximately 500 ha of primary forest as well as additional land in agriculture and pasture use.

ADESCAB's development strategy focuses on financial incentives derived from ecotourism. The association has proposed five projects: a 12-bed albergue, a trail network, financial incentives to maintain standing trees, a youth naturalist program, and a women's artisan cooperative using non-timber forest products. Uso de Bosque is the committee within ADESCAB of local finqueros who are combining efforts to create a network of trails throughout their properties. The association has discussed a tariff system for the use of the trails and for the guide service they plan to provide. With this study, we tried to place ourselves in the role of the tourists that would be visiting Agua Buena and to offer opinions and suggestions on the ecotourism development plans.

Methodology

Four of the potential trails of the Uso del Bosque project were examined. These trails included a variety of terrains: two climbing a mountain, one through the goldmine area, and one to a waterfall; traversing both primary forest and cultivated areas. Recommendations for the project were based on walking the trails, reviewing documented project plans and proposals, and informal interviews. Those interviewed included BOSCOA's social worker and liaison with ADESCAB, an environmental education agent, and a finquero who is presently constructing trails and is an active member of Uso de Bosque.

Recommendations

Our observations suggest that, given the rugged condition of the trails and the proposed lodging, the target audience should be hearty, adventurous travelers. Marketing and management decisions should be specific to this target audience.

It is also imperative that the cooperation and coordination between the farmers of the association be carefully maintained. The trail system and its associated services should be available to tourists as a package, rather than as fragmented enterprises. The albergue must serve as the center of coordination and communication. Careful arrangements are also necessary to guarantee the upkeep of the trails. Further recommendations are divided into six categories: trails; directional/educational materials; guides and other services; tariffs and fees; the albergue; and marketing possibilities.

Trails

--Trail-makers should concentrate on more leisurely, less severe ascents up the mountain, making liberal use of switchbacks. Such trails would serve the climbers, while protecting the soil and flora from excessive erosion. In addition, trails must be stabilized or graded.

--The trails must also be clearly but unobtrusively marked. Paint stripes on the tree would clearly mark the trails without harming the environment. Small signs should indicate trail heads and important turnoffs.

--Perhaps most important for the long-term sustainability of the project is the establishment of a dependable system of monitoring and maintenance for the trails. Trails that are overused or eroded must be quickly identified and steps taken to close or stabilize them.

--Trails should not be established in or near streams that are an important water source for local residents.

Directional/Educational Materials

--It is important that users of the trail network be able to obtain information regarding the diverse species found along the trails. Rather than labeling trees along the trails, which may detract from the natural beauty, perhaps a small arboretum or introductory trail clearly identifying relevant species would be a viable alternative.

--Maps should be available of the entire trail system, indicating the distance, time, and level of difficulty of the trails, as well as highlighting points of interest. Other written materials of interest could be information regarding tree identification, history of the area, or land-use practices.

Guides and Other Services

--Guides need a fairly detailed knowledge of the natural history of the area. With maps and marked trails, guides must do more than show the way. Local finqueros should be provided natural history training. In the meantime, finqueros should take advantage of the information they already have, including uses of forest species and on common forest habitants, such as the leaf-cutter ants.

--ADESCAB should consider offering tours of local agricultural sites and other land-use areas.

--The women's association should consider offering craft lessons for the products they make.

Tariffs and Fees

--Entrance fees are currently 200 colones for foreigners and 100 colones for Ticos. We recommend that the fee for foreigners be raised to 300 colones, but be waived for tourists who hire a guide.

--The fee for horse rental is set at 250 colones/hour, but it could easily be raised to 500 colones/hour. Trails used by horses must be carefully monitored because horses can cause much damage.

--Guides are currently available on a daily basis. In order to accommodate tourists with either a more limited schedule or budget, guides should also be available for a half-day tour.

--Fees could also be charged for the additional informational pamphlets in order to cover costs of printing and paper.

Albergue

--The albergue should serve as the center of coordination for ADESCAB's activities. The availability of guides and other services should be well advertised on an activity board. The albergue should also distribute trail maps, provide information on poisonous snakes and other hazards in the area, and have a check-in/check-out sheet to keep track of hikers.

--For the convenience of guests, the albergue should offer filtered water, bag lunches, and laundry services.

--The albergue should consider establishing a camping area with bathroom facilities for very low-budget travellers.

Marketing

--ADESCAB should notify travel guides that specifically cater to adventurous travelers, such as the Lonely Planet and Ulysses Press, about their facility. The addresses for those guides are:

The Lonely Planet
P.O. Box 2001A
Berkeley, CA 94702 USA

and

Ulysses Press (The New Key to Costa Rica)
3286 Adeline Street, Suite 1
Berkeley, CA 94703 USA

Conclusions

ADESCAB has two objectives for its development program. The first is to promote conservation of the forest resources by offering viable economic alternatives to destructive forest practices. The second is to improve the quality of life of its members and allow them to benefit from the unique natural resources found on their land. The ecotourism aspect of ADESCAB's program has the potential to contribute to both these goals. There are plenty of attractions on the trail system and in the surrounding area to support a small tourist trade. The 12-bed capacity of the albergue should limit the tourist traffic to a manageable level.

The project's most significant potential problem is the extent of its environmental impact. Finqueros are already beginning trail-making without reliable guidelines and specifications regarding trail designs that minimize erosion. Although a certain amount of

rigor is desirable in some trails to challenge adventurous hikers, it is also important to consider how such trails affect an area's vulnerability to erosion. With an effective program of monitoring and maintenance, such environmental impacts could be detected and minimized through an on-going process of trail adjustment, closure, and grading. Such efforts will be crucial to the long-term viability of this project.

Independent Group Field Problem

AN EXAMINATION OF REGENERATION IN SITES OF VARYING DISTURBANCE HISTORY IN THE CORCOVADO BUFFER ZONE

Authors: Norm Bourg, Bruce Ferguson, Jagdish Krishnaswamy, and Nick Shorr
Group Members: Bruce Ferguson, Jagdish Krishnaswamy, Alexander Njue, and Nick Shorr

Resumen

Para estudiar regeneración de árboles bajo regímenes de perturbación, examinamos composición de especies de vástagos y estructura de comunidad en cinco sitios en la zona protectora de Corcovado. Dos de estos sitios han sido cortados selectivamente, uno ha sido un camino de cortar, y dos fueron pastos abandonados. Regeneración en estos sitios fueron comparados usando indicadores tal como dominancia relativa, densidad y diversidad de vástagos, y grado de similaridad al sitio mas parecido a bosque primario. Además, encuestamos especies de árboles en un pasto activo para evaluar el efecto de este uso de tierra intensivo continuando. Explicaciones de diferencias entre los sitios fueron buscados en sus historias de perturbación y sus relaciones al bosque circundante.

Abstract

To study tree regeneration under varying disturbance regimes we examined sapling species composition and community structure in five sites in the Corcovado National Park buffer zone. Two of these sites had been selectively logged, one had been a logging trail, and two were abandoned pasture. Regeneration in these sites was compared using indicators such as relative dominance, sapling density and diversity, and degree of similarity to the site most primary in nature. Additionally, we surveyed tree species in an active pasture to evaluate the effect of this ongoing intensive land use. Explanations of differences between the sites were sought in their disturbance histories and relation to surrounding forest.

Introduction

In continuation of our investigation of successional patterns following disturbances of varying intensity and duration (see La Selva section), this study examines several sites in the buffer zone surrounding Corcovado National Park. Our six study sites, all near the BOSCOSA station, are described below.

A. This (almost) primary forest was high-graded about thirty years by Osa Forestal and has been basically left alone since then. The site is on a slope near a ridge top. BOSCOSA's para-foresters have a permanent study plot here.

B. This was a tractor trail through forest cleared and used about two years ago by an associate of the Agromuebles furniture co-operative to remove logs from his land. It is also on a slope.

C. This sloping forest tract was logged two years using a conservative method: 35% of the total volume of commercial trees greater than 60 cm diameter at breast height (dbh) is removed from a small area each year.

D. This steeply sloping site was cleared, used as pasture for six years and has been abandoned for three.

E. This flat, bottomland area was cleared about five years ago, perhaps grazed, and was left three years ago to regeneration. Cattle trails still cut through the patch.

F. This is a 5 ha. section of active pasture, including a small patch of forest cover left along a stream-side for shade. This is part of a 27.5 ha. active bottomland pasture that supports 50 head of cattle. The land belongs to Johnny, one of BOSCOA's para-foresters.

We sought to compare regeneration at these sites by censuring tree and sapling populations.

Methods

In each of the sites A, C, D and E we laid out a 10 x 10 m study plot out, while in the narrow tractor trail site we chose a 20 x 5 m plot. We censured and measured dbh of sapling and tree growth in these plots, defining a sapling as a plant that grows into a tree as an adult and that was at least one meter in height and less than 10 cm dbh. We identified A tree as any individual greater than 10 cm dbh. Johnny was able to identify the majority of these individuals by common name in the field. We also made note of the presence of non-woody species such as *Heliconia* where they contributed significantly to the flora of our plots. We made a visual estimate of percentage ground cover (herbaceous and otherwise) in addition to an estimate of percentage canopy or crown cover, both of these being horizontal ground projections of the respective cover types.

Site A, the site closest to primary forest in appearance and disturbance history, was chosen as a baseline to which we compared the other sites. Relative dominance (RD), Similarity Index (SI), number of species and sapling density were calculated for each of these sites.

For our calculation of RD we used dbh as a proxy for basal area. The aggregate dbh for each species was calculated, as was the total dbh for each plot. According to our definition, $RD = \text{Total dbh for a species} / \text{Total dbh for the plot}$. A list of species comprising 66% of the total DBH at each site was compiled in order of RD.

We chose the Jacquard Similarity Index as a convenient comparison of species composition between sites B-E and that of site A. This can be viewed as a measure of degree of disturbance. $SI = C / (A + B + C)$, where C = number of species common to site A and B, B = number of species exclusive to site A and A = number of species exclusive to site B.

Sapling density was simply total number of saplings/area.

Results and Discussion

Table 1 presents our results in summary form. As expected, percentage canopy cover decreases from 'selectively cut 30 years ago' (A), through intermediate land-uses and regeneration times, to 'completely cleared 3 years ago' (E). Though herbaceous cover in most cases varies inversely with canopy cover, the tall growth of non-arboreal species (especially *Heliconia*, *Piper* and canes) is an important factor not included in our data affecting both herbaceous cover and regeneration in sites B, C and especially E. Our primary forest site (A), as expected, has the highest percent canopy cover, the highest total number of species and the greatest number of species contributing to 66% of total dbh (i.e., most even species distribution). Moreover, it has a high total sapling dbh and an intermediate sapling density relative to the other sites, indicating healthy regeneration. However, none of the six tree species mentioned by our BOSCOA guides, as most commonly logged thirty years ago, were present as either canopy trees or saplings on the site.

Site B, the logging tractor trail, has by far both the highest total sapling dbh and sapling density. Competition appears to be intense between saplings between 1 and 2.5 m. in height in this narrow light gap surrounded by tall forest. Its total number of sapling species was relatively high, perhaps because it is in an early successional stage. *Apeiba*, a mammal-dispersed pioneer species, dominates strongly, followed by *Lueha seemani* (Guacimo Blanco), a light-gap colonizer. Although it was cleared and compacted two years ago, regeneration in site B is vigorous and fairly diverse.

Site C, selectively logged two years ago, had the second highest canopy cover and was the most similar in species composition to the primary forest site. However, considering the conservative logging regime, we were surprised at the difference in canopy cover. It seems likely that fairly extensive canopy damage was done during harvesting. Though 34.3% may seem a small species overlap with Site A, this may be partially due to the overall tree diversity in the forest itself. A similarity index between our primary site and another of equivalent use-history would have indicated the extent of such background dissimilarity. Another puzzling result was the difference in total sapling dbh and sapling density between this and our primary forest site (about one-half in each case) even though the canopy is more open. One possible explanation is that tall non-arboreal cover is higher in the more recently harvested site; another is that saplings are emerging slowly and have not yet reached our one-meter threshold. Though total sapling

species is only slightly lower than in site A, the evenness is considerably less. *Socratea*, a light-gap palm, dominated the saplings (Table 2). This supports the notion that there was considerable disturbance in this patch of 'selective harvesting'. However, the third most dominant sapling species, *Carapa guiniensis*, is considered a valuable timber crop.

Site D has no species overlap with the primary forest site. It has a fairly high sapling density with by far the lowest total sapling dbh, indicating many very young thin saplings. It has the fewest sapling species and the least evenness of any site. Laurel (*Cordia alliodora*), a species requiring well-drained, relatively fertile soil, strongly dominates. A Laurel plantation stands a few hundred meters away and it is likely that the small wind-dispersed seeds colonized from there. Only three species made up the surrounding canopy: laurel, eucalypto and cedro amargo. Eucalypto is an exotic that is frequently found in nearby plantations. Though ground cover appears adequate to prevent serious erosion and a number of commercial species are regenerating, this steep sloping site, logged and then grazed for six years, is biologically depauperate after three years of natural regeneration.

Site E, the largest completely cleared patch of any site, had the lowest sapling density and an intermediate total sapling dbh. Its tall, thick *Heliconia* and cane cover may have shaded out arboreal seedlings. Site E has ten times the total sapling dbh and one quarter the sapling density of site D: tall sapling growth, *Heliconia* and cane dominate. No canopy and less than 5% herbaceous cover were present. The classic pioneer species, *Inga* and *Cecropia*, dominate in the tree class, but three next most important species were adequate to good timber trees. Though depauperate in total species, this was one of the most even of all sites in terms of species composition. After site D, E showed the least similarity with our primary forest site.

Site F, the active pasture had an impressive sixteen species of mature trees. It is likely that the dominance of the two Guacimo species along with *Cedrela mexicana* is a result of farmer selection. Johnny explained that guacimo leaves are good fodder and *Cedrela* is a commercially valuable timber tree. As a para-forester, it is likely that he recognizes a useful and unusually large number of tree species and has tolerated and/or fostered regeneration more than his neighbors have. However, the absence of saplings suggests that Johnny's current management strategy is limiting new ingrowth.

Conclusions

Our results clearly show that conservative selective logging yields a forest species composition that has significant overlap with less-disturbed forest but reduced diversity. The absence of any overlap in species composition between the sapling stage and canopy cover in this plot was not surprising since seed predation and seedling mortality near the mother tree is likely to be high. Seeds that are dispersed farther from their mother tree may have a higher probability of survival. Site B exhibits a pattern of regeneration that is fairly consistent with intense, short-lived disturbance: a high density of similar-sized

saplings. Land that has been cleared and used as pasture for a number of years requires much more time to recover its species diversity and has little or no similarity to mature forest. Finally, regeneration in active agricultural areas such as pasture is heavily influenced by management practices, and is likely to have a species composition much different than primary forest.

Table 1. Statistical Summary Comparing Tree Species Cover in Sites With Different Disturbance Histories.

Site	Sapling density	% Canopy cover	% Ground/Herbaceous cover	Similarity to A (S.I.)	Total # of sap. sp.	# of sp. comprising 66% of dbh
A	0.615	90	5	100	29	7
B	3.04	5	75	17.1	26	2
C	0.33	50	30	34.3	21	3
D	0.80	45	85	0	5	2
E	0.19	0	5	2.9	6	3

Table 2. Species Comprising 66% of Total dbh and Their Relative Dominance in Plots of Various Disturbance Histories.

Site A	Site B	Site C	Site D	Site E
Copalillo 28.4%	Apeiba 51%	Socratea 42%	Laurel 56%	Inga 30.5%
Fruta 10.8%	Guacimo blanco 21%	Fruta dorada 16.3%	Gallinazo 17.3%	Cecropia 18.4%
Socratea 7.1%	Baco 7.7%	Carapa 8.2%		Jobo 18%
Inga 5.2%				
Lagartillo 4.8%				
Ojochillo 4.4%				
Plomillo 4.2%				

Independent Field Problem

EFFECTS OF SEVERE FOREST DISTURBANCE ON MYCORRHIZAL SPORE DIVERSITY

Author: Chris Picone, Department of Biology, University of Michigan

Resumen

Como los bosques diversos se convierten hacia pastos y plantaciones, propongo que la diversidad de hongos micorrizales también se baja. Espores fueron contados de muestras de suelo de bosque primario, pasto, y una plantación de pína. El bosque tenía 14 especies de hongos, 5 de ellos que no habían en el pasto. Al contrario, el pasto tenía solamente 9 especies, 8 de ellos que estaban más o menos iguales en cantidad en bosque, mientras que un especie abundante casi no existía en bosque. Falta de especies fungales de bosque puede limitar la restauración de pastos degradados. Finalmente, no esperábamos la gran diversidad inexplicable de espores en la plantación monocultural de pína.

Abstract

As diverse forests are converted to pastures and plantations, I predict that diversity of mycorrhizal fungi also decreases. Fungal spores were counted from soil samples from primary forest and pasture in Nicaragua, and a pineapple plantation in Costa Rica. The forest had 14 species of fungi, 5 of which were not present in the pasture. In contrast, the pasture had only 9 species, 8 of which were equally common in forest, while one abundant species was virtually nonexistent in forest. Lack of forest fungal species might limit the restoration of degraded pastures. Finally, spore diversity was surprisingly and inexplicably high in the monocultural pineapple plantation.

Introduction

How is the mycorrhizal fungal population in the soil affected by the transformation of diverse primary rainforest into low-diversity plant communities? In the tropics, the predominant type of mycorrhizal fungi (AMF) are dependent on their host plant species for survival. As forests are converted to pasture and monocultural crops, the reduction in plant diversity may result in the disappearance of certain fungal species. On the other hand, a few lingering mycorrhizal plants may be sufficient to maintain fungal species diversity at levels found in the forest. In addition, spore dispersal by ants and rodents may continue to reinoculate disturbed sites.

In this study, I compared fungal spore diversity between primary forest and adjacent degraded pasture. In particular, I chose pasture sites where sedges are abundant. I predicted that sedges, as non-mycorrhizal plants, would most likely invade an area where fungal inoculum is decreased, or at least where patches of low inoculum might give them

an advantage over mycotrophic species. In addition, I sampled soil in a pineapple plantation, though the site was in a different ecosystem.

Study Site

For the pasture-forest comparison, the area sampled is located in lowland rainforest near the Atlantic coast of Nicaragua, 23 km northwest of Bluefields. The degraded pasture was cleared around 1955 on ultisol clay soils, and now supports only 20 cows on 300 ha. Areas chosen for soil spore samples had not been grazed in years. Inedible grasses and sedges dominated the sample area, in addition to melastomes, mints, and other pasture weeds. The pineapple plantation, found near Buenos Aires on the Pacific side of Costa Rica, also sits on old ultisol soils. Pineapple monopolized the site, except for rare individuals of grass (< 1/m squared).

Methods

In both pasture and forest, five 500 ml soil samples were collected and examined for spores. After taking my first sample, I took two more 30 cm away, another 3 m away, and a fifth 30 m from the first. In the pineapple plantation, I took only two samples, spaced 3 m apart. All samples were sieved and centrifuged by a method described previously (Picone, this Volume). Spores were counted in a petri dish over a 0.5 x 0.5 cm grid. I used a hand-held clicker for smaller, more numerous spores on an area between 30 - 70% of each sample, since small spores were too numerous to count completely. All medium to larger spores (> 150 microns) were counted individually over 100% of the petri plate.

Results and Discussion

As seen in Table 1, spore numbers in pasture far outnumber those in the forest, but fungal diversity seems higher in the forest, as expected. The overwhelming numbers of what may be *Glomus geosporum* are not very meaningful. Most are probably inviable relics, since *Glomus* spore walls degrade very slowly after the spores are dead (Invam, 1993). This *Glomus* is common to both areas sampled. The high numbers in pasture may result from drier soil conditions, which causes death of the fine roots and leads to sporulation by the fungus (Janos, in press). Though I sampled in the rainy season, most of these spores or spore relics may have persisted since their production in the dry season.

Other common species show no difference in numbers between pasture and forest. Both *Glomus* "spiny," a new species, and what may be *Acaulospora foveata*, are larger, easily recognized spores that appear in patches in both site conditions. A soil sample void of these species might lie only 30 cm from a sample loaded with over 100 of these spores. This supports the "swiss cheese" model of Janos (in press), in that mycorrhizal inoculum exists in patches rather than a continuous sea. Such patches may force

mycorrhizal plants to evolve widely spreading root systems at germination to insure contact with sufficient fungal species.

For other species, these data demonstrate some evidence of site specialization by the fungi. For example, a golden *Acaulospora* sp. seems to do well only after disturbance, since it is extremely common in pasture but only found once in the forest, and that was a deteriorated single spore. Perhaps this species has specialized for pasture conditions, determined by host plants, soil hydrology, and/or temperature.

I believe the most significant result of this study is the apparent site specialization of the 5 fungal species that never appear in the pasture. These forest species occur only rarely, perhaps due to associations with plants that are themselves rare, as is typical in the tropics. Or perhaps these are ubiquitous species that sporulate only in the forest. In the future, studies of soil inoculum potential will determine: 1.) if these fungi have really disappeared from the pasture; and 2.) if they are fungal species critical to the success of particular mycotrophic plants. Perhaps lack of certain fungi in old pastures may limit the regeneration of late-successional plants, or prevent the growth of economically important lumber and fruit plants.

Finally, to my surprise the pineapple plantation had spore diversity comparable to that in the study sites above. At least 5 - 7 species of fungi were found in each of the two samples, though number of spores were relatively low (< 200/species). I had predicted that pineapple, a non-mycorrhizal plant (Janos, 1987) that is grown with foliar fertilizers, should sit in soil virtually devoid of any mycorrhizal fungi. Future studies should investigate the mechanisms by which inoculum is maintained in such a site of extremely reduced plant diversity.

Acknowledgements

I wish to thank course coordinators Upton Hatch, Carlos Valerio, and Gabriela de Soto, for permitting me to conduct my independent study in Nicaragua. This paper presents the preliminary results from a larger study supported by a Block Grant of the University of Michigan.

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Table 1. Fungal Species Found in Pasture and Forest Soil Samples.

Sample Distance	Fungal Species	Spore # Pasture	Spore # Forest
0 m	Glomus geosporum	10,310	2,036
	Acaulospora gold	970	1
	Acaulospora grey	10	---
	Glomus occultum	5	15
	Glomus spiny	---	2
	Acaulospora foveata	---	2-3
0.3 m	Gl. geosporum	23,040	2,080
	Acaulospora gold	2,839	---
	Glomus occultum	10	5
	Glomus spiny	18	---
	A. foveata	16	2
	Acaulospora grey	1	---
0.3 m	Gl. geosporum	14,525	971
	Acaulospora gold	760	---
	Glomus spiny	90	54
	A. foveata	63	1
	Unk. glass-white	1	1
	Unk. plate-wall	---	4
3 m	Gl. geosporum	6,830	1,438
	Acaulospora gold	857	---
	Glomus spiny	18	58
	A. foveata	1	2
	Glomus occultum	---	6
	Scutellospora sp.	---	1
	Unknown hexagon	---	1
30 m	Gl. geosporum	6,304	1,948
	Acaulospora gold	798	---
	Glomus spiny	16	1
	A. foveata	2	---
	Unknown ridged	1	14
	Acaulospora grey	---	8
	Glomus occultum	---	1 ⁺
	Scutellospora sp.	---	1
	Unknown halo	---	1
	Acaulospora pin	---	1
	Unknown beady	---	---
Total # Species		9	14

LAS CRUCES
COSTA RICA

Guided Field Problem

PARTICIPATORY RURAL EVALUATION

Group Members: Liz Marshall, Pamela Stedman, Bruce Ferguson, and Chris Rosin
Faculty: Hernan Villalobos

Abstract

The general process of Participatory Rural Evaluation is reviewed, along with a specific application in the town of El Ceibo.

Objectives

To understand the process of Participatory Rural Evaluation (PRE) and consider some examples of its use in local communities.

Sources

Hernan Villalobos, OTS staff;
Mark Malaspina, Peace Corps Volunteer;
Manual de Evaluacion Rural Participativa: Traducccion en Borrador de
"Participatory Rural Appraisal handbook: Conducting PREs in Kenya," Edited by
WRI.

Description of Participatory Rural Evaluation

The PRE process developed by the World Resources Institute (WRI) was first used in rural communities in Africa, and more recently in Latin America. The process is designed to help these communities and development agencies to define and evaluate local natural resource problems and propose solutions in which the communities can participate.

The purposes of PRE are defined by WRI as being:

1. to help communities define problems, prioritized activities, and adopt community resource management plans through mobilization of local human resources
2. to rejuvenate the natural resource base with appropriate policies and actions
3. to focus attention of rural communities on natural resources, particularly vulnerable or fragile ecosystems
4. to integrate all sectors relevant to rural development, focusing them in particular on natural resources

5. to integrate technical and socio-economic themes into the definition of problems and solutions
6. to systematize participation of local communities, governments and NGOs to slow and reverse the loss of soil productivity and quality of life, without losing flexibility

The philosophy behind PRE stresses bottom-up decision-making, on the grounds that:

1. truly sustainable development must involve activities that local communities can manage and control
2. popular participation is fundamental for project planning
3. local technology and projects are fundamental for reversing environmental deterioration

Although the PRE process is flexible and should be adapted to suit each community, the following nine steps are generally applicable:

1. partial formation of a PRE team (comprised of a general coordinator, representatives of relevant development organizations, and technical extensionists)
2. selection of a site and introduction to local leaders
3. preliminary site visit, including a community meeting for open discussion of the process
4. collection of facts: focus on topography, drainage, vegetation, ecological zones, patterns and methods of production, cultivation practices and natural resource management efforts, population changes, commercialization, infrastructure, and general problems and opportunities. All of this information should be collected into easily read graphics, maps, tables and simple reports, as follows:
 - a) spatial: maps (to diagram topography, soil, vegetation, availability of water, etc.), transects (to capture the largest diversity of ecosystems, land uses, etc.), and parcel diagrams (to show how individual land-owners manage their land)
 - b) temporal: chronology (to better understand events that the local communities consider important and how they have influenced natural resource management in the past); trends (to learn how the community view and prioritized changes over time, such as erosion and land use); seasonal

calendars (to compare the activities of the population, month by month, in the different sectors and identify the division of labor, the division of activity over the year, etc.)

- c) social: interviews with community members (to get socioeconomic information with a focus on the management of resources and perceptions of problems and opportunities related to development and quality of life. A wide variety of families should be interviewed. Institutional diagrams developed in a community meeting (to order the relevant institutions according to contributions to community development)
 - d) technical: gather technical information on more obvious community problems before group discussion and prioritization in order to facilitate those discussions and solutions
- 5. synthesis and analysis of facts: compile the available information into a form that can be used in community discussion; identify and analyze themes
 - 6. identification of problems and opportunities
 - 7. prioritization of problems and opportunities based on locally accepted criteria
 - 8. adoption and implementation of a master plan: identify necessary actions and responsible parties and time estimates
 - 9. evaluation and monitoring: conducted by leaders of the community

Potential Problems

A number of potential problems exist in the PRE process. These include:

- 1. loss of interest among PRE team or community participants, especially during long-term studies
- 2. centralization of participation among "representatives" who may not have close communication with other members of the community
- 3. lack of interest among development institutions that do not see how it is in their interest to participate or who feel that the process circumvents established prioritization procedures.
- 4. neglect of problems that, for whatever reasons, were excluded from the master plan
- 5. reliance on external influence and aid rather than community empowerment and mobilization

PRE in El Ceibo and Other Local Communities

In order to assess the needs of local communities, OTS sponsored a program of Participatory Rural Appraisal in the Coto Brus canton of Costa Rica. The project involved four two-week community investigations conducted as an OTS course activity and a more extensive year-long project in El Ceibo. In El Ceibo, Costa Rican extensionists were invited to participate under the leadership of two OTS employees. One of them, Hernan Villalobos, provided his perceptions of the project.

Villalobos stressed the participatory aspects of the PRE project. Nine community members, each from a different committee, were elected by peers to assist the original twelve extension agents with their community evaluation. The evaluation used eight "tools" (such as transects and community calendars) which involved all of the extensionists, the nine elected leaders, and up to forty community members. The community also voted to permit the project to take place.

The project began with group interviews to establish the study area boundaries and to discuss community needs and problems. Four groups (youth, women, and two groups of men) assessed the community's use of the natural resources, especially in regard to agriculture and basic needs. All four groups presented a similar list of problems. These lists were correlated with several other tools. First, a number of households were selected and farm studies undertaken. These studies concentrated on land use: its potential, its impacts, and farmer decision-making; diagrams and descriptions were completed. Next, transects through the community were described. Each transect passed through farmland for approximately one kilometer. Again, land use was emphasized and critical areas, such as springs and waterways, were identified. A cross-section diagram of the twenty-meter mark was drawn. Finally, several households (chosen to represent various social sectors) were chosen for intensive household interviews. The interviews were conducted with both male and female informants and concentrated more specifically on the needs of the household rather than on those of the community.

Following the evaluation of community needs, an assessment of problems and a community synthesis was reached which provides the basis for a PRE master plan.

Guided Field Problem

INVESTIGATING A PLANT - INSECT - FUNGUS RELATIONSHIP: THE *CUPHEA* - BLUE BEETLE - LABOULBENIALES CONNECTION

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Group Members: Chris Picone, Norm Bourg, Laura Howard, Ellen Pedersen, Keith Taulbee, and Ceal Smith

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Resumen

Se estudio un coleoptero de la subfamilia Alticinae. Los aspectos observados fueron infeccion con hongos, tamanno de la poblacion y movimientos entre colonias y atraccion a fermonas y extractos de plantas. El 80% de la muestra estaba infectada con hongos en el exoesqueleto. El grado de infeccion no estaba relacionado con la densidad de la poblacion. No se observo movimiento de los coleopteros entre colonias. El tamano de los territorios eran variables, asi como la distancia entre los mismos. Los experimentos con feromonas y extractos de plantas no dieron resultados significativos en cuanto a la determinacion de las causas del aglomeramiento (reproduccion o alimentacion).

Abstract

A beetle from the subfamily Alticinae was studied regarding fungal infection, population sizes and movements, and attraction to pheromone and food extracts. Eighty percent of the sampled beetles had fungal infection on their exoskeleton. The infection rate was not related to population density. No movement of beetles between colonies was observed during the study. Territory sizes were variable, as well as the distance between colonies. Experiments using food extracts and pheromone intended to determine the causes of the formation of colonies (food or reproduction) failed to show significant results.

Introduction

This study began from observing colonies of a species of blue beetle (Family Chrysomelidae, Subfamily Alticinae) clumped on vegetation in a pasture near the Gamboa Marsh above the Las Cruces Biological Station. Dr. L. D. Gomez, the station director, indicated that this unidentified beetle species can be a crop pest and is sometimes infected with a parasitic fungus. However, this beetle has also been known to feed on *Cuphea* sp., a weed often found in agricultural fields. It is thus somewhat of an open question whether to consider the beetle a crop pest or a potential biological control agent for *Cuphea* sp. In addition, the fungus could also serve as a control agent for the beetle.

The main objectives of this study were: 1.) to conduct an initial natural history study of the fungus/beetle relationship, and 2.) collect initial data on beetle population ecology and determine whether the beetles were aggregating for mating or food needs.

Methods - Fungal Study

We examined about 20 beetles from each of the five populations, for a total of 108 beetles. In addition to determining whether each was infected, the number of infection sites were counted for extent of infection.

Methods - Laboratory Pheromone/Plant Extract Study

A sample of 20 beetles were collected from each of the five populations. These beetles were used for a laboratory chemical assay. An additional 5 beetles from each population were collected for use in the pheromone extract.

Cuphea plants were collected from the study site. Plants were homogenized in a blender with approximately 500 ml water. A concentrate was made by boiling 50 ml of the homogenate until the volume was reduced to approximately 25 ml. The remaining blenderized plant extract was separated into the more aqueous layer (aqueous) and the layer with more plant material (pm). The pheromone extract was made by crushing 25 beetle abdomens in a mortar and pestle with approximately 10 ml of mineral oil. The control was made using green and brown food coloring mixed with water.

The laboratory chemical assay was run using the following five trials: 3 plant extracts (concentrate, aqueous, and pm), the pheromone extract, and a control. Six drops of each extract was used to saturate a piece of filter paper (5 cm triangles). A triangle of each mixture was placed equidistant from the others in a plastic bucket or an aluminum tray. A sample of 20 beetles from each population was released into the center of each container which was then covered with a thin mesh. Beetle movements were monitored every 5 minutes for the first hour, then every 20 minutes thereafter. The experiment was run overnight for a total of 16 hours.

Methods - Mark-Recapture and Field Pheromone/Plant Extract Study

Colonies were plotted on a map with the use of a compass to judge direction and a tape measure to determine the distance between colonies.

The size of the colonies was determined by measuring the perimeter of each colony. For purposes of this study, the colonies were assumed to have a rectangular shape.

Population density of each colony was measured by counting the number of beetles within a colony, and dividing that number by the area of the colony, for an estimate of

beetles per colony. The beetles were counted on both days of the study, and the density was calculated for both days.

On the first day of the study, 5% of each beetle population was given a mark unique to its colony and released within the same colony. On the following day, 10% of each colony, based on figures from the first day, was recaptured and the number of marked beetles, along with the colony from which they came, was noted.

Ten pieces of filter paper each were saturated with the three plant extracts and the pheromone extract. In the field, two samples of each extract were placed within each colony, one in the center and one on the colony's perimeter. These pieces of filter paper were mounted on 20 - 25 cm sticks. An untreated piece of filter paper was mounted in the center of each colony as a control. Each colony was observed three times for three minute periods, to see whether or not the beetles were attracted to any of the extracts.

Results - Fungal Study

Of the 108 beetles examined, approximately 80% were visibly infected by the fungus (Figure 1). Percent of infected individuals did not correlate with population size or density (Table 1). Though many beetles had only a few fruiting bodies (ascocarps), most had over fifteen protruding from the insect exoskeleton, and thirteen individuals had over 50 ascocarps. Overall, fungi were not restricted to a particular infection site; they emerged from the back, antennae, legs, head, and ventral surface. However, in some individuals the back was predominantly infected, while in others primarily the legs and ventral surface were covered. This may result from the mounting behavior at mating, which could allow transfer of spores between the ventral surface of the male and the dorsal surface of the female (Gomez, pers. comm.).

Results - Laboratory Pheromone/Plant Extract Study

The chemical assay failed to produce meaningful results. Over the course of the assay, the beetles showed no preference for the plant material extracts or the pheromone extract. Instead, the beetles seemed to wander randomly over all four extracts and the control.

Results - Mark-Recapture and Field Pheromone/Extract Study

The territories were relatively evenly spaced along the sides of a road, with an average distance of 32.4m +/- 11.6m. Territory size was highly variable (Table 2), averaging 8.36m² +/- 4.95m². The number of beetles at each colony changed during the two days, but beetle density was highest at colonies 0 and 1, and lowest at colony 4, for both days.

The results of the mark-recapture study, however, indicated that the individuals were moving very little, if at all. All of the recaptured beetles were from the same territory in which they had been marked and released and the number of beetles caught at any location was well within expected parameters, as shown by a X^2 test of significance (Table 3).

The beetles showed no response to any of the extracts placed on filter paper. In three observational periods for each colony, only two trials had beetles contact the paper. In both cases it was a single beetle which crossed the filter paper in a matter of seconds. One time a beetle crossed a piece of single concentrated plant extract in the center of colony 1, and the other time a beetle crossed over a control in the center of colony 2. The beetles did not pause at any time on the filter paper, apparently using it only as a pathway.

Discussion - Fungal Study

The parasitic fungus infecting the beetles, previously unstudied and probably a new species, belongs to the Ascomycete order Laboulbeniales (Gomez, pers. comm.). The 1500 described species in this order are arthropod parasites, generally specifying on a particular host species (Alexopolous and Mims, 1979). Therefore, if the beetle turns out to be a pest species, this fungus may serve in biological control.

The Laboulbeniales are unique in several ways compared to most fungal orders (Alexopolous and Mims, 1979). First, they lack extensive vegetative mycelia, and thus spend most of their lives as a sexual thallus, or ascocarp (Figure 2). The ascocarp embeds in the insect exoskeleton by a pointed foot cell, from which rhizoidal mycelia penetrate into the host tissues. Since they are primarily superficial, the fungus may completely cover an individual beetle, yet still allow it to continue to feed and to copulate (personal observation). This may also explain why infection is so pervasive in the beetle populations - it may have little effect on health. On the other hand, by penetrating the exoskeleton, the fungus may permit secondary infections of more dangerous diseases, such as bacteria or other fungi (Gomez, pers. comm.).

Secondly, reproductive strategies of this order are unique (Alexopolous and Mims 1979). Most other fungal species fuse haploid mycelia before producing a fruiting body, such as a mushroom. In contrast, the Laboulbeniales have a reproductive cycle more like a moss or alga. Without fusing hyphae, the ascocarps of these fungi bear separate male and female sexual organs called antheridia and gynecia, respectively. Sperm are sent out of the antheridia to the gynecia, where fertilization occurs. Ascospores are soon produced through meiosis in a structure called a perithecium (Figure 1). The sexually-produced spores are sticky, and when released from the perithecium, they will attach to a new site on a beetle. There they develop into a new fungal ascocarp.

Finally, several species of the Laboulbeniales are dioecious, meaning separate individuals have either male or female organs, but not both (Alexopolous and Mims, 1979). It appears that the fungus in our study ranks among these unique species, because no male antheridia were seen on ascocarps with female sexual organs.

Discussion - Laboratory Pheromone/Plant Extract Study

The pheromone trials failed to show that the beetles had an affinity for pheromone or plant compounds. The lack of a preference may be attributed to several factors. First, the extracts may have been too weak to have had a significant effect on the beetles pattern of movement. Second, the beetles used in this experiment were wild-caught beetles which may have had an adverse reaction to captivity. Third, containers used for the chemical trials may have interfered with the behavior of the beetles. Beetles placed in the aluminum trays grew sluggish and died by morning whereas the beetles placed in the plastic buckets remained active and alive throughout the experiment.

Discussion - Mark-Recapture and Field Pheromone/Extract Study

Field results seem to indicate that adult beetles are not in a dispersing mode. Although relatively few beetles were observed to be mating during the morning hours, 80 - 90% of individuals were mating in the afternoon on both observation days. The beetles may be gathering primarily for mating purposes but they showed no special attraction to the pheromone extract. This may have been confounded by using the entire beetle body (excluding the head) in the extract rather than trying to use only the pheromone-producing organ. It was unable to determine this due to the short time frame of the study. The beetles also appeared to have no preference for the plant extracts even though they fed heavily on the plants in the field. This heavy herbivore on *Cuphea* could be just a secondary consequence of congregating for mating but the blue beetle-*Cuphea* association needs further investigation. Additional research is also needed on the effect of the parasitic fungus on the beetle, particularly in light of the high infection rates found in this study.

References

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- Gomez, L. D. 1993. Director, Wilson Botanical Garden. Las Cruces Biological Research Station, Costa Rica.

Table 1. Population Data for Chrysomelide Beetles and Percent of Individuals Infected by Fungus.

Population	Number of Individuals	Density (#/m ²)	Percent Infected
1	2265	228	67
2	1149	374	83
3	1023	50	90
4	344	140	81
5	307	25	90

Table 2. Territory Size, Beetle Numbers, and Beetle Densities.

Colony #	# Beetles	Day 1		# Beetles	Day 2	
		Colony Size(m ²)	Beetles/m ²		Colony Size(m ²)	Beetles/m ²
0	2265	8.1	279.6	1835	8.1	226.5
1	1142	6.2	184.2	1431	6.2	230.8
2	1023	9.0	113.7	443	9.0	49.2
3	327	2.5	130.8	349	2.5	139.6
4	307	16.0	19.2	401	16.0	25.1
Total	5064	41.8	121.1	4459	41.8	106.7

Table 3. Chi-Square Table for the Capture-Release Data of the Beetle Population.

Colony Number	Observed	Expected	Chi-Square
0	9	11.4	0.523
1	4	5.8	0.559
2	8	5.1	1.257
3	3	1.7	0.994
4	2	1.6	0.1
Totals			3.43

For $P > 0.05$ and 4 degrees of freedom, X^2 is significant at 9.49 (one-tailed test). The data fails to differ significantly from the expected values ($3.43 < 9.49$).

Figure 1. Chrysomelid Beetle (infection on upper half and uninfected on lower half).

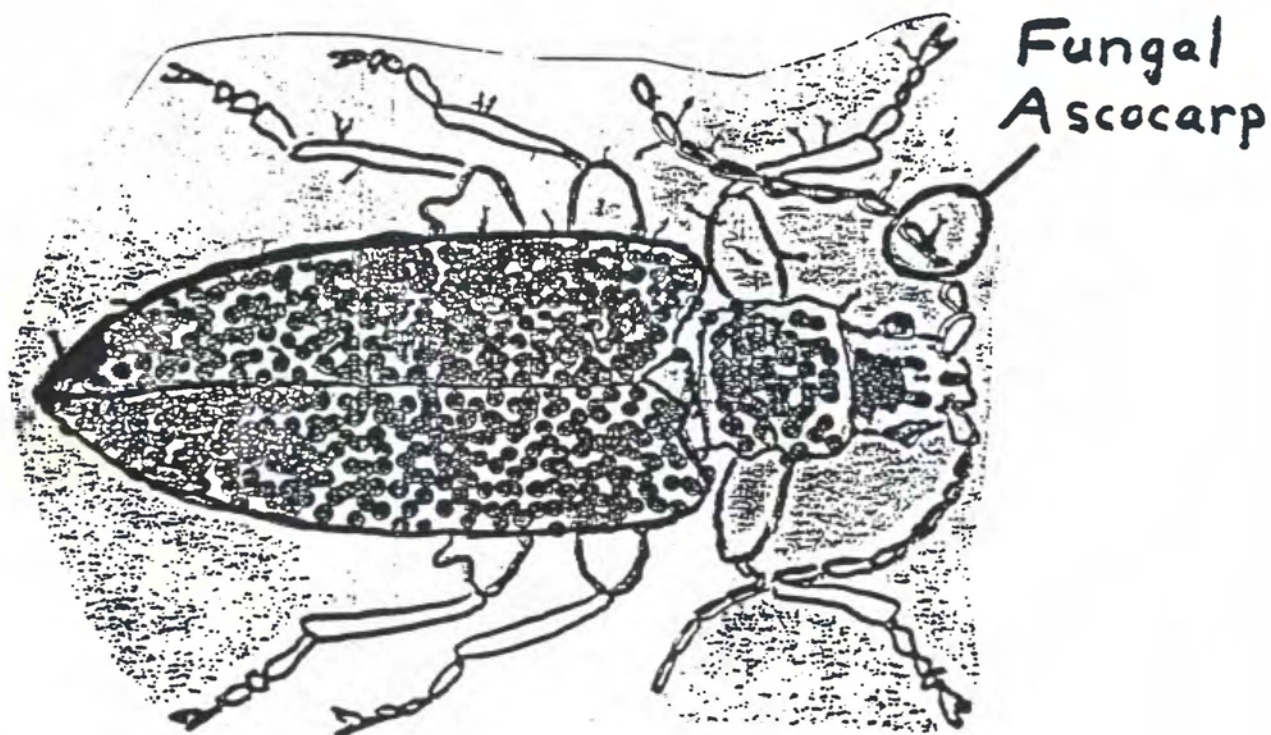
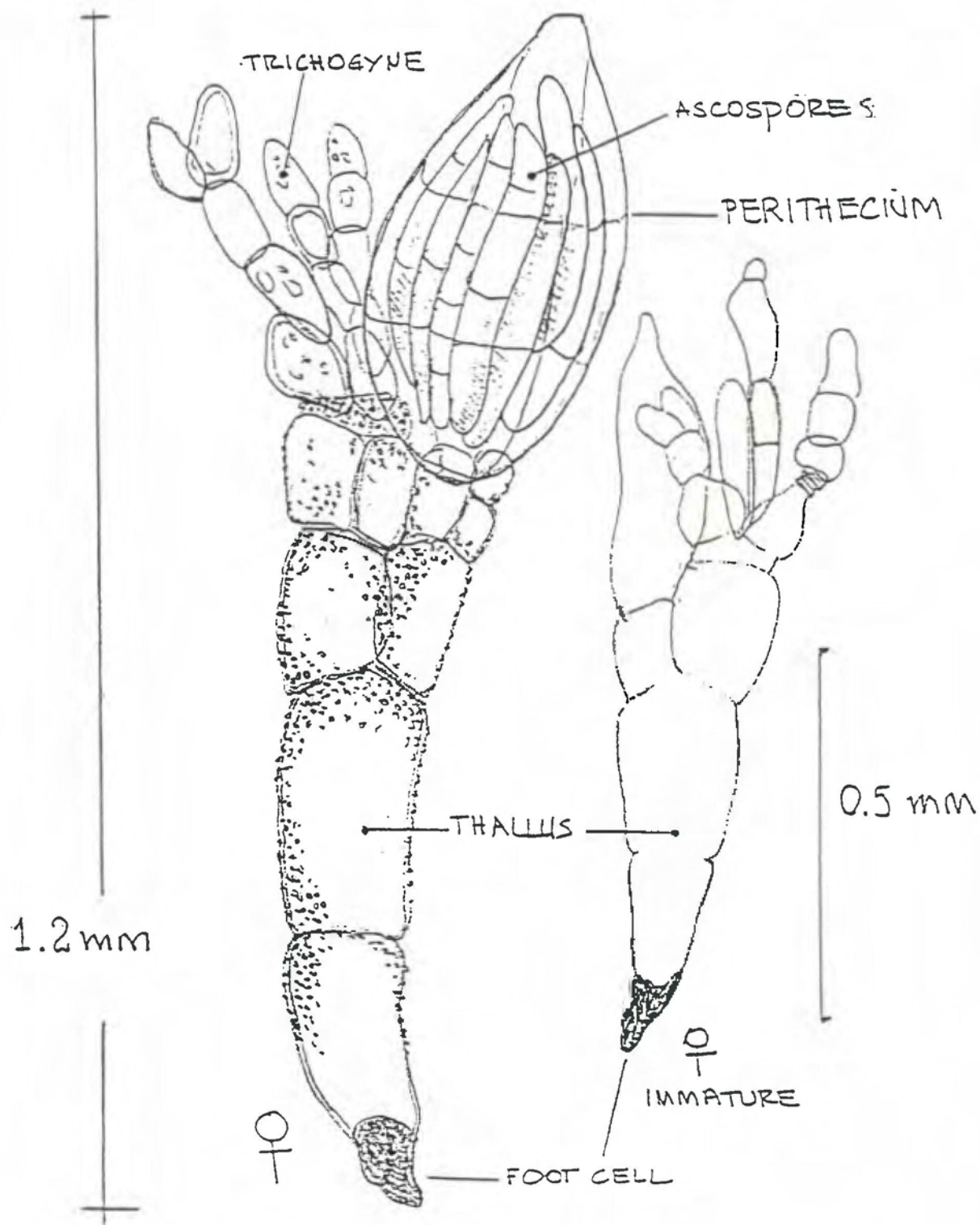


Figure 2. Enlargement of Ascocarp circled in Figure 1, as seen under light microscope. (Drawing by L. D. Gomez, structure names based on Alexopolous and Mims, 1979.)



HOMEGARDENS IN CAÑAS GORDAS: BUFFERING THE PAINS OF COFFEE PRICES

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Group: Amelia Oliver, Nick Shorr, and Pantaleo Munishi

Resource Person: Gabriela Soto

Abstract

A study of homegardens to investigate their composition, ecological conditions, and significance was done in Cañas Gordas. Observations, surveys, informal interviews, and soil temperature measurements showed that there was a trend toward crop diversification with increasing subsistence crops. This trend was attributed to the effect of the fall in coffee prices on the small-scale coffee growers.

Introduction

The importance of homegardens to the local households of Cañas Gordas is obvious: they provide the family with food, while requiring little investment. The classic definition of a homegarden requires that the garden be in close proximity of the house and that it include a diversity of crops. We assumed that diversity and subsistence would be the more dynamic phenomena associated with homegardens. The variety of crops would secure a production portfolio which would provide the household with a year-round supply of outputs. Solely, family labor would be utilized. Due to the high diversity of species and the inter-relationship among plants and animals in the homegarden, the ecological impacts of this integrated agricultural system would be lighter than an input-intensive monocrop system: erosion and soil degradation would not be much of a problem, organic matter in the soil would be high, and the soil temperature would be low. This study provided us the opportunity to investigate the composition of crops, the ecological conditions, and the significance of homegardens to the local households of Cañas Gordas. The biggest problem was defining the boundaries of what constitutes a homegarden. The variability of the land-use near the home, the total amount of land, and the layout of the land obscured the definition of the home garden.

Methodology

Seven neighboring households were investigated in Cañas Gordas. Six could be classified as possessing a homegarden. The seventh was not a subsistence venture, but rather a monoculture of tiquisque, soon to be converted into pasture. At each site the procedure was observations, surveys, informal interviews, soil temperature measurements, and the collection of soil samples. Observations revealed the layout of the garden.

Surveying involved identifying and counting the species, determining their inter-relationships, and assessing the overall conditions of the garden. Informal interviews provided information regarding why and how long a particular process had been utilized, as well as future expectations. Soil temperature provided data on the effects of different cropping patterns. Due to time and equipment constraints, soil samples, which were collected to measure organic matter, could not be analyzed.

Site Description

- Site 1: The homegarden of site 1 is .25 ha. It is unattended and contains relatively few crop species. The proprietor was unavailable for interviewing.
- Site 2: This homegarden is roughly 1.5 ha, the slope of which is approximately 45%. The crop selection is mixed and includes intercropping of bananas and coffee. Many fruit trees and nontraditional monocrop-vegetables contribute to the mosaic. The farmer moonlights as a carpenter but the 8 children provided much information.
- Site 3: This site did not qualify as a homegarden.
- Site 4: This homegardener has much experience with intercropping and mulching. The 3 ha garden contains a wide variety of crops and demonstrates unique agroforestry techniques. The owner openly supplied information regarding practices and expectations. Previously this land was devoted to coffee, but in recent years there has been a shift into a more diversified cropping pattern.
- Site 5: Coffee is the dominant crop of site 5. Trees and bananas are important nutrient contributor to the coffee system, as recent financial problems have eliminated the use of inorganic fertilizers. The 2 ha garden contains a small portion dedicated to subsistence crops. The wide selection of fruit trees are being plagued with incurable diseases and pests.
- Site 6: A canopy of tiquisque dominates this .7 ha garden. There is a variety of fruit trees, cheyote, and yucca. The primary agricultural venture of the household is not at the home site.
- Site 7: Nontraditional monocrops of vegetables dominate the flatter terrains of this 6 ha field. Coffee is still the major crop, but is situated on the sloped area and is intercropped with bananas and other fruit

trees. Many other vegetables and subsistence crops are included in the garden.

Results

Pattern of shifts

The fall in the price of coffee of the 1980s had a definite impact on these farm households of this predominately coffee-growing region. Almost all gardens had previously grown coffee exclusively. We noted specific trends which were consistent throughout many of the homegardens:

- 1.) Target coffee: a small area in the finest part of the garden is set aside exclusively for coffee. Trees are important sources of mulch and nutrients as inorganic fertilizer usage has been almost completely eliminated. These trees often serve multiple purposes by providing shade for the coffee, firewood, and sometimes, fruit.
- 2.) Reserve coffee: this is the most common garden composition. Coffee is cut back and alley crops use the spaces between the rows. These alley crops are generally subsistence crops such as corn, beans, or yucca. Basically, the coffee harvest is on hold in hopes of increases in the coffee price, and the land is being utilized for other purposes.
- 3.) Plantation Crops: this practice occurs on the edges of the garden. Coffee is completely removed and trees, usually fruit trees such as orange or coconut, are planted. These trees are maintained for their market value.
- 4.) Monoculture: other crops have completely replaced the coffee plants. These monocultures are usually situated on the best land and are inorganically grown. Tomatoes, chilies, tiqisque, and cheyote are examples of types of monocultures.

Soil temperature surveys

Table 1 shows the average soil temperature for different farms and different cropping patterns. It is observed that the air (ambient) temperature ranges from 22° C - 25° C, while the soil temperature ranges from 16.4° C - 23.6° C. The soil temperature range is bigger, implying a shading effect by the crops. Cropping patterns with tree/banana shade showed lower soil temperature, while monocropping showed higher soil temperature.

The implications of these results are that different cropping systems have different effects on soil temperature, depending on their shading effect. Patterns that cast more shade will probably result in lower soil temperatures. Trees, as observed in this study,

possibly cast more shade resulting in lower soil temperatures. Generally, cropping patterns with high crop diversity will tend to keep soil temperatures low.

Overall diversity and subsistence species

Table 2 shows the number of total species in the homegardens and the number of subsistence crops. Subsistence crops are defined as corn, beans, tubers, and chickens. A regression analysis of total number of species against the number of subsistence crops indicates a high correlation among the two ($R^2=0.83$).

Crop Scheduling

Because of the trend toward more diversified cropping patterns, there now exists a more constant output flow for the household throughout the year. Appendix I illustrates a possible harvest schedule for a household. Fruits and other crops such as cheyote, which have no specific season, can buffer the times between harvests. Target coffee and other cash crops provide additional income rather than being the sole income source. Risk is decreased and labor is more evenly allocated.

Conclusions

In conclusion, we found that there is a high diversity of species, overall and subsistence, in the homegardens of Canas Gordas. This diversity can be attributed to the change in coffee prices, which greatly affected small-scale growers. With no alternative coffee market, there was no choice but to modify cropping patterns and reduce inputs into coffee.

As a result, the 'homegarden' has become the norm. Substitutes for purchased inputs, such as mulching and intercropping, in addition to the shift toward new and subsistence crops, demonstrate the self providing nature of these gardens. These homegardens offer the household the opportunity to retreat from the market and remain buffered from the impacts of market fluctuations. Their partial integration in the bigger economic market contributes to a more sustainable, long-run stability for the households.

Table 1. Mean Soil Temperature by Farm and Cropping System.

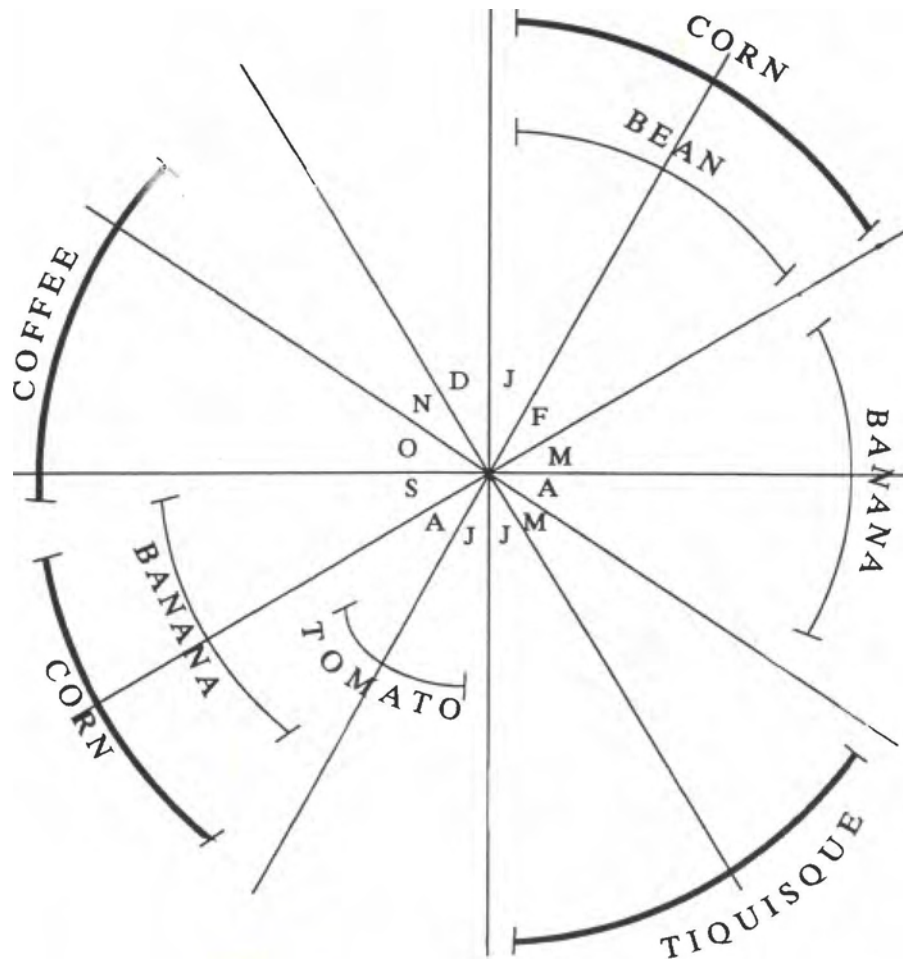
Crop Pattern	Mean Soil Temperature (° C)					
	I	II	III	IV	V	VI
Banana/coffee	19.5	19.9	18.3	---	---	---
Maize/coffee	---	20.7	---	---	---	---
Coffee/shade trees	---	---	16.4	---	---	---
Orange (mono)	---	---	21.3	---	---	---
Coffee/shade tree/banana	---	---	---	17.2	---	---
Guayaba/cheyote/banana	---	---	---	---	17.2	---
Tomato (mono)	23.6	23.3	---	---	---	---
Tiquisque (mono)	---	---	---	---	---	21.7
Tisquisque/coffee/ banana/cassava	---	---	---	---	---	20.3

Table 2. Number of Total Species in the Homegardens and the Number of Subsistence Crops.

CROPS	Site Number						
	1	2	3	4	5	6	7
Key Subsistence*	3	7	3	7	8	5	6
Total	9	20	4	19	18	9	17

*Key Subsistence was defined as corn, beans, tubers, and chickens.

Appendix I. Harvest Schedule (January - December)



Independent Field Problem

PATCH EVALUATION FOR PROPOSED COTO BRUS CORRIDOR

Author: Cecelia (Ceal) Smith

Group Member: Cecelia Smith (the corridor group)

Introduction

Loss of habitat resulting from forest fragmentation is the most serious threat to biological diversity and the primary cause of the present extinction crisis (Wilcox and Murphy, 1985). The reduction of recently vast forests (temperate and tropical) to isolated "islands" has prompted a call to establish corridors between protected areas in order to maintain population viability of native flora and fauna.

Although many agree that corridors are needed, their effectiveness has been difficult to evaluate for two reasons. First, there are no established criteria for evaluating the mosaic of landscapes likely to exist in corridors and how this heterogeneity may influence the movement of plants and animals using the corridor. Second, there is a lack of empirical knowledge about the basic biology of many organisms with respect to movement and response to habitat fragmentation.

The proposed Coto Brus corridor linking the Wilson Gardens with the Guaymi Reserve in Southwestern Costa Rica provides an excellent opportunity to address these problems. The purpose of my independent project is twofold. First, to propose and test ideas for evaluating the biological "value" of patches within the proposed corridor. Secondly, to begin to compile what is known from the literature about the possible response of native flora and fauna to the mosaic of landscapes which will potentially make up the corridor. Thus, this study may provide a starting point for evaluating the biological costs and benefits of the proposed corridor.

Methods

We focused on the Gamboa marsh area because of its importance for watershed protection, bird migration, and diversity and accessibility of patches. Two small and two larger patches were evaluated for patch "integrity", forest structure, forest composition, microenvironment, human impacts, and special biological values (Table 1). The criteria were derived mainly from the literature and through empirical observation. Many of the criteria were pilot tested in the 4 patches and secondary and primary forest in the Wilson Reserve. Out of this process additional criteria were added and others deleted or revised. Most criteria were measured in transects starting at the edge of the patch, 25 m and 50 m into the patch. In some cases more than 1 transect was taken in a patch. Number of forest layers, % herbaceous, understory, and canopy cover were estimated visually and are rough estimates. Density of Palms, Heliconia, Cecropia and dbh of trees were estimated

by Nabiha Megateli and reported separately in the corridor paper. Soil and ambient temperatures and soil samples for estimating soil moisture content were taken at the edge, 25 m and 50 m into the patch (or reserve), and occasionally in adjacent pastures.

Results

The results of the pilot evaluation are represented in Figures 1 - 3, and on Table 3. In terms of forest structure (Figure 2), all patches were found to be more disturbed than secondary and primary forest areas sampled in the Wilson reserve.

Level of disturbance (as indicated by the forest structure criteria, Table 1) did not always correlate with size. Patch 1 was the most disturbed. Patches 3 and 4 were intermediately disturbed and patch 2 was the least disturbed, although the second smallest in size. Patches 1 and 3 are characterized by soft edges and both have a high level of heterogeneity within a 50 m transect. Patch 2 was fenced on the West and South sides and had a very hard edge.

All 4 patches had fewer structural layers than the primary forest, but patches 2 and 3 approached that of the secondary forest which averaged 3.3 layers. Patches 1 and 3 have the highest percent herbaceous cover (.44 and .40) found primarily around the edges of the patches. Secondary and primary forest, by comparison had only .17 and .13 of this type of cover. The forest understory, comprised mainly of palms, heliconia, and ferns, was markedly absent in Patch 1 (only .14). Patches 2, 3, and 4 were also low (.31, .20, and .35) when compared to the secondary (.74) and primary (.52) forests. As expected, canopy cover was much lower in the patches (.13 - .30) than in the Wilson reserve (.75 - .85). However, there were remnant patches within all of the patches where canopy cover was high.

Human caused disturbance such as trails, cow grazing, and firewood and timber harvesting were highest on the eastern margins of patches 1 and 3 (active logging was going on in patch 3 while we were surveying). Both patches are adjacent to a road. Patch heterogeneity, as measured by the average number of changes in the number or composition of forest layers per transect, was highest in patches 1 and 3 and intermediate in patches 2 and 4.

The microenvironmental data (Figure 3) is more difficult to interpret. In general, these data reflect the ability (or inability) of the forest patch to buffer the extremes of climate (rain and heat) characteristic of tropical latitudes. The greatest extremes are found (as one would expect) between the pasture and interior of the patches.

Consistently comparing temperatures and soil moisture within patches and on adjacent non-forested lands on an a.m., mid-day, p.m. schedule would provide more useful data on buffering ability than the one-shot measurements made for this study. More precise methods for estimating % herbaceous, understory, and canopy cover (such as using

a spherical densiometer) would also improve the accuracy and usefulness of the data. Further analysis of this data would be useful to explore possible correlations between forest structure and microenvironment, and forest composition.

Conclusion

Although the results of the pilot evaluation of the Gamboa Marsh patches are tentative and techniques need refinement, some useful insights may be brought to bear. As the marsh patches currently exist, they are of limited (but not unimportant!) value as a biological corridor. With gaps >100 m and highly degraded forest structure, they may comprise the weakest-link in the proposed corridor zone.

Using the information from Table 1 on animal responses to habitat disturbance, in its current condition the patches will support generalist species and a few forest dwellers, but will be most useful to edge species. The results of the bird census (this project) confirms this prediction. Interior dwelling specialists (such as antbirds and fruitivores) are unlikely to benefit from a corridor comprised of discontinuous patches. If plans proceed to "reforest" areas between the patches, care should be taken to provide sufficient "filters" so as not to lure animals into a dead-end or funnel where they can become subject to predation or starvation.

Further conclusions are possible from the information compiled in this project and it is the authors hope that it will spark further debate.

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Table 1. Patch Evaluation Criteria.

PATCH INTEGRITY

- 1) size and shape (area/perimeter ratio)
- 2) degree of isolation or connectivity
- 3) distance from major source

FOREST STRUCTURE

- 4) # forest layers
 - a) 0 -.5 m herbaceous cover
 - b) .5 - 3 m forest understory
 - c) 3 - 15 m subcanopy
 - d) 15 - 25 m canopy
 - e) > 40 m emergent
- 5) % herbaceous cover
- 6) % understory
- 7) % canopy cover
- 8) heterogeneity of patch at transect level
- 9) # tree fall gaps
- 10) standing dead trees

FOREST COMPOSITION

- 11) density of trees (by size class)
- 12) density of interior palm/heliconia spp.
- 13) density of pioneer spp. (Cecropia, berrys, etc.)
- 14) abundance and composition of "indicator groups" (potential groups include tiger beetles and butterflies)
- 15) density of "keystone resources" (palms and figs)
- 16) fruit fall abundance along transect

Table 1 continued.

MICROENVIRONMENT

- 17) edge and internal soil and ambient temperatures, soil moisture, photosynthetically active radiation.
- 18) windward margin effects
- 19) leaf litter fall

HUMAN IMPACTS

- 20) level of anthropogenic disturbance (paths, grazing, firewood cutting)
- 21) proximity to roads, human settlement

SPECIAL BIOLOGICAL VALUES

- 22) marsh, riparian, watershed protection

Table 2

GROUP	RESPONSE TO GAPS, DISTURBANCE & FRAGMENTATION
MAMMALS	
Primates	diet generalists (esp. folivores) more tolerant of disturbance. Diet specialists (esp. frugivores) highly sensitive to forest disturbances (A)
Marsupials	species diversity, biomass, and individuals in 1 and rodents and 10 ha patches only 100 m from continuous forest declined dramatically (D)
Small mammals	species richness, biomass, and abundance may increase in 1 - 10 ha patches, especially in terrestrial mammals (D)
BIRDS	
Opportunistic feeders	colonizing trees may provide food for some forest species (G)
Mixed-species flocks	13 spp. disappeared after 1 - 2 yrs. (D)
Understory birds	

Table 2 continued.

insectivore/ (G)	assoc. with successional vegetation (Tangera, Ramphocelus, icterids)
fruitivores insectivores	highly sensitive to habitat disturbances (G) microclimate and structural changes that effect arthropod comm. Antbirds, ant tanagers, wood creepers (G)
small m passerines	need well-developed understory of native shrubs (C) as little as 80 break can isolate (D)
Sm parakeets	not present in logged forests (G)
Pigeons	can use "stepping-stones" or discontinuous vegetation (C)
Sweeping insectivores	do well in cleared areas (swifts, swallows martins) (G)
Picidae	require dead trees
.RTHROPODS	density correlated with % ground cover (G)
Orthopterans	dominate early seral vegetation
Euglossine bees	deep forest species will not cross 100 m gap (D)
Dung/carrion feeders	decline with 100 m break from continuous forest. Can lead to lower rates of decomposition of dung in forest isolates (D)
Butterflies	Highly sensitive to vegetation structure around forest patch (D). Burning at edge can decrease species richness. Light loving species increase with secondary vegetation growth at margins of patch, interior species decrease (D), Interior fruit and dung feeders (Adult stage) may be good indicators of overall diversity of patch (E)
<i>Cissia satyrina</i>	larvae feed on Poacea, indicator of forest disturbance (E)
<i>Morpho peleides</i>	will cross gaps (E)

Table 2 continued.

MAMMALS	Level of predation risk strongly affects dispersal pattern. Groups w/high predation pressure make rapid transfer by joining neighbor groups. Those subject to less predation disperse until they locate unoccupied areas.
small mammals	species richness, biomass and abundance may increase in 1 - 10 ha patches, especially in terrestrial mammals (D)
Marsupials only and rodents	species diversity, biomass and individuals in 1 and 10 ha patches 100 m from continuous forest declined dramatically (D)
PLANTS	do not spread progressively along corridors although certain species may be moved by animals along corridors (C)
trees shrubs	90% of tropical wet forest dwellers require seeds to be dispersed by animals. Many birds pollinated.

A = Johns and Skorupa 1987

B = Johns 1985

C = Saunders and Hobbs 1991

D = Bierregaard, Lovejoy, et. al. 1992

E = Daily and Ehrlick (in press)

F = Harrison, R.L. 1992

G = Loiselle and Blake 1992

Table 3. Temperature Data for Patch Evaluation.

Patch	Distance	Soil	Air	Diff. between Air/Soil	Diff. edge/core soil/air	
P1 (8 am)	Edge	21	19	2	1.5	1
	25 m	19.5	18	1.5		
	50 m	20	18.5	1.5		
P2 (10 am)	Edge/south	19.5	20.5	1	.5	1.5
	25 m	19.5	20	.5		
	50 m	19.5	21	1.5		
	Edge/east	20.5	23	2.5		
	25 m	20	21	1		
	Pasture	21.5	25	3.5		
P3 (8 am)	Edge	20	21	1	0	1
	25 m	20	20	0		
	50 m	20	20	0		
	Edge/north	20	22	2		
	25 m	20	21	1		
P4	no data					
Wilson sec/for (11 am)	Edge/south	20	22.5	2.5	0	.5
	25 m	20	22	2		
	50 m	20	23	3		
	Edge/north at pasture	21	27	6		
Wilson pri/for (10 am)	Edge/trail	20	21	1	0	1
	25 m	20	20	0		
	50 m	20	20	0		

Figure 1. Patch Integrity.

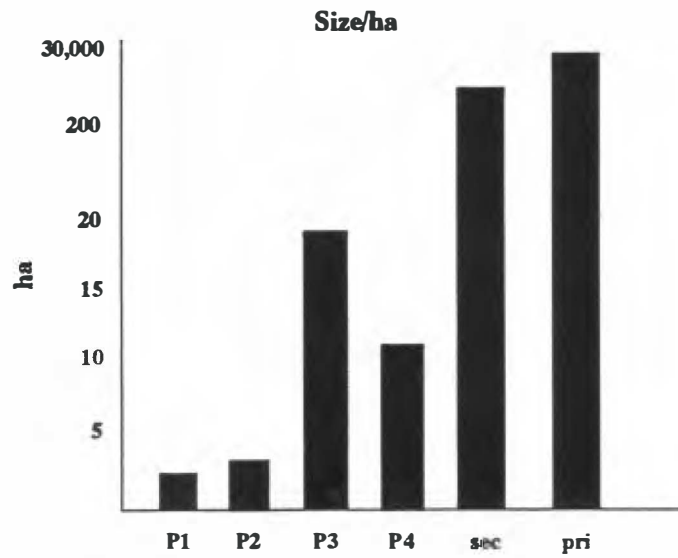
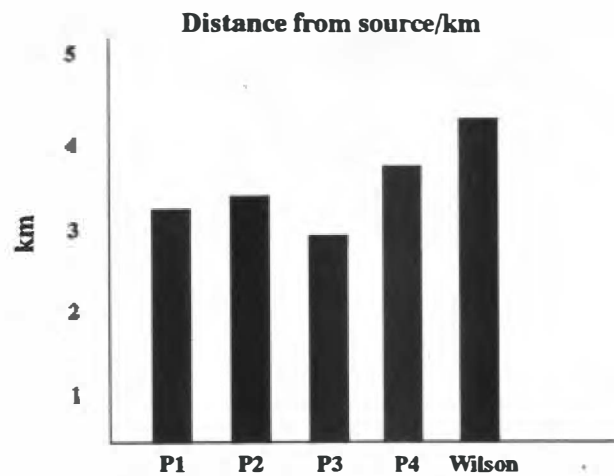
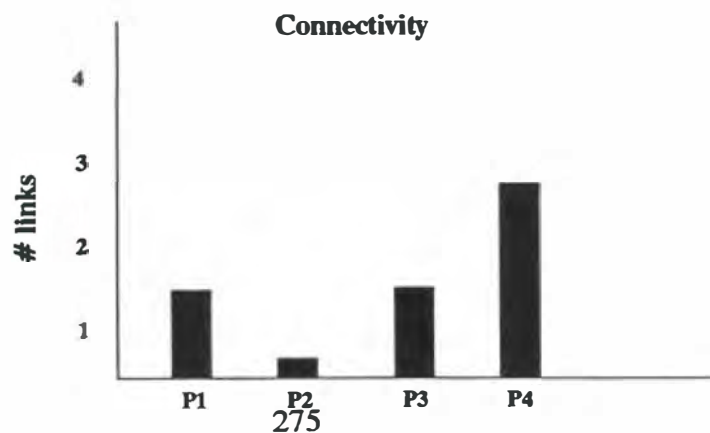


Figure 2. Forest Structure.

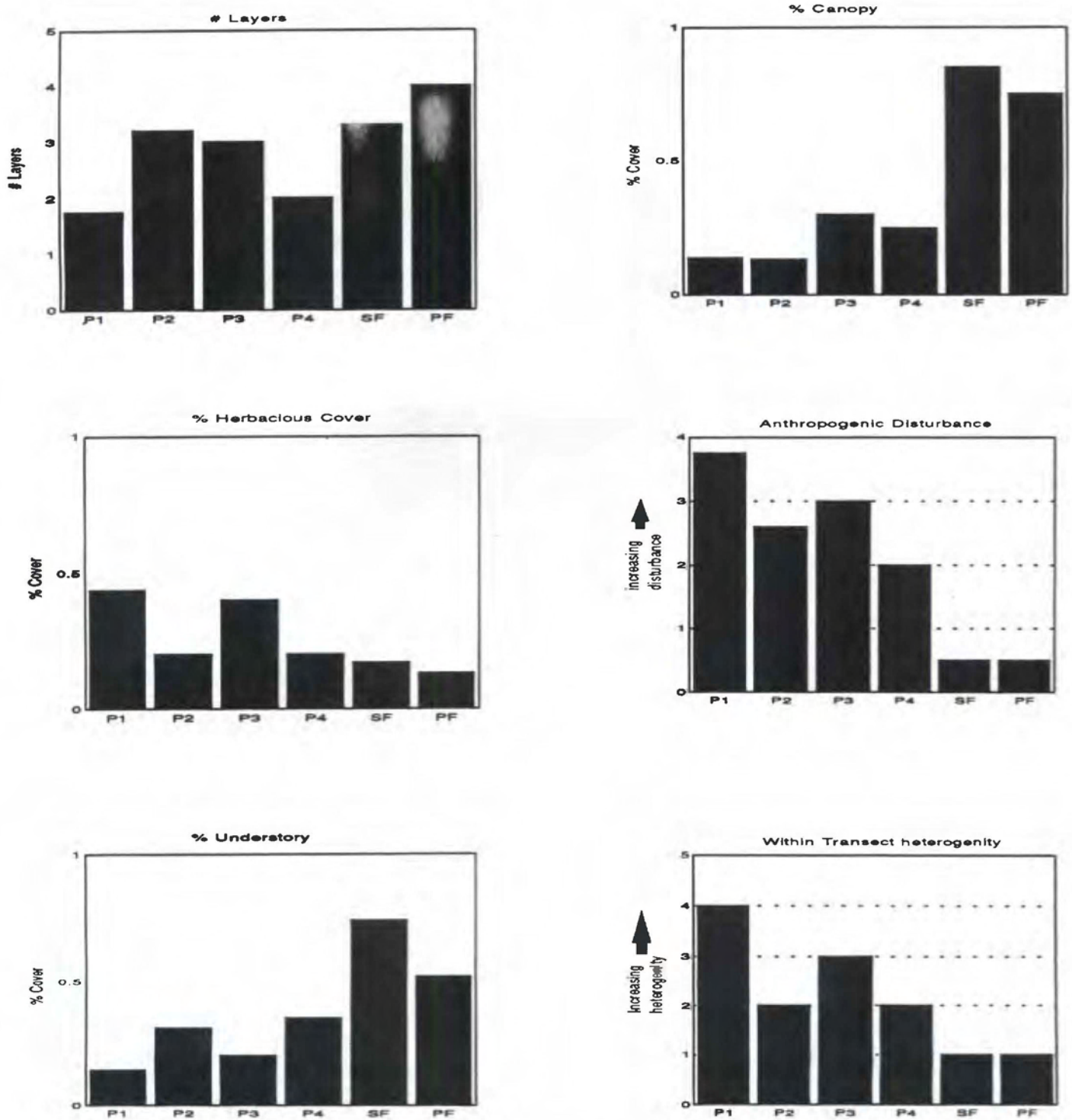
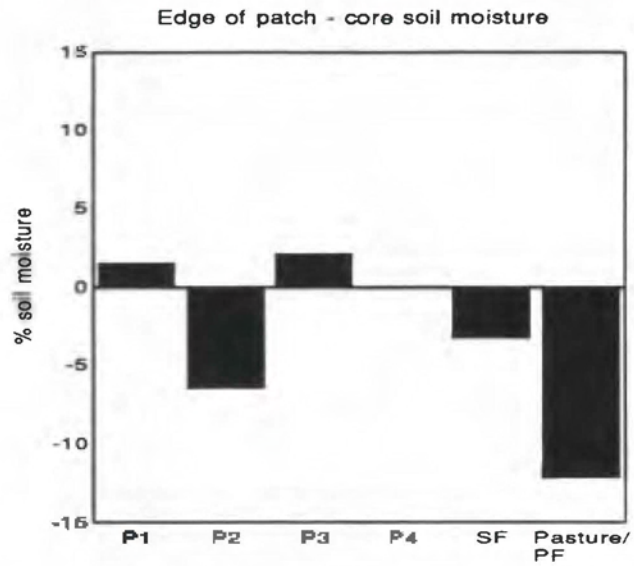
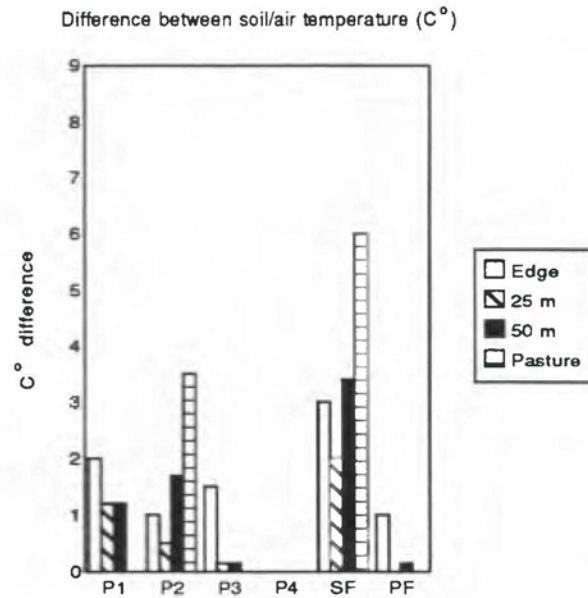
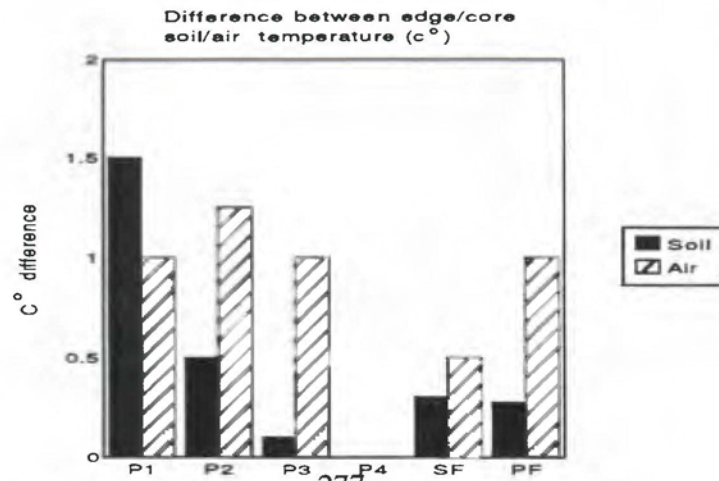


Figure 3. Microenvironment



BIRD CENSUS OF GAMBOA MARSH

Authors: Norm Bourg and Laura Howard

Resumen

En este momento existen pocos estudios que hayan evaluado los pequeños parches de bosque que serán incorporadas en el propuesto corredor que unirá la Reserva Guaymi y la Estación Biológica Las Cruces/el Jardín Botánico Wilson. Este estudio desarrolló una lista de pájaros en el Pantano Gamboa, y después se aplicaron los resultados al propuesto proyecto del corredor. Se hizo una lista preliminar de conuyente especies pájaros. El pantano no sólo les da a los pájaros un hábit para las especies que dependen del pantano, pero también existe una interface altitudinal entre 4muchos especies de pájaros de tierras bajas elevación y de altitud media-alta.

Abstract

Currently few ecological studies have focused on the evaluation of patches to be incorporated into the proposed corridor linking the Guaymi Reserve and Las Cruces Biological Station/Wilson Botanical Garden. This study first developed a checklist for birds at the Gamboa Marsh, and then applied the findings to the proposed corridor project. A preliminary list of fifty species of birds was compiled. The Gamboa Marsh not only provides a unique habitat for marsh dependent species, but also exists at an elevational interface between many lowland and mid-highland bird species.

Introduction

The proposed Coto Brus Biological Corridor would connect Las Cruces Biological Station/Wilson Botanical Garden (LCBS/WBG) with the Guaymi Indigenous Reserve. The seven kilometer corridor currently contains several large forest patches (~10 ha each in size) and numerous small forest fragments (~1 ha each) surrounded by extensive areas of degraded pasture. Between two of the large patches lies Gamboa Marsh, a natural freshwater marsh which is the source of the Rio Jaba. This marsh provides a unique habitat for migratory and resident bird species. The forest patches surrounding the marsh have been logged and reduced significantly in size over the past ten years. Additionally, cattle in bordering pastures continue to have access to unfenced portions of the marsh.

Carroll (1993) has stated that baseline data on bird diversity in the corridor is needed to evaluate the project's ecological feasibility. Gomez (1993, pers. comm.) has also indicated that a bird checklist for the marsh area would be a useful contribution to

the corridor project. The goals of this study were to develop a preliminary bird checklist for the marsh and adjacent patches.

Methods

The Gamboa marsh was censused on four consecutive days (August 5 - August 8, 1993). An informal census method was used to collect presence/absence data for birds in the marsh area. The marsh was surveyed by walking the perimeter and stopping periodically to identify bird species. The route passed through the three major habitat types near the marsh: forest, pasture, and marsh edge. Species were identified visually and recorded.

Results

A total of 50 bird species belonging to 21 families were recorded during the survey period. Table 1 shows the complete checklist for the marsh, which includes abundance ratings, special habitat and range characteristics. Table 2 provides a summary of habitat, food and nesting requirements for each family and the more uncommon or rare species found in this study. Finally, Table 3 lists the number of species and percent of the total species found in eight categories based on habitat, range, and abundance ratings. Of the 50 species recorded, 25 (50%) approached their altitudinal range limit at the site, 20 (40%) associated typically with primary forest, 17 (34%) depended entirely or mainly on forest for food and nest sites, and 17 (34%) were thicket/pasture/edge-preferring species. Fourteen (28%) of the bird species were classified as either rare, uncommon, or not previously recorded on the LCBS/WBG checklist, and of this number 8 (57%) associated with primary forest. Species restricted to the South Pacific slope of Costa Rica numbered 5 or 10% of the total and 1 species (2%) had a range limited to the San Vito-Coto Brus region of Costa Rica and adjacent Panama. Additionally, 4 species (8%) have been undergoing range expansion on the Pacific slope.

Discussion

Several interpretations can be made from the presence/absence data. Few marsh-dependent species appeared on the list. However, many marsh birds are migratory and would not be present in the marsh at this time of year. The relatively large percentage of forest-associated birds present may be artifacts of once undisturbed forest areas. Aerial photographs from ten years ago show a much larger area of contiguous forest surrounding the marsh. Logging and subsequent fragmentation of this forest accounts for the large percentage of edge-dwelling and open habitat birds. Another indicator of the recent forest loss is the presence of four species of birds capable of expanding their ranges into deforested areas. In addition, the marsh area provides a unique and valuable habitat for six species with restricted ranges.

Protection of the remaining forest fragments near the marsh and implementation of the corridor could affect the bird community in two ways. First, protection would facilitate the recovery of uncommon and rare forest birds. Second, open area species, which are generally common or abundant, would probably decrease in number. This assumes that the corridor would be wide enough so as to not adversely impact forest-associated birds by serving as a population sink or increasing edge effects. Research to address these issues is needed and is an activity mentioned in the corridor project proposal (Carroll, 1993).

In conclusion, the marsh clearly provides a unique habitat within the proposed corridor. It lies at an elevational interface between many lowland and mid-highland bird species. If one of the main objectives of the corridor project is to maintain biodiversity, then the protection of the Gamboa marsh area should be an integral step in achieving this goal. The marsh should therefore be made a conservation priority in any future corridor plans.

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Table 1. Bird Species List for Gamboa Marsh Area.

Scientific Name	Common Name	Abundance ¹	Note ²
PODICIPEDIDAE	Grebes		
<i>Tachybaptus dominicus</i>	Least grebe	C	
CATHARTIDAE	American Vultures		
<i>Cathartes aura</i>	Turkey Vulture	A	
<i>Coragyps atratus</i>	Black Vulture	A	
CRACIDAE	Curassows & Guans		
<i>Penelope purpurascens</i>	Crested Guan	R	*
RALLIDAE	Rails, Coots & Gallinules		
<i>Porphyryla martinica</i>	Purple gallinule	C	
COLUMBIDAE	Pigeons & Doves		
<i>Columba speciosa</i>	Scaled Pigeon	U-R	*^
PSITTACIDAE	Parrots		
<i>Pionus menstruus</i>	Blue-headed Parrot	O	#^\$
<i>Amazilia autumnalis</i>	Red-lored Parrot	C	^
CUCULIDAE	Cuckoos		
<i>Crotophaga ani</i>	Smooth-billed Ani	A	#^\$
APODIDAE	Swifts		
<i>Chaetura spinicauda</i>	Band-rumped Swift	U-C	+^
TROCHILIDAE	Hummingbirds		
<i>Phaethornis guy</i>	Green Hermit	A	*
<i>Lophornis adorabilis</i>	White-crested Coquette	U-R	*+^
<i>Threnetes ruckeri</i>	Band-tailed Barbthroat	N	^
<i>Lampornis castaneiventris</i>	Grey-tailed Mountain-gem	C	*
<i>Lampornis cinereicauda</i>			
<i>Lampornis</i>	Purple-throated Mountain-	C	*
RAMPHASTIDAE	Toucans		
<i>Pteroglossus frantzii</i>	Fiery-billed Aracari	U	*+^
PICIDAE	Woodpeckers		
<i>Melanerpes rubricapillus</i>	Red-crowned Woodpecker	A	*+

Table 1 continued.

Scientific Name	Common Name	Abundance ¹	Note ²
DENDROCOLAPTIDAE	Woodcreepers		
<i>Sittasomus griseicapillus</i>	Olivaceous Woodcreeper	C	*
<i>Xiphorhynchus guttatus</i>	Buff-throated Woodcreeper	R	*^
FURNARIIDAE	Ovenbirds		
<i>Synallaxis brachyura</i>	Slaty Spinetail	U	#^
PIPRIDAE	Manakins		
<i>Corapipo altera</i>	White-ruffed Manakin	C	*^
TYRANNIDAE	Tyrant Flycatchers		
<i>Tyrannus melancholicus</i>	Tropical Kingbird	A	#
<i>Legatus leucophaeus</i>	Piratic Flycatcher	C-U	#
<i>Megarhynchus pitangua</i>	Boat-billed Flycatcher	C	#
<i>Myiozetetes similis</i>	Social Flycatcher	A	#
<i>M. granadensis</i>	Grey-capped Flycatcher	A	#
<i>Terenotriccus erythrurus</i>	Ruddy-tailed Flycatcher	C	*^
<i>Elaenia chiriquensis</i>	Lesser Elaenia	U	+^
<i>Myiarchus tyrannulus</i>	Brown-crested Flycatcher	N	
TROGLODYTIDAE	Wrens		
<i>Troglodytes musculus</i>	Southern House Wren	C-A	#
TURDIDAE	Thrushes, Robins, & Allies		
<i>Turdus grayi</i>	Clay-colored Robin	A	#
COEREVIDAE	Bananaquit		
<i>Coereba flaveola</i>	Bananaquit	A	^
PARULIDAE	Warblers		
<i>Geothlypis chiriquensis</i>	Chiriqui Yellowthroat	C	@^
<i>G. poliocephala</i>	Grey-crowned Yellowthroat	C	\$^
<i>Myioborus miniatus</i>	Slate-throated Redstart	C-A	*
THRAUPIDAE	Tanagers & Honeycreepers		
<i>Dacnis cayana</i>	Blue Dacnis	U	*^
<i>Tangara icterocephala</i>	Silver-throated Tanager	A	*
<i>T. larvata</i>	Golden-hooded Tanager	A	*^

Table 1 continued.

Scientific Name	Common Name	Abundance ¹	Note ²
<i>T. guttata</i>	Speckled Tanager	U-C	*^
<i>Thraupis episcopus</i>	Blue-grey Tanager	A	
<i>Ramphocelus passerinii</i>	Scarlet-rumped Tanager	A	#^
<i>Habia rubica</i>	Red-crowned Ant-Tanager	C	*^
<i>Chlorospingus ophthalmicus</i>	Common Bush-Tanager	A	*
<i>Buthraupis arcaei</i>	Blue-and-Gold Tanager	N	*
EMBERIZIDAE	Sparrows, Finches & Allies		#
<i>Saltator maximus</i>	Buff-throated Saltator	A	#^
<i>Tiaris olivacea</i>	Yellow-faced Grassquit	A	#
<i>Sporophila aurita</i>	Variable Seedeater	A	#^
<i>S. schistacea</i>	Slate-colored Seedeater	N	#\$^
<i>Arremonops conirostris</i>	Black-striped Sparrow	A	#^
<i>Zonotrichia capensis</i>	Rufous-collared Sparrow	A	#

¹Abundance ratings, taken from Stiles (1991), defined as follows:

- A = Abundant: many individuals recorded on most days (in appropriate habitat)
- C = Common: a few individuals recorded on most days or many individuals at frequent intervals, but usually not daily
- U = Uncommon: one or several recorded at frequent intervals, but usually not daily
- O = Occasional: one or a few recorded in most years
- R = Rare: one or a few recorded at long intervals
- N = Not recorded on Stiles (1991) checklist

²Special habitat and range characteristics, based on Stiles and Skutch (1989):

- * = 1° forest associate
- + = Costa Rican range restricted wholly or mainly to S. Pacific slope
- ^ = Approaching altitudinal range limit at marsh site
- # = Thicket/pasture-preferring species
- @ = Costa Rican range restricted to San Vito - Coto Brus region
- \$ = Expanding range on Pacific slope

Table 2. Bird Family Habitat, Food and Nesting Requirements, Based on Stiles and Skutch (1989).

Family	Habitat	Food Habits	Nest Needs
PODICIPEDIDAE (Grebes)	open water, small veg covered ponds	aquatic insects, crustaceans	shallow water floating veg.
CATHARTHIDAE (Vultures)	open country	carrion fruit(palms)	caves,tree cavity
CRACIDAE (Crested Guan)	semi-open forest, tall 2° forest	canopy fruits new foliage	trees or stumps
RALLIDAE (Purple Gallinule)	ponds, emergent veg, marsh	aquatic plant berries, rice insects, frog	above or beside water
COLUMBIDAE (Scaled Pigeon)	canopy, edge, semi-open forest	fruits- trees epiphytes Melastomes	tree tops or thickets
PSITTACIDAE (Blue-headed parrot)	edge, semi-open, 2° growth, patchy	fruits, nuts seeds, palm	holes of trees, palm stubs
CUCULIDAE (Smooth-billed Ani)	pasture, savanna, marsh	insects, lizards, berries	trees, shrubs
APODIDAE (Band-rumped Swift)	forest, semi-open, ag-land pastures	winged insects	tree hole
TROCHILIDAE (Hummingbird)	clearing, forest, 2° growth	nectar, spiders, insect	clearing, edge
RAMPHASTIDAE (Toucans)	1° & 2° forest	mainly frugivorous	natural or woodpecker cavities
Fiery-billed Aracari	forest canopy/ nearby clearings	fruit/insects/ nestling birds	old woodpecker cavities
PICIDAE (Woodpeckers)	general forest dwellers	mainly insectivorous	tree cavities
DENDROCOLAPTIDAE (Woodcreepers)	general forest dwellers	mainly insectivorous	natural tree cavities

Table 2 continued.

Family	Habitat	Food Habits	Nest Needs
Buff-Throated Woodcreeper	1° forest edge old 2° growth	mainly insectivorous	hollow palm stub; nook in strangler fig roots
FURNARIIDAE (Ovenbirds)	wide range of habitats	mainly insectivorous	covered nests or cavities
Slaty Spinetail	old pasture thickets, riverbanks	mainly insectivorous	complex nest in shrub/ vine-draped tree
PIPRIDAE (Manakins)	forest dwellers	mainly frugivorous	cup nests in vegetation
TYRANNIDAE (Tyrant Flycatchers)	wide range of habitats	mainly insectivorous some fruits/ arillate seeds	diverse; some cavity & covered nests
Piratic Flycatcher	forest edge, tall 2° growth open country w/ some trees	insects/small berries/ <i>Cecropia</i> catkins	takes nests from other birds
Lesser Elaenia	weedy fields/ brushy marshes	insects/small berries/arillate seeds	cup nest in tree/shrub
TROGLODYTIADAE (Wrens)	wide range of habitats	mainly insectivorous	cavities or nests in vegetation
TURDIDAE (Thrushes and allies)	generally forest dwellers	mainly frugivorous and insectivorous	cup-like nests in tree/shrub
COEREBIDAE (Bananaquit)	forest canopy/ edge, 2° growth, open woods, hedges	pierces flowers/fruit for nectar/juice	globe nest in shrub/tree/vine
PARULIDAE (Warblers)	forest in mountains, light woods, thickets, marshes	mainly insectivorous arillate seeds/berries/nectar	cup next high in tree/bush/on ground; open nest in moss/epiphytes
THRAUPIDAE (Tanagers)	general forest dwellers	mainly frugivorous; some insects	cup nest in tree/shrub
Blue Dacnis	forest canopy nearby edge/2° growth/scrub clearings	fruit/arillate seeds/nectar/insects	deep cup nest in isolated tree

Table 2 continued.

Family	Habitat	Food Habits	Nest Needs
EMBERIZIDAE (Sparrows, Finches & Allies)	wide range of habitats	seeds/insects fruits	cup, bowl or roofed nest in shrub/tree/ on ground

Table 3. Numbers of Bird Species and Percent of Total According to Habitat Range and Abundance Ratings.

Number of species	50
Number of families	21
Primary forest associates	20 (40%)
Restricted to S. Pacific Slope	5 (10%)
Altitudinal range limited	25 (50%)
Thicket/edge species	17 (34%)
San Vito / Coto Brus Region	1 (2%)
Expanding Pacific Slope	4 (8%)
Forest dependent nest/food	17 (34%)
Number R/U/N	14 (28%)
Number primary forest associates	8/14 (57%)

A SOCIOECONOMIC ANALYSIS OF THE PROPOSED COTO BRUS BIOLOGICAL CORRIDOR

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Resumen

Entrevisté a varias personas en la región del propuesto corredor biológico de Coto Brus, Costa Rica, para examinar las condiciones socioeconómicas de la región y la factibilidad del proyecto que fue descrito. Aunque hay mucho entusiasmo sobre el proyecto, hay problemas también, muchos de los cuales están relacionados a la falta de acuerdo sobre los objetivos y la definición del proyecto. Este papel describe esos problemas.

Abstract

I interviewed several people in the area of a proposed biological corridor in Coto Brus, Costa Rica, to examine the socioeconomic environment within which the project was introduced and how feasible the existing proposal is within that environment. Although there was much enthusiasm about the project, there were also several problematic issues raised, many of which were related to a lack of general consensus on the objectives and definition of the project. This paper describes those issues.

Introduction

In the years 1984 - 1992, much of the land between the Robert and Catherine Wilson Botanical Garden and the Guaymi Reserve in Coto Brus, Costa Rica, was deforested. This area is steeply sloped and runs along the top of a ridge draining into the Turrialba watershed. In response to the high rate of deforestation, which threatens the area's watershed and increases its vulnerability to soil loss through erosion, a couple of landowners in 1992 decided to pursue the possibility of reforesting a corridor from the garden to the reserve. The project has been picked up by several groups in the area, and one of them, the Centro Agrícola Cantonal (CAC), recently (July 15) submitted a proposal to the United Nations Development Programme for 25 million colones with which to develop the corridor.

In this study I am interested in examining the socioeconomic context within which this corridor is being proposed and developed. I hope to fill in some of the details about the proposed project and to address the questions: What are the objectives of this corridor? How can the corridor and incentives program best be designed to meet these objectives?

Methods

The first step was to identify all of the groups and organizations who had an interest in the corridor project. I then selected representatives of the different groups to interview and review documents regarding the corridor they had prepared in order to determine how they perceived the various costs, benefits, and obstacles involved with the corridor project. I interviewed five people: Gerardo Brenes and Abelardo Madrigal (landowners), Luis Diego Gomez (OTS; Director of the Wilson Botanical Gardens), Marvin Mora (Journalist; Aprenabrus), and Carlos Fonseca (MAG/CAC).

I also attempted to map the holdings of landowners within the proposed corridor area. Gerardo Brenes, Gabriella Soto, and I drove the length of the road to Rio Claro that stretches between the garden and the edge of the reserve and we reconstructed maps from Brenes' information on where properties began and ended (Figure 1).

Results

The corridor proposal calls for voluntary landholder participation in a program of reforestation with native tree species along a chosen corridor area. Landholders will dedicate some portion of their land for reforestation with tree species of their choice, whether timber, fruit, or mixed forest species, and in return will receive free seedlings and a certain amount of "care money" to ensure seedling maintenance and care for 5 years. This amount has not been specified, but seems likely to be in the range of 30,000 - 50,000 colones/ha. A legally binding contract will be established between CAC and the landholder to ensure that the trees are maintained until the stand is old enough to be managed for timber. At that point it is unclear what arrangements, if any, will be made regarding timber management.

Landholders who are not able to dedicate land for reforestation can still be involved through the construction of nurseries, and will receive subsidies for their participation as well.

The corridor design has not been chosen but, although no technical studies have been done, two alternative designs have been suggested (Figure 2). Alternative A runs along the road to Rio Claro and would at some points be only 500 meters wide. This alternative would provide for the reforestation of the top of the Turrialba watershed, but runs adjacent to the road and does not take full advantage of existing forest fragments. Alternative B, which is also only 500 meters wide at places, runs parallel to alternative A but displaced from the road by 500 meters. This alternative may make better use of existing stands of forest but leaves the very top of the watershed unprotected.

The groups identified to have an interest in the Coto Brus Biological Corridor are: local landholders, Aprenabrus, Centro Agrícola Cantonal, the Ministry of Agriculture, the Organization for Tropical Studies, the TRIALS III native tree program, MIRENEM,

UNDP, local development organizations, and the Guaymí. Landholders in the proposed corridor area are in the process of forming an association to represent their interests in planning and managing the project. Aprenabrus is a local non-profit organization with a specialization in environmental education. Centro Agrícola Cantonal (CAC) is an agricultural development group comprised of landholders as well as representatives from MAG, local municipalities and banks. CAC submitted the proposal to UNDP and will be responsible for distribution of the funds. TRIALS III is a native species reforestation project administered by OTS and based at La Selva Biological Station that will provide recommendations on the methods and species used for planting and will continue to monitor the areas as field experiments. The role of the other interests will become clear as other issues are discussed below.

A review of the objectives of the different groups revealed that there is a wide variety of objectives and goals for the corridor, some of which are potentially conflicting. These goals include: stimulation of gene flow and the maintenance of biodiversity, protection of existing stands of forest, watershed and soil management and conservation, generation of income through timber industrialization, increased environmental awareness, generation of revenue from tourist trade, and increased availability of research opportunities in the corridor area.

Landholders involved in the project stress that the critical factors for success of this project are money and educational efforts. Reasons for deforestation in this area appear to have changed over time. One MAG representative believes that there is more than enough land in pasture already to support the cattle population in the corridor area. However, the economic crisis in Costa Rica has led many landowners to log trees for financial reasons; this seems to be the predominate motivation for current deforestation. Landholders are therefore reliant on the proceeds from logging and are unable to suspend deforestation without some type of financial compensation. The proposed project would provide this financial incentive at the outset, but ultimately the timber income from managed stands should pay for itself.

Money is also necessary for the educational efforts required by a project of this scale. Don Gerardo emphasized the importance of education in what is essentially a "cultural" change; landowners need to be made aware of the need for conservation, as well as given the practical knowledge necessary to make reforestation on their own land practical. The educational efforts proposed include training farmers to be more aware of natural regeneration and how to take advantage of it, by noticing when trees flower, how seeds are dispersed, when they should be collected, and how they can be planted. Farmers must also be given training in forestry, timber management techniques, and ways to use timber to produce more valuable timber products.

The reforestation project has therefore become more than merely a conservation project; it is also a local development project. Landowners involved in the project hope to form a timber association to industrialize their timber production through construction

of a mill and production of furniture, charcoal, or some other forest products. Success in such ventures will require a great deal of education about the timber industry; these educational efforts will require a lot of money as well. The feasibility of the corridor project is therefore highly dependent on the availability of funds.

Another serious problem in the corridor planning is the lack of information available on the biology of corridors in general and the proposed corridor area in particular. There are a number of unanswered questions about the usefulness of timber stands as habitat, and therefore about their utility in a corridor that is supposed to provide habitat for wide-ranging or migratory species. There is also no clear idea of what biological objectives the corridor is supposed to meet: what species are expected to use it? It is difficult to design a corridor without a clear idea of what it is to be used for.

The corridor project also involves a significant research component. In addition to the "timber as habitat" question mentioned above, landowners suggested that more information was required on how to use pasture more efficiently (which would free up land for reforestation) and how cattle and reforestation can be most efficiently and successfully combined. The funds for such research would not come out of this project's funds, but the results would augment the information that will need to be disseminated to farmers, increasing the demand for, and the costs of, educational extension.

One landowner expressed concern about land expropriation. As seen in the case of La Selva's biological corridor, corridor establishment often involves the expropriation of land rather than program development with local landowners. In this particular case, landowners are concerned that their land may be expropriated after it has been forested and returned to a more ecologically attractive state. Although it appears that MIRENEM has no interest in expropriating the land, this is a legitimate fear, and this landowner suggested that a contract be drawn up between MIRENEM and the landowners assuring them that their land would not be seized.

Another issue raised by the landowners regarded fees for researchers' use of their land. A preliminary contract prepared by CAC and Aprenabrus suggested that landowners would be asked to sign a release allowing researchers access to their lands. Although landowners are willing to open their lands to researchers, they feel that they should be paid some compensation. Researchers in national parks pay the park service 1200 colones/day, and ADESCAB, an association of landholders in Agua Buena, plans to charge short-term researchers 1000 colones/day for the use of the association's land, so there is a precedent for fees of this kind. Perhaps the proposed association of landholders could negotiate some collective agreement of this type.

One significant and contentious omission in the proposed program is the lack of incentives for maintenance of already standing forest. One of the expected benefits of the corridor is the protection of already standing forest fragments, and yet no provisions are made to protect already forested areas. Because incentives are only offered for

reforestation, there may actually be an incentive for landowners to remove standing patches and then apply to receive financial assistance to reforest those patches. Short of such a bleak scenario, however, landowners feel that they have sacrificed a certain amount in terms of the opportunity costs of not removing those patches, and that they should be compensated in some way if their patches are to form an integral part of the biological corridor.

One of the landholders' goals for the corridor project is to attract revenue from tourism that has traditionally been limited to the Wilson Botanical Gardens. The area has several natural attractions: the marsh is a particularly nice site for birdwatchers, and a forested strip with trails could expand the range of recreational opportunities. Landowners hope to build an albergue or two to provide lodging for tourists and for the increasing numbers of researchers who are expected to arrive. It is important to consider what types of environmental impacts these visitors might have on the corridor and develop a management plan that will minimize their effects, perhaps by limiting beds, strategically locating trails, etc.

One interest that has been conspicuously absent from this discussion is that of the Guaymi Indians. Their reserve would serve as the source for many migratory species and is therefore a crucial building block in the corridor project, particularly in the biological sense. It is possible, and I believe probable, that an increased traffic in tourists and researchers will have an impact on the Guaymi reserve in terms of increased visitation, increased use of the forest for research, etc. Up until this point, little has been recorded on what the Guaymi think of the corridor and its ramifications for their reserve, both biologically and culturally. It is imperative that they be involved in the development process. The Guaymi rely heavily on the species in the reserve for subsistence, and they may have valuable insights into how the corridor would function, including how it would affect different species and which species use which habitats. They should have a role in the planning and decision-making from the very beginning; their involvement, however informal, is crucial for the early identification and resolution of any problems that might arise later when increased demands are placed on their reserve.

All of these issues point to a larger, more fundamental problem in the proposed program -- the lack of a clear distinction between a corridor project and a reforestation project in the area between two biological reserves. Is there really a need for a "corridor," in the sense of a genetic conduit, between the two reserves? Or are the main objectives that of a reforestation project, with the name "corridor" attached to attract funds? Reforestation of the area would yield a number of benefits, but a "reforestation" project would take the emphasis off the goal of gene flow and focus more on soil and water conservation, among other things.

The relative priority given to different objectives will have an enormous impact on how the project can best be designed; an efficient design for a reforestation project may differ considerably from the most appropriate corridor design. If watershed management

is a higher priority than gene flow, for example, the corridor's alternative A, which reforests the very top of the watershed, might be preferable to alternative B, and perhaps could be expanded to include the area south of the road to protect the top of the Rio Claro watershed. As alternative B encompasses more standing forest remnants than alternative A and because habitat fragments are crucial in the process of habitat restoration, perhaps B would be a more appropriate site for a "biological corridor" project. On the other hand, the area north of the road to Torre Alta, which isn't included in either A or B, is the steepest slope in the area and so might be critical for a project focusing on soil conservation. The relative importance of these objectives, therefore, and the overall "definition" of the project, is an extremely important factor and must be determined at an early stage to optimize project design.

The proposed corridor will rely heavily on community efforts to protect the corridor from threats such as hunting. It is likely that the feasibility of a biological corridor will also depend on the willingness of local communities to work with corridor managers to develop appropriate logging schedules, plant fruit tree species to draw migrants into or through the corridor, or even set aside particularly vulnerable habitat areas, such as the marsh, for preservation. Generation of community dedication to the corridor objectives, however, will require a clear definition of those objectives. It must be made clear why the corridor is important, how it is supposed to work, and why it was designed the way it was. Otherwise, the community may find it difficult to commit to objectives that even the planners seem unsure of.

Conclusion

The Coto Brus Biological Corridor is a thought-provoking case study of grassroots efforts to wed conservation and development. The key component in this effort is the landowner himself, and it is acknowledged that the only truly viable, nondestructive (or less destructive) land use alternatives are those in which he is both willing and able to participate. There is far more to sustainability than just biological considerations of soil enhancement and water protection; these considerations fit into a much larger social, economic, and political framework, and all must be considered simultaneously to design a successful project. The need for a multidisciplinary approach to program design is reflected in the variety of issues and concerns raised in this study (Table 1).

To ensure that all these perspectives are considered, the project must enlist the participation of all the parties with an interest in the project and use their input to construct a framework of parameters that define, and limit, the project's possible designs. All planning and management decisions must fall within this framework, or they will ultimately be infeasible. There will, of course, always be need for compromises, but they must be arrived at by mutual consent of the group.

In the Coto Brus corridor, the most immediately pressing decision to be reached is an agreement on the corridor project's objectives. This decision is subject to the limiting

framework mentioned above. For example, it may be impossible to reconcile the landowner's need for timber industrialization with the habitat stability requirements of corridor species. In that case, it may be necessary to redirect the program toward a forestation project. These are the issues that should be addressed now so the project can proceed with a well-defined mission.

It is important to remember that UNDP is also a limiting factor within the framework; it may be exclusively interested in funding a corridor project as currently described in the proposal. Any attempt to redirect the program toward reforestation may result in a loss of consideration for those funds. This is, of course, an important factor in the decision-making process, for a less-than-ideal corridor would still yield more benefits than a project with no funds at all. On the other hand, funds could be sought elsewhere.

My gut feeling about this project is that it is leaning toward a reforestation project rather than a corridor. The size alone of the proposed corridor -- only 500 meters wide at points -- may disqualify it from suitability as a genetic conduit. Increasing the size of the corridor may be impossible given the needs of the landowners. Moreover, there is no clear idea yet what species the corridor is supposed to serve. Although biological inventories are planned for the coming year, the project planning is proceeding without the results of those studies, which are critical in the planning process. This is putting the cart before the ox.

One idea mentioned was to divide the project into two different projects, one focusing on a corridor area and the other on reforestation in surrounding areas. This would allow the objectives to be divided by project, each with its own mission. Again, however, the limiting factor may be the landowners; depending on how the land use is planned for the corridor, they may be unwilling to set land aside.

Once a decision is reached about project definition and goals, many other problems raised in this report can be more easily tackled. The most important tool in conflict resolution will be a constant dialogue among the interested parties; potential problems can be identified and addressed before they become contentious and divisive. I hope this document will be a useful step in the process. This project is unique in its determination to involve the landholders and to learn from them what is "sustainable" in a practical sense. The addition of this perspective in development planning, which reflects the social, economic, and political environments within which development occurs, represents an enormous advance in efforts to protect and sustainably manage natural resources.

Acknowledgements

My sincerest thanks to Gabriella for all her help and to Don Gerardo and Don Abelardo for their time and information.

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Table 1. Issues Affecting the Feasibility and Sustainability of the Proposed Coto Brus Biological Corridor.

A. Biological

1. Inventories and natural history studies
2. Identification of species expected to use the corridor
3. Research on timber/cattle combination
4. Research on efficient pasture use
5. "Timber as habitat" research

B. Economic

1. Financial incentives for participation in program
 - a. reforestation incentives
 - b. incentives for protection of standing forests
 - c. researchers' fees as a source of revenue
2. Timber industrialization
3. Tourism management plan

C. Political

1. Mutually acceptable, legally binding contract
 - a. expropriation protection
 - b. maintenance of forest/reforested stands

D. Social

1. Cohesive set of objectives
2. Importance of community involvement
3. Importance of education
 - a. environmental (including children)
 - b. related to timber industrialization
 - c. related to cattle/timber combination

Figure 1. Landholdings in the Proposed Corridor Area.

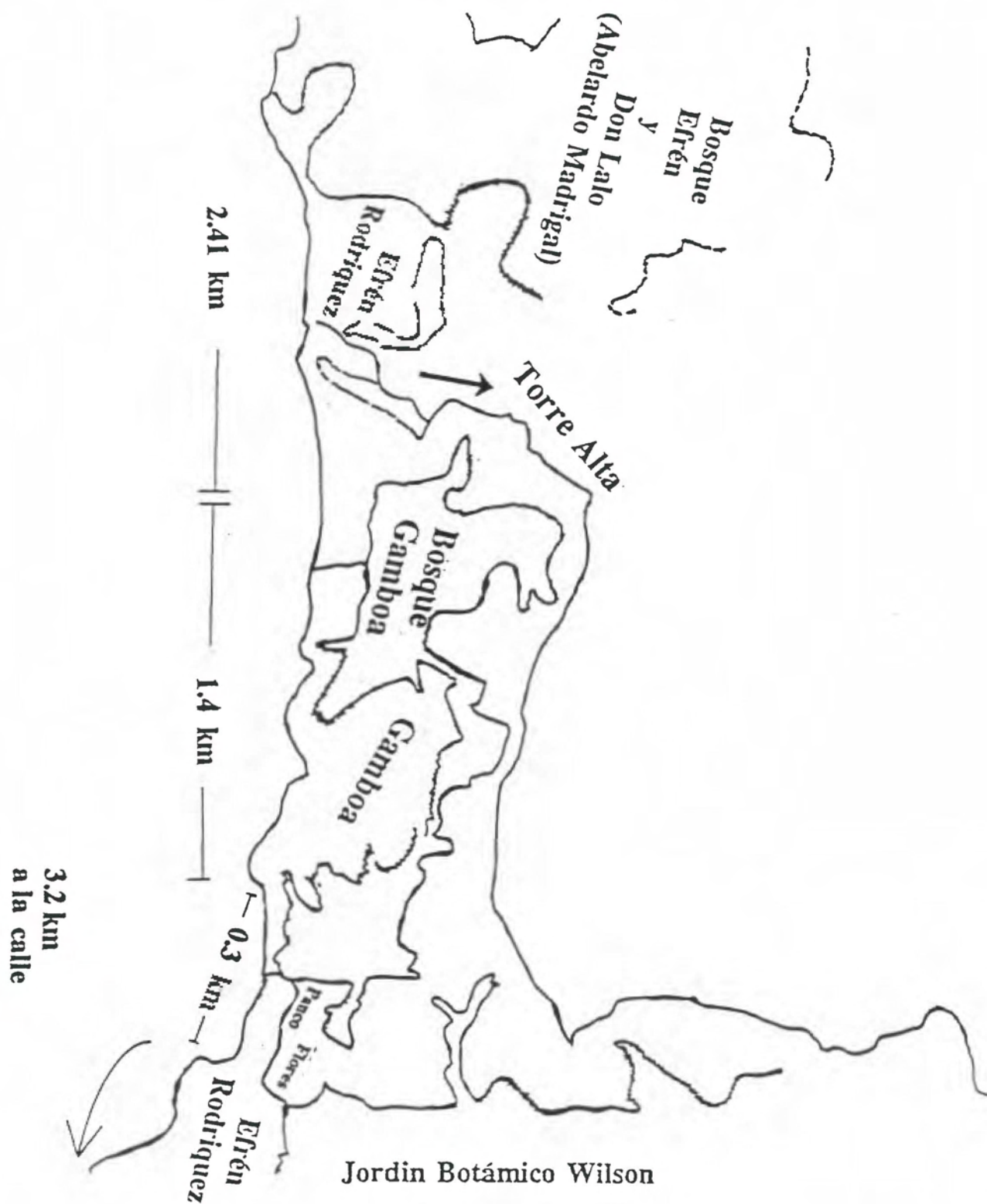


Figure 1. Continued.



Figure 2. Forest Patches and the Proposed Corridor Alternatives.



PASTURES AS BARRIERS FOR BUTTERFLIES IN THE COTO BRUS PROPOSED CORRIDOR

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Resumen

Se estudiaron las mariposas de dos parches de bosque separados por un potrero para ganado ubicados cerca de la laguna de Gamboa usando tramps y redes. *Cissia satyrina* fue la especie mas abundante en ambos parches (75% de las capturas) mientras que *C. renata* tuvo una dominancia del 100% en el pastizal. No se pudo comprobar si las especies del bosque usan el pastizal para movimientos diarios o si las mariposas del bosque usan el pastizal ya que no hubo recaptura.

Abstract

Butterflies of two forest patches separated by a narrow pasture in the Gamboa marsh area were surveyed using nets and traps. *Cissia satyrina* was most abundant in both forest patches (75% of the captures), while *C. renata* was the only species captured in the pasture. The use of pastures by forest species, or the use of forest patches by pasture butterflies, was not demonstrated by recapture.

Introduction

The great speed in which the tropical rain forest is disappearing would not allow the realization of inventories or the needs and usefulness of corridors based on a great array of taxonomic groups. Therefore, taxa that are biogeographically informative, relatively well characterized and easy to measure or observe should be targeted (Kremen, 1992). Butterflies, birds, small mammals, and parasitic Hymenoptera have been proposed as target species for biological assessments (Ehrlich, 1990).

The proposed Coto Brus corridor will include pastures which may act as barriers for some species. In this study I will focus on the use of these pastures by butterflies for daily movements between forest patches.

Objectives

The purpose of this study was to determine the distribution of fruit eating butterflies in two patches of forest separated by a 100 m pasture, and to determine the use of this relatively small pasture for daily and temporal movement by forest species. The

bottom line is if small deforested areas cannot be used by some species of butterflies for movement between patches, they should be considered as barriers for several species.

Methods

This experiment was carried out during August 6 - 9, 1993 at the Gamboa property, near the marsh. A dense 2.7 ha forest patch was separated from a more open 2 ha forest patch by an ~100 m pasture that had 2 guayaba trees. Three Van Someren-Rydon butterfly traps were hung from limbs of both forests at 2 - 3 m above the ground and baited with a mixture of rotten banana, rum, sugar, and vanilla extract. The traps were checked at 6:00 and at 14:00 each day. The butterflies caught were identified, marked with a unique number on the left wing using a Sharpie pen, and released.

A transect along the pastures passing by both guayaba trees was established for trapping the greatest amount of butterflies in this area using a butterfly net. These butterflies were also marked and released. The location of each capture was recorded as follows: the border of the forest, by the guayaba trees, or between trees and between trees and forest, in order to determine if these individuals use different sections of the pasture, and if they move from the forest to the pasture and vice versa.

Results

Twenty eight butterflies were caught in the traps, 14 in each of the forest patches, of which 3 were recaptured in the same forest where they had been previously marked (Table 1). The most abundant species (75% of the captures) for both forest patches was *Cissia satyrina*. They were captured in 10 and 11 occasions in the open and older forest patch, respectively. *Memphis beatrix* was captured once in each forest patch, while *Caligo eurilochus* and *Memphis arginussa* were only captured in the open forest.

Seventy *Cissia renata* were captured using the net at the transect (Table 2). Of these, 18 were recaptured in one or more opportunities. Of the recaptured, 38% were in the same location corresponding to the previous capture. Only one individual moved from the edge of the open patch to the edge of the older forest patch. Table 3 includes all species captured using both methods; host species for the larvae, altitude range, and habits for the adults are mentioned (De Vries, 1987).

Discussion

The high dominance of *Cissia renata* indicates habitat alteration; the larvae depends on pastures. The fact that there were no recaptured from the adjacent pasture or the other forest patch can be explained by the short sampling period, or the habitat specificity of both *C. satyrina* and *C. renata*. However, it may indicate that some forest butterflies need continuous forest for successful daily movement. The proposed corridor includes open areas that may in fact act as barriers for species with low dispersal capabilities. Other

species of butterflies were observed moving actively or aided by strong winds through the pasture.

Recommendations

A future study involving more intensive trapping in terms of time and number of traps, both at different heights from the ground and at different distances from the border of the forest, is highly recommended, as well as the establishment of a transect with traps in the pasture. Different sizes of patches and different distances from each other should be tested to see the minimum viable size of forest patches and maximum distance of migration for key species.

Literature

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Table 1. Data Corresponding to Captures in the Van Someren-Rydon Butterfly Traps.

Day	Time	Loc	Trap	Species	#	Previous Location
6/8	2	0	1	<i>Cissia satirina</i>	1	
7/8	1	0	1	moth		
7/8	1	0	4	<i>Cissia satirina</i>	2	
7/8	1	0	1	moth		
7/8	2	0	1	<i>Cissia satirina</i>	23	
7/8	2	0	1	<i>Cissia satirina</i>	24	
7/8	2	0	1	<i>Cissia satirina</i>	25	
7/8	2	8	4	<i>Cissia satirina</i>	26	
7/8	2	8	5	<i>Cissia satirina</i>	27	
7/8	2	8	5	<i>Memphis beatrix</i>	1	
8/8	1	0	2	<i>Cissia satirina</i>	2	2
8/8	1	0	1	<i>Caligo eurilochus</i>	1	
8/8	2	0	2	<i>Cissia satirina</i>	6	3
8/8	2	0	2	<i>Cissia satirina</i>	24	1
8/8	2	0	2	<i>Cissia satirina</i>	40	
8/8	2	0	2	<i>Cissia satirina</i>	41	
8/8	2	8	4	<i>Memphis beatrix</i>	2	
8/8	2	8	5	<i>Cissia satirina</i>	43	
8/8	2	8	5	<i>Cissia satirina</i>	44	
8/8	2	8	5	<i>Cissia satirina</i>	45	
8/8	2	8	5	<i>Cissia satirina</i>	46	
8/8	2	8	6	<i>Cissia satirina</i>	47	
8/8	2	8	6	<i>Cissia satirina</i>	48	

loc: (0) old forest, (8) open forest

Previous loc: trap where marked

Table 2. Data Corresponding to *Cissia Renata* Captured and Marked in the Pasture.

	Time	#	Location	Previous Location
8/7	7:30	1	3	
	7:42	2	2	
	8:43	3	3	
	8:50	4	3	
	8:55	5	3	
	8:57	6	3	
	8:36	7	3	
	9:41	8	3	
	9:43	7	2	3
	9:45	a	1	
	9:56	9	7	
	9:58	10	7	
	10:09	11	3	
	10:10	12	8	
	10:13	13	3	
	10:16	13a	3	
	10:20	14	3	
	10:28	15	5	
	10:29	16	6	
	10:31	16	6	
	10:48	17	5	
	10:49	a	5	2
	10:52	18	5	
	11:06	19	3	
	11:12	17	3	
	11:28	b	6	
	11:30	18	5	5
	11:32	20	5	
	11:37	3	3	3
	11:40	7	2	2
	11:40	21	2	
8/8	7:29	23	7	
	7:40	24	3	
	7:42	3	3	3
	7:46	14	3	3

Table 2 continued.

7:48	25	3	
7:49	16	2	6
7:54	1	3	3
7:56	7	3	2
8:05	26	5	
8:05	20	2	2
8:08	27	3	
8:12	27	2	
8:16	7	c	
8:23	28	7	
8:25	29	7	
8:41	26	3	5
8:44	30	3	
8:49	31	3	
8:50	32	3	
8:53	33	5	
9:09	13	5	3
9:11	24	5	3
9:16	16	3	6
9:22	24	2	3
9:36	31	1	
9:50	34	2	
9:54	1	2	
9:59	35	3	
10:02	35	3	
10:07	36	2	
10:30	37	2	
10:37	38	2	
10:44	27	1	
11:10	7	1	
11:12	20	1	2
11:20	30	1	
11:31	1	1	
12:10	39	1	
13:52	16	2	3

Locality: (0) old forest, (1) edge of old forest and road, (2) between road and guayaba tree, (3) guayaba tree, (4) between guayaba trees, (5) second guayaba tree, (6) between guayaba tree and edge of open forest, (7) edge of open forest, and (8) open forest.

Previous Capture: if recaptured, locality of the previous capture.

Note: some individuals have the same number, but in different color, it does not mean recapture unless noted.

Table 3. List of Butterfly Species Captured at Gamboa's Marsh, Considering Their Host Plant, Range, and Habits (based on DeVries, 1987) (from Ehrlich, 1990).

<i>Species</i>	Host Plant	Altitude (m)	Habits
<i>Cissia satyrina</i>	grass (Poaceae)	800-1000	Common, widespread in all forest habitats. Fly in understore. Abundant in dry season. Males and females feed on rotten food.
<i>Memphis beatrix</i>	<i>Piper</i>	700-1600	Common. Montanae species.
<i>Caligo eurilochus</i>	<i>Heliconia</i> , <i>Catatheia</i> , <i>Musa</i>	0-1600	Widespread, common. Associated with forest habitats. Can be pest of banana.
<i>Memphis arginussa</i>	<i>Croton</i>	0-1500	All forest types, except dry. Secondary growth where pioneer <i>Croton</i> is grown in hedgerows. All year round.
<i>Osiphanes cassina</i>	<i>Acrocomia</i> , <i>Bactris</i> , <i>Cocos</i>	0-1400	Common in secondary growth areas. More common in the rainy season in the Pacific slope. Feed on rotten fruit in understory and forest canopy.
<i>Cissia metaleuca</i> *	Poaceae	0-1000	Wet and dry forests. Flies along forest edge and light gaps. Solitary. Most abundant in dry season, but not common. Feeds on Araceae.

SYNTHESIS OF CORRIDOR RESEARCH

Author: Laura Howard

The proposed Coto Brus Corridor will connect the Guaymi Reserve with the Las Cruces Biological Station/Wilson Botanical Garden. Unfortunately, the objectives of the proposed corridor remain unclear, thus the corridor project seems to lack focus and fails to be goal-oriented. Clear and specific goals would allow the planning and execution of tasks to take place in a logical and efficient manner. Without defining priority issues, the corridor project may fail to meet any of its objectives. For example, species of particular interest to the corridor project remain unidentified. If a target species is expected to utilize the corridor, then the species natural history should be taken into account when designing and maintaining the corridor.

Other reasons for the establishment of the corridor include watershed management, soil erosion, research and environmental education. Watershed management goals may be conducive to soil conservation and the maintenance of an effective biological corridor. Similarly, the goals of research and timber development may conflict with one another or with the needs of an effective biological corridor. Without a clear list of priorities and objectives, the corridor design may be flawed with inconsistencies and ultimately fail to accomplish the goals that fostered its initial conception.

Any plans to establish a corridor must consider the socio-economic constraints of the people involved. In this case, farmers and small landholders must agree to participate in the corridor project. The proposed corridor project involves offering economic incentives for planting native trees. Most landholders are willing to participate in the corridor project as long as it remains economically feasible.

The right to log the timber, when at harvestable age, will remain a landowners right. However, the logging itself may ultimately become a problem for species unable to live in disturbed habitats. Regulation or monitoring of logging in the corridor may prevent species loss due to disturbance.

Another incentive for landowners will be an effort by extension agents to maintain cattle production on smaller plots of pasture. This would allow farmers to put aside pasture for the planting of native tree species, without decreasing cattle production. Another incentive exists in the potential for monies from ecotourism and research fees. However, economic gains may not outweigh the disruptive effects of numerous tourists descending upon areas unaccustomed to handling or welcoming visitors. The deluge of tourists, ecotourists, and researchers may not be welcomed by all individuals in the corridor community.

The proposed corridor sites have been split into two plans. Plan A runs next to a road and is 500 m wide with few patches at the top of the watershed. Alternatively, Plan B is 500 m away from the road at the bottom of the watershed, includes more patches and would require less reforestation. Due to their widths neither plan would facilitate the movement of large animals. Furthermore, a corridor located next to a road would be constantly disturbed by road traffic and human encroachment or interference.

One of the most useful applications of ecological research is the power of prediction. To apply the concepts of patch dynamics, three scenarios were created to illustrate the potential fate of patches in the proposed Coto Brus corridor. Scenario I envisions the ideal situation of a complete forest regeneration project. The forest canopy and understory will remain intact. Plant diversity will slowly increase, as would inner patch humidity. Light penetration and temperature would decrease. Soil erosion may decrease as the watershed became more protected. The rare or uncommon forest dependent birds will increase in number. The common and abundant edge dwellers would decline with the loss of edge. The butterflies will increase diversity and the patches will facilitate movement along the corridor.

Scenario II entails maintaining current practices: patches utilized for selective logging and pastures with cattle. The forest structure will initially increase edge effects with the degradation of patches continuing. Eventually, the disappearance of patches will enhance soil erosion and watershed degradation. The bird community would increase in edge dwellers and open habitat species accompanied by a simultaneous reduction of primary/secondary forest species. The butterflies will also increase edge dependent species and reduce primary/secondary species.

Scenario III describes the most realistic depiction of patch use: logging patches and reforestation efforts. Patches will become managed forests or converted to pasture. Native mono/mixed culture stands will predominate in the reforested areas. Monocultures will fail to support as much biodiversity as multiculture stands. Reforestation will reduce soil erosion and a potential exists for watershed protection. This regime will maintain edge dwellers and secondary forest species. If the patch is close to a primary forest, forest fragment birds might be found within the adjacent logged fragment. If the marsh has been incorporated into the management scheme, then migratory waterfowl might use the marsh area more intensely. Primary and secondary forest butterfly species will be lost, and edge dependent species will predominate.

In conclusion, more biological studies need to be conducted in the proposed corridor area. Sound management practices should be based upon an understanding of patch dynamics. If current land practices continue, both patches and watershed will likely become degraded. Biodiversity will be lost due to patch degradation. If the corridor plan includes the maintenance of biodiversity, then patch evaluations need to be conducted. This information will allow for informed planning of corridor management.

The corridor study recommends protecting the Gamboa Marsh to target both waterfowl conservation and watershed protection. Before planning the corridor location, a biological inventory of the potentially incorporated patches should be conducted. The objectives and priorities of the corridor project should be outlined in order to develop an effective management strategy. After collecting and assessing the patch evaluations, the proposed corridor plan may require reassessment.

The Coto Brus Corridor Project will be both a development project and a conservation program. The corridor will involve management of semi-natural areas and disturbed habitats. This will be a difficult task. On the one hand, a mosaic of severely degraded lands will not facilitate the maintenance of biodiversity. On the other hand, attempting to recreate a pristine habitat remains unrealistic. The alternative is to try to integrate conservation efforts, logging, agriculture, and cattle ranching. We need to remember that while primary forests will remain important sources of rainforest species, logged forest patches can potentially be used to sustain various animal populations. Although these mosaic patches can never substitute for primary forest, learning to manage these mosaics of tropical ecosystems may provide for the long term conservation of some tropical species.

SYNTHESIS OF CORRIDOR RESEARCH: SOCIAL/ECONOMIC/BIOLOGICAL

SUMMARY OF FINDINGS: PRISTINE IDEALISM VS MOSAIC REALITY

PLANNING: WHY A CORRIDOR? UNCLEAR OBJECTIVES/TIME FRAME

- a) Conservation of biodiversity/buffer zone for Guaymi
- b) Watershed management/soil conservation
- c) Research novelty
- d) Environmental education/community involvement

SOCIO/ECONOMIC: CHOICE ULTIMATELY UP TO THE LANDHOLDER

- a) Can afford/willing to reforest/maintain if subsidized (legally bound, trees provided)
- b) Right to log when timber harvestable age
- c) Reforest PART of pasture (maintain cattle production on less pasture--extension)
- d) Economic gains: tourism, timber, subsidized
- e) Cultural intrusion (of Guaymi)

PROPOSED CORRIDOR SITES:

- a) next to road 500 m wide, not many patches, top of watershed
- b) 500 m from road, 500 m wide, more patches included, less reforestation, bottom of watershed

THREE SCENARIOS: PREDICTIONS BASED ON RESEARCH OF TWO PATCHES

I. IDEAL: FOREST RESTORATION

- a) Forest Structure: canopy and understory maintained
 - increase plant diversity
 - less patchiness more integrity
 - decrease soil erosion
 - increased watershed protection
- b) Birds: increase rare/uncommon forest dependent birds
 - decrease common/abundant edge dwellers
 - (Marsh: maintain migratory waterfowl flyways)
- c) Butterflies: increase diversity, facilitate movement

II. NO CHANGE: LOGGING OF PATCHES, PASTURES WITH CATTLE

- a) Forest Structure: initially increase edge effects
degradation of patches
eventual disappearance of patches
soil erosion, watershed degradation
- b) Birds: increase in edge dwellers/open habitat species continued loss of
primary/secondary forest species
- c) Butterflies: increase edge dependent species
loss of primary/secondary forest species

III. REALISTIC: LOGGING PATCHES AND REFORESTATION EFFORTS

- a) Forest Structure: patches become managed forests OR
converted to pasture
native mono/mixed culture stands
reduce soil erosion
potential watershed protection
- b) Birds: maintain edge dwellers, secondary forest species
if close to primary forest--forest dependent
facilitate movement between fragments
protect marsh-enhanced waterfowl use
- c) Butterflies: increase edge dependent species
loss of primary/secondary forest species

CONCLUSIONS:

- 1) If current land practices continue, both patches and watershed are likely to become degraded. Loss of biodiversity.
- 2) Corridor planning needs to include patch evaluations.
- 3) Uncontrolled logging may compromise potential benefits of the corridor.

RECOMMENDATIONS:

- 1) Protect/Reforest the Gamboa Marsh - Watershed Protection
- Migratory Waterfowl
- 2) Biological Inventory of Proposed Corridor Patches/Reserves
-Patch evaluations
- 3) Define Corridor Objectives and Priorities
- 4) Reassess Proposed Corridor Plan

MARKET CONDITIONS AND COFFEE PRODUCTION

Author: Pamela Stedman

Abstract

Coffee production is reviewed to examine the effect of market conditions, including policies and prices, on production and land use. Comparisons are made between national policies in Panama and Costa Rica and production and prices across time in Costa Rica.

Objective

The objective of this study was to determine the effect of market conditions on levels of coffee production in order to provide a basis for estimating the amount and intensity of land use for coffee production.

Methods

Two sets of comparative data were collected in order to evaluate the effect of market conditions on levels of coffee production. Because applicable data on land use was not available, data on production levels is used as a surrogate. Changes in production levels are indicative of changes in land use and/or intensity of production methods. The first comparison is between two similar coffee-growing regions, one in Costa Rica and one in Panama. Production can be expected to differ between the two because of different government policies and market opportunities. The second comparison is across time in Costa Rica, with a focus on the canton of Coto Brus. This comparison can be used to evaluate the impact of international coffee prices and quota systems on production. Data for both comparisons was gathered through informal interviews with large and small-scale coffee producers, coffee processors and exporters, input merchants, and extension agents, and from government documents.

Background

Coffee is an important export for many tropical countries. The instability of international coffee prices has led to various attempts by producer countries to control the market. International coffee cartels have established quota systems several times, most notably 1939-47, 1962-72, and 1976-88, which have all eventually collapsed because of the large number of participating countries, and the lion's share in production held by Brazil and Colombia. When in effect, quota systems have served to maintain higher prices. The last quota system collapsed during the 1988-89 harvest season, and prices in

the international market for all types of coffee have been very low since then (see Figure 1). Recent attempts to revive the cartel are floundering.

Findings

Policy Differences in Costa Rica and Panama

The Coto Brus canton of Costa Rica and the neighboring Chiriqui region of Panama are both important coffee-producing areas. They can be assumed to have very similar climatic and ecological conditions. Any differences in production intensity and amount of land given over to coffee production probably stem from differences in national policies and economic conditions in the two countries. Due to "renovation" programs in both countries two cultivars, caturra and catuai, predominate. A comparison of the two regions should provide a valuable estimate of the importance of national market conditions to coffee production. Unfortunately, recent data on production in Panama was not available. However, some comparison of government policies and relative export levels can be made.

In Panama, the government has maintained a "hands-off" approach in recent years allowing domestic prices to follow fluctuations in international prices. Producers sell to the *beneficios* (which carry out the first stage of processing and often are exporters as well), at the price on the day of sale. Panama participated in the various international schemes discussed above. About 50% of production in Panama goes to the domestic market, and there is no control of domestic prices. Prices for domestic consumers are determined by international market prices.

Most Panamanian coffee is produced in the northern region, in or near Chiriqui. According to local officials, there has been a substantial drop in production in the region since the beginning of the international crisis in 1988. Small producers in particular are taking land out of coffee and substituting vegetable production or pasture. Others are reducing inputs. Labor costs in Chiriqui run about \$5 per day, about the same as in Coto Brus. However, costs for other inputs, such as fertilizer, are higher than in Costa Rica. It can be expected, therefore, that the drop in these inputs may be higher in Panama than in Costa Rica. The drop in production in the region since 1988 was estimated variously between 15 and 50 percent. However, the large-scale producer interviewed, Cafe Duran, is increasing production in the hopes of an increase in prices or accessing specialty markets (gourmet coffees) in the U. S.

In Costa Rica, the Instituto del Cafe de Costa Rica (ICAFE) functions to buffer the producer and consumer from extreme fluctuations in international markets. While *beneficios* and exporters make contracts on the international market at reigning international prices, producers are paid in installments across the year. Thus, producers receive an average price for the year, rather than the price of the day of sale, which could be substantially lower (or higher) than the yearly average. This protects the producer from extreme fluctuations in the market, and also serves as a form of credit system,

providing a cash-flow to the producer throughout the year. Moreover, for the benefit of the domestic consumer, a certain amount of production (between 11% and 13%) is required to be set aside for national consumption, at lower than international prices.

Production of coffee in Coto Brus has fallen as it has in the adjoining region of Panama. Some producers are putting their land into other crops--primarily tequisque and tomatoes--and pasture. Others are reducing intensity by intermixing other crops--primarily plantain and tree crops--with coffee and by reducing inputs of labor and agrochemicals. Production in Coto Brus has fallen about 4% in the last year. Data on changes in production levels over time is discussed below. Looking at the differences in the marketing systems in Costa Rica and Panama, it seems that reductions in production levels, since the fall in coffee prices, may be greater in Panama, given the lack of a buffering system, than in Costa Rica. Further data would need to be collected to confirm this.

Coffee Production in Costa Rica Over Time

Production of coffee in Costa Rica, while showing an overall increase over the last twenty years, has fluctuated with international quotas and prices (see Figure 2). Costa Rican production rose from 6.8 million liters to 14.6 million liters between the 1976-77 and 1991-92 harvest years. Costa Rica has participated in all of the international quota schemes, usually within a share of 2% to 3% of world exports. Production has followed prices with some lag, creating a cyclical pattern in coffee markets (see Figure 3). Yearly changes in volume exported between 1983 and 1991 range from 1.4% to 66.9%, while yearly changes in prices range from 2% to 66.2%. Notably, the harvest year of the greatest percentage fall in export volume (1985-86) was also the year of highest increase in prices. The opposite occurred in 1986-87. Total value of exports has held more steady, since low prices are generally associated with high production and vice versa.

The fall in coffee prices, combined with an expansion of banana plantations in Costa Rica, has meant that coffee has fallen from its place as Costa Rica's number one export. As of 1991, coffee accounted for 14.8% of export value, compared with 35% in 1986. Bananas accounted for 28.2% of exported value in 1991.

Coffee productivity per hectare in Costa Rica is the highest in the world. The type of coffee produced in Coto Brus is known as Medium Hard Bean. This type of coffee is suited to the transition zone between very humid subtropical forest and humid tropical forest, areas with heavy rainfall and low-fertility soils. Coto Brus produces more coffee than any other canton in Costa Rica (see Figure 2). About 6,660 hectares were under coffee cultivation in Coto Brus in 1988. According to agricultural specialists, the region is particularly well adapted to coffee-growing. Therefore, Coto Brus coffee growers may be less likely to reduce production or shift to other crops in times of low prices than growers in less suitable regions. The available data appear to support this hypothesis. Nevertheless, interviews with local extension agents, farmers and the owners of an

agrochemical store revealed that Coto Brus coffee growers are reducing production. Some are practicing more intercropping with tree and fruit crops. Others are shifting to other crops, such as tomatoes and pasture. Almost all are reducing inputs. For example, according to the agrochemical salesman, most producers are now using only one application of fertilizer rather than two. However, Coto Brus remains the leading producer of coffee.

According to statistics from ICAFE, use of inputs has fallen all across Costa Rica (see Figure 4). This includes fertilizer, herbicides and fungicides. Labor inputs have also been reduced. In the 1990-91 harvest season, 60% of producers in Coto Brus reported that some beans were not harvested because of the high cost of labor; this compares with 39% for all of Costa Rica. However, reduction in the percent of producers using fertilizer inputs in Coto Brus was less than in other regions; but the percent using fertilizer was already lower in Coto Brus than elsewhere in the country. The failure of recent negotiations for a new coffee cartel may mean that more land will be taken out of coffee and production intensity reduced in areas remaining under coffee cultivation.

Conclusions

Coffee production is an obvious case in which international market forces (and to a lesser extent, national policy decisions) exert control over producer decisions about changes in land use. The environmental implications of these changes are complicated but critical, not only in these regions but in all coffee-producing countries. If intensity is reduced or intercropping increased, the effect is likely to be beneficial. However, if land is put into pasture or vegetable crops, degradation may be increased. National policies and international agreements should ideally be designed to buffer these effects.

Further Study

The Coto Brus and Chiriqui regions could provide some fruitful comparisons and insights into the effect of international markets on land-use decisions because of their similarity and long history of coffee production. However, readily available data is scant. A number of points deserve further study:

- the relationship between production and area of land under cultivation
- the environmental impacts of various production systems and intensities
- the crops chosen to replace coffee
- other feasible land-use and production systems for the area
- the difference between production costs and market prices

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**Figure 1. International Prices
US \$ per Pound -- Type Otras Suaves**

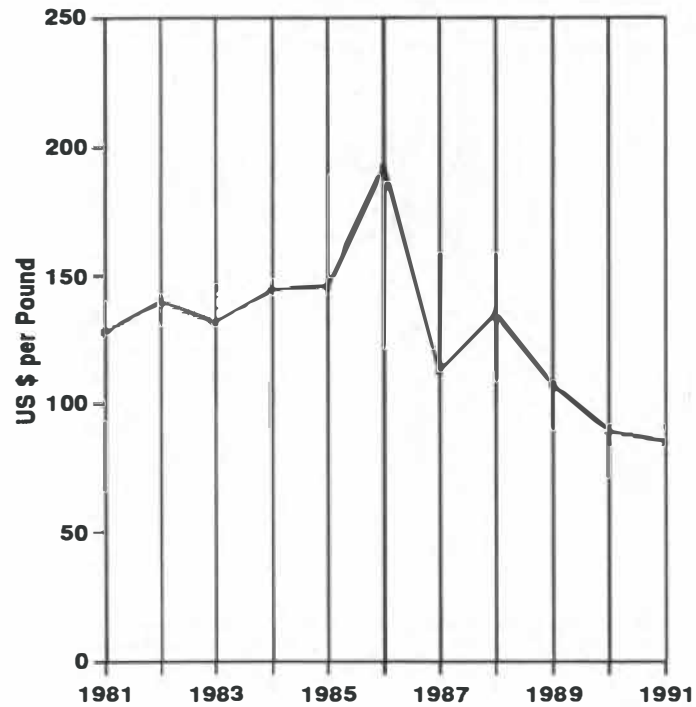


**Figure 2. Coffee Production in
Costa Rica and Coto Brus**

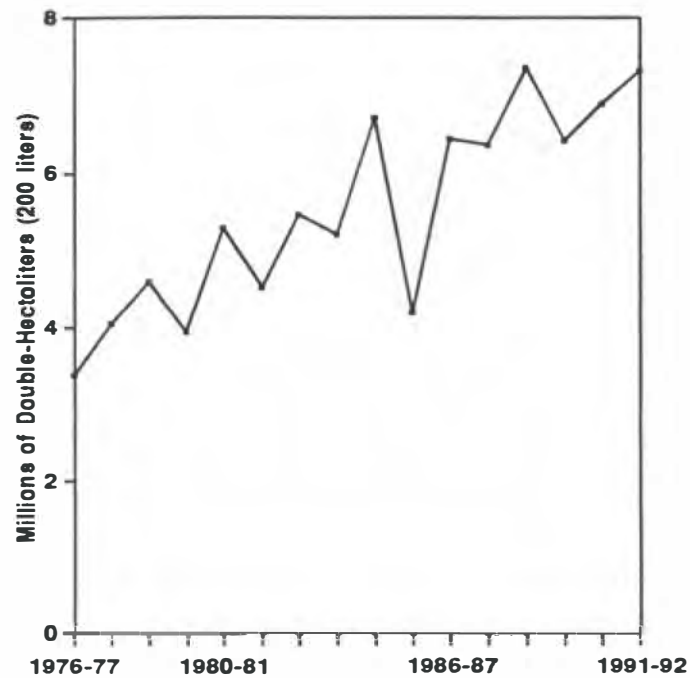


**Figure 3. Percent Change:
Exports and Prices**

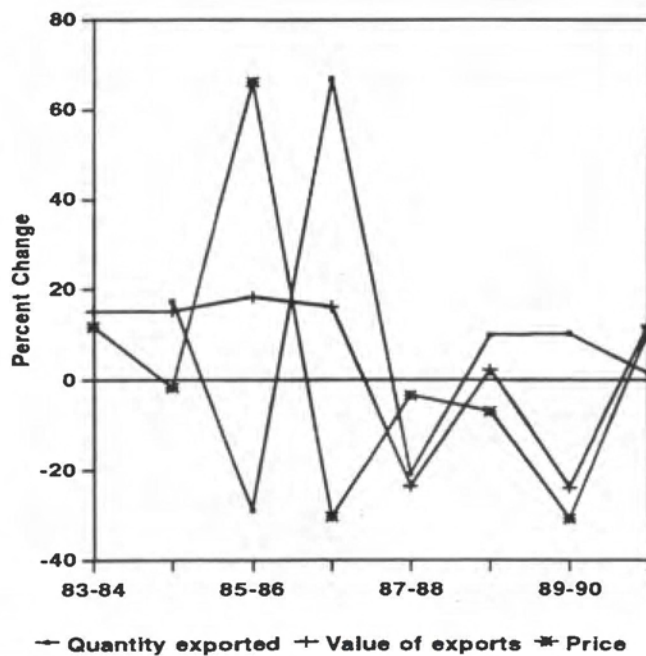
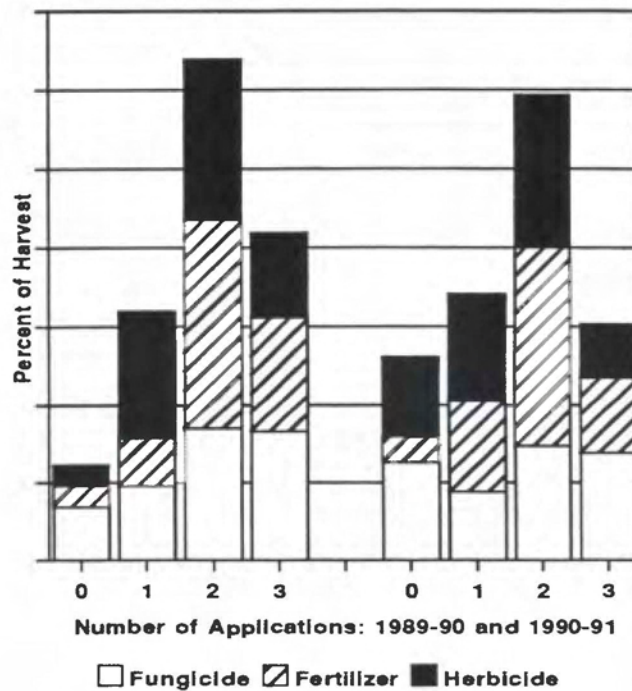


**Figure 4. Use of Inputs
for Coffee Production**



Independent Field Problem

THE POTENTIAL OF LAND USE POTENTIAL CLASSIFICATION

Author: Christopher Rosin

Resumen

El Concepto de la clasificación del uso potencial del terreno como una herramienta dentro la conservación fue estudiado. La habilidad de la sistema para determinar las areas de la degradación probable fue reconocida; sin embargo, fue criticada en caso de su omisión de las factores sociales del uso del terreno. Un estudio del sitio sobre las percepciones de agencia de extensión agricola y del agricultor revelaron las racionalidades basicas del uso ineficiente del terrenos en Cantón Coto Brus.

Abstract

The concept of land use potential classification as a conservation tool is examined. The system's ability to determine areas of probable degradation is recognized; however, it is also criticized due to its disregard of social factors of land use. A case study of agricultural extension agent and farmer perceptions of land use reveal underlying rationalities of inefficient land use in Coto Brus Canton.

Land use potential is dependent on both physical and social factors. Climate, topography and soils--and their interactions--may limit potential land uses while encouraging others. On the other hand, human interpretation of a landscape and the ability to augment natural processes may cast aspersions on such limitations. A desert, for example, might limit potential due to the lack of precipitation. An enterprising farmer, however, may recognize the agricultural potential of the cloudless days and level land, and with the aid of irrigation and fertilizer, grow vegetables and alfalfa.

Human ingenuity and self assurance have often been the cause for environmental degradation as well. The exploitation of particular lands thought to offer some level of agricultural potential have, instead, frustrated the farmer and resulted in that land's evolution to a denuded state. In an effort to minimize such impacts, lands may be classified according to their potential. Most of these classification schemes are based on that of the USDA which classifies land into eight classes ranging from excellent farm land with no limitations to land restricted to protective plantings (Classes I-VIII). Classes are established by their physical properties, particularly slope (as a factor of erosion), climate, and soil properties (Peace Corps, 1985). Using this system facilitates the determination of lands that can justifiably be exploited.

The rationalization of landscapes on the basis of physical restrictions is not always readily assimilated into human perceptions of that landscape. Where an agronomist or soil scientist might classify land as too steep for crop production, a land manager can distinguish a potential livelihood. Fallowing, terraces, and intercropping patterns offer protection against potential erosion making production possible. Furthermore, economic, land tenure, and cultural factors may necessitate the exploitation of a particular land parcel. Land use potential classifications may, thus, present elegant blueprints for land use decisions, but fail to assess the humanity of a landscape.

The canton of Coto Brus, Costa Rica is one such human landscape. The steep broken hills of the region would potentially prohibit some agricultural uses of the land. Much of the region, however, has been subject to deforestation and the land put into agricultural production. Small holdings of coffee and vegetables are interspersed among larger pastures. Maize and bean are secondary crops primarily intended for consumption. The mismatch of potential and actual uses is referred to as land use inefficiency (Laurent, 1992).

Underlying the inefficiency of land use, one would expect to find farmer perceptions of land potential which contrast with those of the classification system. This paper attempts to uncover some of the factors governing land management decisions among small holders in Coto Brus Canton. The intent is to provide a descriptive analysis of their decision making processes, as well as to assess the applicability of land potential classification.

Methods

The study relied principally on informal interviews aimed at land use perspectives and perceptions. A total of 20 interviews were conducted, one with the head of the local Ministry of Agriculture (MAG) extension office and the remainder with small farmers from the communities of El Cieba, Concepción, Valle Azul, Alfa, Bajo Reyes, and Santa Teresa. In all cases, the interviews focused on the cultivation of steep lands--its advantages/disadvantages, the recognition of degradation, the use of conservation practices, etc.-- but farmers were encouraged to express their conceptions of land management, as well. The factor of slope was given emphasis in the study as it was considered to be the primary limitation to cultivation in the region.

Extension Service Perception

The interview at MAG established a baseline of extension agent perceptions of farmer motivation. The head of the office, Ingeniero Chavez, readily recognized the land use potential classification system. A classification of Coto Brus Canton had been conducted, but as part of a national level analysis. He claimed that a majority of Coto Brus agricultural land was Class III (i.e., suitable for cultivation with extreme limitations) and that the average slope for these lands was 20 - 25% and ranged from 5 - 70%. Most

of this area was planted to perennial coffee which provided good ground cover. According to Chavez, these lands were being cultivated as the sole means of the farmers' livelihoods.

Based on the necessity of extensive farm use as a means of survival, Chavez suggested that land use was rather indiscriminate in regard to classification. Small farm size resulted in extensive use of land holdings with little area for land consuming conservation practices. Farmers were also perceived as having minimal time or capital to invest in these practices. The extension service encouraged farmers to utilize contour strips, live barriers, diversion canals, and terraces; however, despite a good reception from the farmers, the suggested practices were seldom initiated. Chavez believed that farmer participation in conservation projects was dependent on incentive programs (i.e., the office had 242 farmers enrolled in a FAO Alimentos para el Mundo program which provided 7,000 Colones of food per month for six months to farmers following conservation guidelines).

The impact of MAG extension services is evident in farmer recognition of conservation practices. Areas where farmers either practiced or indicated the possibility of practicing conservation practices were sites experiencing greater contact with extension agents. Among these farmers, live barriers, contour cultivating and diversion canals were reiterated as solutions to degradation.

Current Land Use Perceptions

Farmers' perceptions, as expressed in their interviews, only partially confirmed MAG's understanding of farmer actions. Many farmers indicated some sense of indiscriminate land use based on the necessity of exploiting the entirety of their limited resource. Several farmers, however, differentiated land use according to landscape characteristics. Coffee cultivation was preferentially located on flat to steep slopes (slopes allowing greater disease resistance) and Andesols. Land would be classified as too steep and, thus, is subject to lower production or use as pasture. Often low lands which required drainage were the last to be exploited. In one instance, trees were being planted on the steepest land.

The conditions of soil degradation were also generally recognized by the farmers. Criteria for analyzing the soil included color, compaction, weed types, presence of superficial roots, and coffee production. Degraded areas were described as being washed (lavados), without leaf litter, susceptible to dry periods, and containing bad weeds. Soil degradation was commonly viewed as a matter of concern, especially in the face of increasing costs of chemical inputs.

Responses to observed degradation varied among farmers. The most readily recognized and employed conservation practices were ground cover, trees and tanqueadas. Most farmers interviewed at least occasionally practiced weeding by machete. This

method conserved the root mass of the weeds and the above ground mass was used as a mulch. Shade trees were also commonly interplanted with the coffee for additional ground cover and leaf litter. Tanqueadas are often placed in steeper coffee fields and consist of a system of 50 x 100 x 40 cm (approximately) holes between coffee rows. The holes act as small catchment basins, slowing the flow of water down the slope and trapping soil and litter. The system requires a lot of upkeep as the holes fill rapidly with soil.

Less frequently observed practices were attributable to the distinct experiences of various farmers. Several farmers, especially in Alfa, with MAG or INA (National Learning Institute) contact had established water diversion canals along contours with live violeta grass barriers. Others were experimenting with various shade trees with the goal of greater litter production while maintaining compatibility with coffee. One farmer with coffee production experience from the Palmeros region practiced a form of terracing. He created level paths uphill from each row (planted along the contour) by shoveling soil to the other side of the row.

Farmers justified non-adoption of conservation techniques on economic grounds. Primarily, the practices were perceived as excessively labor intensive. One farmer had placed diversion canals in his coffee but lacked time and seed for planting the live barriers or maintaining the canals. Two interviewees, who relied solely on hired labor, found fertilizer applications and herbicides to be more cost efficient than conservation practices or machete weeding. Fields presented as examples of extensive input use were often those of farmers said to have little time. These conditions were exasperated due to low coffee prices.

Basis for Responses

Farmer perception of land potential and their response to impending land degradation fell into four groups and one subgroup. Each of these groups was distinguished by the farmer's rationalization of her or his relationship with the environment. This understanding governed their eventual management practices. As such, each farmer could be placed within a particular land ethic which will be referred to as "conservationist" with the subgroup "technician," "religious," "survivalist", and "economistic."

The archetype of the conservationist ethic is the farmer who attributes all actions to the stewardship of the environment. Conservation practices are employed, or will be employed, with respect to sustainability. Thus, farmland is protected and given care. The goal of management is compatibility with natural processes. All farmers practicing this ethic were actively pursuing improved conservation practices. Two of them were also members of their communities' ecological committees.

As a subgroup to the conservationist ethic, the technician is concerned with the health and sustainability of the land, as well. The environment's condition is, however, a by-product of particular practices. The farmer, as a technician, relies on good techniques which contribute to production and usually protect the farm ecosystem. Conservation practices were perceived as techniques which are beneficial to farm production. The farmer belonging to this classification used terraces and selected a specific coffee variety for its disease resistance. Each activity was principally a means of improving farm management in which conservation plays an important role.

According to the religious land ethic, stewardship is the result of one's relationship to God. The farmer asks for and receives guidance from God. Practices are employed as representative of God's nurturing character. Their value is determined by their success in respect to the farm's ecosystem. One farmer of this group explained the superiority of his practices (thanks in part to tithing) through comparison with the farm of a less dedicated neighbor. The religious farmer practiced traditional conservation methods and planned to include live barriers.

The survivalist strives to survive. Land represents a substrate from which to extract his survival. This ethic seems based in a more antagonistic relationship with the environment. The land gives what it wants and the farmer contributes only as much as will ensure continued survival. Thus, conservation practices which require additional labor or capital are not readily adopted. An extreme in this category, one farmer explained that he was too old to change and that his slash and fallow system provided sufficient food for his family's needs.

The final ethic, which may be an oversimplification, is the economic ethic. Questions of conservation are reduced to an assessment of economic costs and benefits. Emphasis is on immediate impact. Farmers following this ethic also perceive land as a resource to be manipulated. Those interviewed complained that low coffee prices restricted their inputs and implied that the labor involved in establishing conservation practices was more expensive than chemical additions.

The Potential

A classification of land use potential provides an excellent means of determining potential degradation. As such, it illuminates areas needing concentrated attention. The extension agent using a generalized classification could prepare programs focusing on conservation practices prior to visiting a site. The ability to identify these areas rests in the classification scheme's evaluation of physical characteristics.

The classification does not, however, consider the human factors of land use. In particular, farmers' understanding of degradation processes and their perceived need to cultivate for subsistence are ignored. Farmers in these areas believe that they can adapt to environmental limitations. They are not willing participants in programs that encroach

upon their current land use. In this case, the extension agent should prepare to work with the farmers' desires to manage the land and introduce techniques which contribute to extant knowledge and experience.

Finally, the farmers approach land use on the basis of certain land ethics. These ethics, rather than the physical properties of the landscape, determine land potential. The presence of these land ethics suggests that the extension worker prepare to approach a conservation program which can emphasize a variety of advantages which might appeal to differing ethics. Thus, the incentive program currently used by MAG may not always be necessary or desirable.

Further Study

The study was conducted within a very limited, non-random sample. As such, it has limited predictive applicability. Further research would ideally include a random sample of farmers and a survey of their social backgrounds. The resulting data would allow for a greater range of analysis. The study was also limited in its temporal assessment. Questions relevant to time include: Do land ethics remain constant? Does the incentive program realize continued practices beyond six months? What is the effect of continued extension services? and other questions.

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DEAD OR ALIVE: WHY DO COSTA RICANS USE LIVING FENCES?

Author: Jill Fischer

Resumen

Por medio de una serie de entrevistas informales afuera de Linda Vista y San Francisco se hizo un estudio del uso de árboles como cerca. Este proyecto tenía dos propósitos: 1) el determinar el por qué los costarricenses utilizan las cercas vivas (en vez de los postes muertos) y 2) el obtener un entendimiento general de cómo se construye una cerca viva (desde la selección de los árboles hasta el siembra de ellos).

Abstract

Through a series of informal interviews outside Linda Vista and San Francisco, a study of the use of trees as fences was undertaken. The purpose of this study was two-pronged: 1) to determine why Costa Ricans use living fences (as opposed to wooden posts) and 2) to obtain a general understanding of how a living fence is constructed (from tree selection to planting).

Introduction

Throughout the Costa Rican countryside, the use of living fences is a common practice. However, in other Latin American countries such as Mexico, Colombia, and Peru, fences are generally not constructed of trees. From this observation developed the curiosity as to why Costa Ricans implement this unique land management strategy.

As little information on the subject of living fences was available, the origin of the practice was difficult to determine. In 1841 however, a law was passed which required that all fences designed to protect fields had to be constructed of live trees (Monge - pers. com.). It is not clear, however, if this legislation had an impact on fence-building practices. When questioned as to why they used trees to form fences, none of the interviewees made reference to such a law.

Why Use Living Fences?

Tradition

When asked why Costa Ricans use tree stakes to build fences (as opposed to wooden stakes) the most common response was that it was a tradition or cultural practice. Most interviewees were not sure why they began using living fences, but all remember using nothing but live stakes in their fences.

Efficient

There are numerous reasons for wanting to use living fences instead of wooden posts. A practical reason for implementing this practice is that living fences are also efficient in terms of capital and labor. If one were to purchase the seeds, the structure could be costly to construct. Few people knew exact prices for the various cuttings used as initial building materials except for Caña de Indio cuttings. This ornamental was formally cultivated as an export crop, but recently the market became flooded. Presently, there is still an abundance of this tree as a result of the recent market problems, yet no market for it. Thus, it is common knowledge that c/\$ 5 is a fair price for one cutting of Caña de Indio. This price was not perceived as burdensome, as few people actually purchased the cuttings or live stakes. They were easily obtained from trees on one's own property. And, if for some reason one simply had no trees of their own capable of producing a cutting or live stake, it is common practice to obtain them from family members or neighbors; others took cuttings from the forest.

Unlike crops, once planted these stakes require no agro-chemicals. There are other inputs that may or may not be added to the fence. An unnecessary input that some chose to use in the construction of the structure is wire to connect posts/trees. This is quite costly, as the normal practice is to make two to three rows of wire; one role of 250 - 300 m costs c/\$ 1400 - 1500. As a result, the cost of building a live fence can vary: from quite inexpensive to costly.

In terms of labor, the initial input is relatively low. Although no one was able to give me exact figures, I was told that the cutting of branches used in fence construction was not time consuming. The planting did require more time, as small holes (the size and depth of which is determined by the individual species, the average size is 15 x 15 x 15 cm) must be made before placing the live stake into the ground; however, none of the interviewees believed that planting was a time consuming task.

Additional labor inputs vary, depending on the individual's tastes and the desired function of the fence. If the objective is to create a fence made of closely positioned stakes, it may be necessary to plant many trees over time. For example, many Itabo and Caña de Indio stakes are often planted close together to form a windbreak, or to keep small animals from passing through. As this example demonstrates, distance between trees is determined by the function of the fence, and in part by the species used. And, the more densely they are planted, the higher the labor inputs. Another example of fences that require more time and labor inputs are hedges, usually found near the house. One man who was interviewed stated that he trimmed his hedges once a month. In general, however, pruning is only necessary once a year or every couple of years.

In comparison with living fences, those made of dead posts do not appear to be as efficient in terms of capital and labor inputs. Although no actual figures could be obtained for the cost of a post, the perceived cost of the posts is quite high. This is

partially due to the high quality hard wood timber used in making the posts, and also due in part to the transporting of this material from the areas of lower altitude and hotter climate, where these trees prosper, to this region. Furthermore, these dead posts require frequent replacement as they last anywhere from two to five (and if the wood is of extremely high quality possibly ten) years, whereas live fences last a lifetime and never need replacement. Unlike the live fence, a fence made of dead posts requires wire, as there are no crowns that will grow together, no trunks that will widen over time, and no new fence-building material that will be produced by a fence made of dead posts. For obvious reasons, no chemical inputs are required when constructing structures of timber.

As was previously mentioned, the labor inputs are greater for the care of a dead wood fence, as a result of the need to replace them frequently. The wooden posts are also more labor intensive because their weight requires that a deeper hole be made, so that they do not easily fall over. Due to the thickness of the posts and the depth at which they are placed in the ground, they are perceived as being stronger; for that reason, they are often used in the construction of fences for cattle.

Other Uses

A common reason for which people use fences made of live stakes is that many other uses can be derived from the trees forming the structure. The most obvious reason is that people plant trees because they like them. Many are planted with the intent of beautifying the area; thus it follows that many trees with pretty flowers are planted close to the house.

Another desirable quality attainable from the fences is shade; however, in this region especially, even though shade is necessary finding the appropriate amount can be somewhat problematic. Because of the high rainfall, fungi can be a limiting factor in the production of certain crops, such as coffee. The land manager must look for a shade tree that will not provide too much shade, or the lack of sun over an area might encourage the growth of fungi. In terms of pasture, the farmer must also look for a tree that does not produce an overbearing shade, as too much shade will inhibit the growth of grasses. For that reason, a tree known as Targuá is not used commonly in fences surrounding coffee fields and pasture.

Firewood is a by-product of the living fences. Branches may be cut as needed from the trees forming the fence or entire trees may be cut from the fence. In either case, relatively hard wood trees, such as Guachipelín, are often selected for fence construction because they make good firewood.

Fruit for home consumption is yet another benefit that can be derived from the living fence. Trees such as Itabo that produce a flower that can be eaten, and many fruit trees such as Guayaba, Mango, and many citrus trees are common components of live fences. These trees define the boundaries of pasture land, coffee fields, and yards.

However, they are most prevalent in the latter two, as the fruit is for human consumption, and will more likely be eaten if close to consumer. One farmer said that he liked to have fruit trees surrounding his coffee fields so that he can take a break and eat the fruit while working in the field.

Green manure can also be produced by the living fence. One tree known as Llave del Bosque or Flor del Bosque is planted in fences surrounding coffee specifically for this reason; in the summer the tree drops its leaves which are apparently rich in nutrients, as farmers perceive them to be extremely beneficial to the soil.

Creating structures that act as both a boundary definition and a windbreak is a common practice in Costa Rica. The two most frequently used species in tapavientos (windbreaks) are Itabo and Caña de Indio. There are numerous other benefits derived from windbreaks. For example, they improve crop yields by creating more hospitable micro-climates. A windbreak will simultaneously maintain the existing organic matter by decreasing the amount lost due to wind erosion, and create more organic matter through the increased amount of leaf litter. Shelterbelts also decrease the amount of moisture lost through evaporation, both from open water and the soil surface. The amount of damage to crops as a direct result of the wind is also decreased with the presence of windbreaks.

Trees with medicinal properties, such as Indio Desnudo, are also frequently found in living fences. Again, because of this specific secondary benefit of a fence containing medicinal plants and trees, such fences would most likely be found closer to the house.

The last use of living fences expressed by the interviewees was that of land division. For obvious reasons the delineation of property is necessary for cultivated fields or pasture, but many people also felt the need to define property boundaries surrounding houses, as well.

Contrary to Gregersen, Draper, Elz (1898) and the OET (1986), farmers in this region do not plant fodder-producing trees in the living fences. Not one interviewee obtained fodder from the fences.

How are Living Fences Constructed?

The Decision-Making Process

The first decision to be made is the purpose the fence will serve; this is probably the most important piece of information in the decision-making process because it determines the options available to the land manager. For example, the process of species selection is determined by various other factors, the first of which that should be considered is, as was previously stated, the function of the fence. The second most important factor that the land manager considers is what resources are available. For example, if a number of cuttings are available to the farmer at no cost, he will most likely choose from those species. However, if the farmer must purchase the cuttings or seeds, his

decision will be based on the amount of expendable capital he has to determine the number and type of cuttings he can purchase.

Once the available species are determined, other factors come into play. Another important factor to consider is what species root well and grow quickly. After the possible species are determined and the choices are narrowed to those that are best suited to the conditions, the other factors such as personal tastes and the other needs that can be met by the live fence are considered.

The decision of whether or not to use wire is also dependent on a series of factors. Again, the first thing to consider is the desired function of the fence. If the farmer feels strongly about not wanting animals or people to pass through, he will most likely use wire to inhibit passage. The species used in the fence also play a role in the decision-making process. Instead of using wire, some farmers use young citrus (or even Poró gigante) trees in fences because they have spines.

Cutting

The farmers time the cutting of the branches to be used for living stakes with the waning period of the lunar cycle. It is believed that during the waning moon the plant should root quickly. What does the moon have to do with cutting trees? According to local farmers, during the waning moon, the agua (water/liquid) of the tree is in the branches and upper portion of the tree (i.e., the branches to be cut for the live stakes). This is considered important because the water will give the trees the strength needed to develop roots. One disadvantage of cutting at this time is the risk of losing this beneficial water. To avoid this, it is recommended to lay the stakes on their side immediately following cutting. They should remain in a horizontal position for three days, and after this period they can then be planted.

Because of this presence of liquids that coincides with the waning moon, the period during which the plant should root quickly is during the menguante (waning moon). When I questioned as to why the moon influences the water movement in trees, one interviewee explained that the moon affects the rise and fall of the tides (possibly due to gravitational pull), and thus, it seems logical that the moon is capable of affecting all liquids in nature.

To determine the appropriate period of the moon, a few generations ago, it was common practice to look at a cat's pupil. It was believed that during a waning moon (luna menguante) cats' pupils become noticeably smaller. The reason that farmers formerly judged the cycle of the moon in this manner (as opposed to looking **directly** at the moon) is that the cat method was believed to be a more accurate measure. One older interviewee informed me that during a waning moon there is a brief period in which the moon is waxing (durante luna menguante hay un período de creciente). Unfortunately, this practice is becoming extinct: only two of fourteen interviewees knew of this practice.

Presently, most farmers rely on the moon itself to indicate the appropriate time for cutting the live stakes.

Planting

In terms of planting the recently cut stakes, they do not require the same delicate treatment in planting, as does a crop. As was previously mentioned, a small hole is made (again, size is really dependent on species type) in which the stake is placed. The spacing between holes was discussed in an earlier section (efficiency of labor) and thus, does not require further mention.

Conclusion

The low capital and labor inputs required to construct a living fence, combined with all of the additional benefits the structure can provide make this land management strategy an attractive one. I find it interesting that such a system is not widespread outside the Cost Rican borders. One possible explanation of this low adoption rate in other countries is the lack of tradition: to my knowledge no other Latin American country developed legislation during the early years of independence requiring the use of living fences. It is my feeling that this law, although presently forgotten, fostered the custom of utilizing living fences.

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Independent Field Problem

MORE N, MORE PROTEIN, MORE LIFE, OR SOIL MACRO-INVERTEBRATE POPULATIONS UNDER NITROGEN FIXING AND NON-NITROGEN-FIXING TREES

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Faculty: Martha Rosemeyer

Introduction

In recent years there has been much attention focussed on the positive attributes of nitrogen-fixing trees. In this field problem I chose to investigate the diversity and abundance of soil macro-invertebrates under nitrogen (N)-fixing trees and trees that are not N-fixing, an area relatively unstudied. My hypothesis being that if a plant is able to fix atmospheric nitrogen for its own use then the plant will be less conservative with nitrogen and its leaf litter and decaying roots will be higher in available nitrogen which would provide more nutrients for other organisms. Soil macro-invertebrates, aid in the decomposition of organic matter, translocate organic matter and nutrients through the soil profile, improve soil structure, and serve as food sources for other organisms.

Materials and Methods

Soil was collected from beneath 3 N-fixing species and 3 non-N-fixing species. Three vegetation types were examined. The first was woody/herbaceous secondary vegetation, the N-fixing species of this type was *Flemingia macrophylla* and the non-N-fixing species was *Solanum jamaicensis*. The second vegetation type was woody secondary vegetation with *Calliandra Calothyra* being the N-fixing species and *Heliocarpus appendiculata* being the non-N-fixing species. The third vegetation type was woody forest vegetation where *Erythrina* sp. was the N-fixing representative and *Heliocarpus* sp. being the non-N-fixing representative.

For each vegetation type, soil was sampled from beneath individuals approximately the same height and dbh. Woody/herbaceous secondary individuals were 3 m in height and had multiple stems. Woody secondary individuals were 5 m in height and had a dbh of 6 cm. Woody forest individuals had a height of 3 m and a dbh of 4 cm. All individuals of the secondary vegetation types were within 30 meters of one another, however, the non-N-fixing individuals were not within the root zone influence of the N-fixing individuals. The forest individuals were all within 100 m of each other with the non-N-fixing individuals being beyond the zone of root influence of nitrogen fixing trees. All forest individuals were at the same elevation and on the same soil type.

All soil was collected on Finca Loma Linda, near Cañas Gordas, Costa Rica, August 6 and 7, 1993. Soil was collected by inserting a 8 cm PVC pipe into the soil

(4 cm the core) and then placed in a plastic bag. Soil was then brought back to the lab where the samples were placed in funnels lined with 2.5 mm mesh. A reading light was then placed over the soil samples and a vial of alcohol was placed below each funnel with the bottom of the funnel below the surface of the alcohol. After 48 hours the vials were removed from the bottom of the funnels and most of the alcohol was removed with a syringe making sure not to remove any of the insects. The contents were then mixed with a sugar and water solution, placed in a centrifuge tube and centrifuged for 3 min at 750 rpm. The sugar and water solution consisted of one liter water and 900 g of table sugar. This process separated the soil particles from the insects. The solution and insects were then placed in petri dishes and examined under the dissecting microscope. The individual insects were then identified to order or class and recorded.

Results and Discussion

As can be seen from Tables 1, 2, and 3 in all vegetation types, there were more soil macro-invertebrates under the N-fixing individuals. However, there were no statistically significant differences among the treatments. Possibly with a larger sample size differences could be elucidated. Suggestions for future research include: a larger sample size, leaving soil samples under the lights for a longer period of time, and placing soil in 3 mm mesh sieve above the funnel to allow more surface area for drying. With these modifications, one might be able to show differences in numbers and diversity of soil macro-invertebrates under N-fixing trees and non-N-fixing species.

Table 1. Woody Secondary Vegetation.

Insect Class/Order	N-Fixing					
	Calliandra calothyra			Heliocarpus appendiculatus		
	1	2	3	1	2	3
Dipluran		2			3	2
Thelyphondia		1				
Hymenoptera	10		2			
Hemiptera		2				
Coleoptera	6					
Diptera		4				
Pseudoscorpion					1	
Acari		2			1	
Symphylan				2		
Diplopoda						
Chilopoda						
Isopod	1					
Thysenura	3					
Total Individuals	20	11	2	2	5	2
Groups Represented	4	5	1	1	3	1
Total	Individuals		33			9
	Groups Represented		10			5

Table 2. Woody/Herbaceous Secondary Vegetation.

Insect Class/Order	N-Fixing					
	Flemingia macrophylla			Solanum jamaicensis		
	1	2	3	1	2	3
Dipluran						
Thelyphondia						
Hymenoptera	47	2	2		8	1
Hemiptera			1			
Coleoptera	2		1		1	1
Diptera						
Pseudoscorpion						
Acari			2		1	
Symphylan						
Diplopoda					2	
Chilopoda						
Isopod						
Thysenura	1					
Total Individuals	50	2	6	0	12	2
Groups Represented	3	1	4	0	4	2
Total	Individuals		58			14
	Groups Represented		8			6

Table 3. Woody Forest Secondary Vegetation.

Insect Class/Order	N-Fixing						
	Erythrina sp.			Heliocarpus sp.			
	1	2	3	1	2	3	
Dipluran							
Thelyphondia	2						
Hymenoptera	13	3	1			3	
Hemiptera	1						
Coleoptera	1	1	1	1	4	2	
Diptera							
Pseudoscorpion		1					
Acari	1		3	1			
Symphylan							
Diplopoda							
Chilopoda		1			1		
Isopod	1					1	
Thysenura	1						
Dermaptera	1			3	2		
Collembola	1		2		1	2	
Nuroptera			1				
Homoptera			1				
Total Individuals	22	6	9	5	8	8	
Groups Represented	9	4	6	3	4	4	
Total	Individuals		37				21
	Groups Represented		19				11

WHERE HAVE ALL THE BEJUCOS GONE?

Author: Amelia Oliver

Resumen

Sistemas de producción del bosque que utilizan productos no maderables ofrecen incentivos para la práctica de actividades sostenibles. Este estudio es de las industrias canasteras de pequeña escala de Coto Brus. Estos canastos forman un lazo importante en la industria cafetalera, pero su producción se está chocando con la falta de los bejucos. En este estudio se investigan los aspectos socio-económicos de la industria, además de los cambios que los canasteros hacen como respuesta a este choque.

Abstract

Nontimber forest production systems offer incentives for sustainable forest activities. This study is of the small-scale basket-making industries of Coto Brus. These baskets are an important link in the coffee industry, but their production is being confronted with a lack of the necessary vines. In this study the socio-economic aspects of the industry are investigated as well as the changes that are being made by basket makers in response to these limitations.

Introduction

As preservation of primary forests enters the spotlight of worldwide conservation efforts, there simultaneously exists the impacts these efforts may have on populations that depend on forest products. There is a need to explore the nature of small-scale nontimber production systems in order to properly implement policies and research agendas that do not ultimately destroy these industries, which often have existed for years on a sustainable basis. When practiced correctly they are not a threat to the forest. In order to increase local incentives to conserve natural resources, there needs to be a profitability attributed to sustainable forest activities.

The coffee basket industry of the Coto Brus region is an excellent example of an industry affected by two extreme forces: the limiting access to forested land generated by conservation efforts, and the declining availability of forest resources due to improper, unsustainable harvesting techniques. Baskets represent an important longstanding industry in the region, where coffee is a prominent crop. As the access to the supply of the vines diminishes, there is a trend toward alternative or imported baskets and basket making supplies. This study investigates the basket-making industry in Coto Brus, specifically concentrating on the reactions of makers in the region to the mounting constraints of the availability of materials.

Brief Introduction to Basket Making

A canasto is a basket specifically for coffee. It is constructed of bejucos vines, of the primary forest. These bejucos are primarily of the Bignoniaceae family. The finest quality vine available for canastos is called Cucharilla, which at present exists mainly in reserve areas where permits are needed to access them. A Cucharilla baskets can last up to ten years. Baston, the second most popular bejuco, is more difficult to weave, but is more prevalent in the region. These baskets last 3 - 4 years. The processes are similar for the two bejucos: searching and collecting the vines, dividing into strips, drying, and weaving. Often the Baston vines are woven before drying to simplify the process.

Canastas, on the other hand, are more ornamental baskets. They are usually made of miembros, roots of Araceae plants, also collected in primary forest. These miembros are easier to collect but are more tedious to weave. The process involves searching and collecting, bleaching, weaving, and drying. The market orientation of the canastas is completely different than of the canasto, but many of the canasto makers have diversified into this type of basket making.

Methodology

Four basket makers in the area were interviewed regarding the basket-making process, including: labor hours, travel time, availability of inputs, marketing and pricing practices, and overall perspectives on the basket industry. An income per day was calculated by dividing net revenue by labor days. In addition, three sites were visited where vines have been propagated in response to the existing supply constraint in the natural environment: the ecological park of San Vito (the vines are planted directly behind the Kodak store), the community educational park of Fila Pinar, and the property of Don Jesus in Valle Azul. At Fila Pinar the president of the ecological committee, Don Carlos Alvarado, was interviewed regarding this propagation project. The written proposal of Alice Benzecry provided important information regarding the ethnobotanical nature of the plants involved.

Basket Makers

Don Carmen Cascante (Melo)
4 K al este de la escuela de Siete Colinas
Siete Colinas

Don Jesus Arguello
Valle Azul de Agua Buena
Pulperia de Don Rejulio Lobo

Don Miguel Jimenez
Las Cruces
Contact: Ana Herra of the cocina at WBG

Don Pablo Alpizar
Valle Azul de Agua Buena

Results

All basket makers in the region supply baskets on a demand basis. They all have land and are, therefore, also involved in some sort of farming. Each has their own personal flair which is reflected in their basket styles. At the time of interviewing, just before the coffee harvest, all were busy making coffee baskets. It is interesting to note that a fifth basket maker was pursued in Sabalito, Don Danilo Cascante, but he had moved to Puriscal to work at the basket factory.

Don Melo is a third generation basket maker, and is the father of 13 potential basket makers. He is well-known throughout the region for his quality coffee baskets, although he resides in remote Siete Colinas. As of two years ago, he weaves exclusively with Baston, which he can locate near his home: travel time to the vine locale is 2 hours round-trip. In one trip he finds enough vines to make approximately five baskets. He has perfected the art of Baston basket making, and although he prefers the Cucharilla baskets, both in terms of weaving and quality, he will continue to make quality baskets with Baston, given the lack of Cucharilla. On a per day basis, he can make approximately 625 colones/day.

Don Jesus of Valle Azul is another old-timer basket maker. Presently he is making both canastos and canastas, for which he receives 560 and 300 colones/day, respectively. He insists that he uses Cucharilla exclusively, although where he locates these vines is ambiguous. He must travel far to gather vines: three days collecting enough for 10 baskets. Don Jesus has recently begun propagating vines on his property. He predicts that in three years he will be able to harvest. The site he choose was heavily shaded and next to a creek. Stalks had been planted and all had sprouted at least once.

Don Miguel lives close to the Wilson Botanical Garden. He has been making baskets for 10 years and specializes in canastas. He has easy access to miembros, and he can make 1370 colones/day from canastas, as compared to 715/day for canastos. He finds canasto making boring and would like to concentrate on canastas.

Don Pablo makes baskets and spends no time locating bejuco. He purchases them in Panama. His baskets are a mix of bejuco, hose, and wire, where the bejuco is the body of the basket, the wire is the frame, and the hose is the rim. He can make 840

colones/day making these canastos. He is not a real enthusiastic basket maker and would much rather branch off into more exciting enterprises, such as macrame.

The prices varied among the basket types. Bejuco baskets cost about 500 colones, depending on size and bejuco type. The mixed baskets of Don Pablo cost 700 colones. Ones constructed exclusively of hose and metal sell in San Vito for 600 colones. And the 100% plastic imported baskets cost 1270 colones.

All the basket makers expressed concern regarding the availability of bejuco. The more experienced weavers attributed the lack of bejuco to the careless harvest practices of the inexperienced. If harvest correctly, the vine will sprout. It is also a concern of the elders to cut only what is needed. When a vine is cut, all of it should be harvested instead of carelessly cutting off just what is needed, leaving the rest.

The potential for propagation of the bejucos, the outlook is relatively positive. All basket makers, especially Don Carmen, expressed interest. The bejucos planted in the San Vito botanical garden by Alice Benzecry four years ago were thriving and appeared well adapted to the site. Don Jesus' propagated vines also appeared rather adaptable, although he would need more plants to keep up with his production level. The project in Fila Pinar was not so optimistic. The vines, which were apparently planted one year ago, are still tiny. But it is more inspirational to note that the ecological committee has realized the problem with the bejuco shortage and is acting upon it.

Conclusions

Given the constant demand for coffee baskets in the Coto Brus region, without a dependable supply of bejucos for baskets, alternative products will continue to be demanded. The negative consequences that synthetic baskets may have are plenty: 1) they are more expensive, 2) they deteriorate more quickly due to the acidity of the coffee, 3) they may effect the quality of the coffee, 4) they will effect the local basket industry, 5) they will increase dependence on imports, 6) they are difficult to dispose of, and 7) there will be a lost potential of a possibly sustainable forest industry.

In order to save the basket-making industry of Coto Brus, there needs to be bejuco available to the basket makers. To properly analyze the harvesting techniques and to make conclusions regarding the sustainability of these practices, there needs to be more information. Otherwise the exact location, type, and method of harvesting remain unknown. If this industry could be maintained sustainably, the value of the remaining primary forest would increase for those that depend on bejuco baskets. The permit policy also needs to be more carefully examined.

Biological research into the harvesting methods, regeneration, and propagation possibilities for bejucos are other important instruments for measuring the sustainability of the basket-making industry. Insights into these options could shed light on the case of the

bejuco basket makers, securing both the forest conservation efforts and the economies of the weavers families. Successful forest conservation depends on small projects such as these, which sustainably utilize the forest resources while offering economic benefits to the local households.

Acknowledgements

I would like to acknowledge the following people for their ideas and assistance on this project: Martha Rosemeyer, Ana Herra, Luis Diego Gomez, Gail Hewson, and Carlos Valerio.

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CATTLE IMPACT ON SOIL IN PASTURELAND

Author: Brent Blair

Abstract

Cattle pastures currently cause a large amount of land degradation throughout most of the wet tropics. Due to the predominating soil types in these areas, degradation, while grazing cattle, appears to be unavoidable. The purpose of this study was to try and quantify cattle impact on pasture soil. This was done by gauging infiltration rates and soil compaction in a severely degraded cattle pasture. Three major areas were tested: a gently sloping hill with little overall erosion, a slump, and a steep slope created by the slump. Within these areas three microsites were examined: highly degraded cattle trails, moderately degraded cattle trails, and grassy areas without trails. The results found that the lowest level of compaction and highest levels of infiltration were found in the grassy areas, while highest levels of compaction and lowest rate of infiltration, in general, were found in the cattle trails.

Introduction

There are two basic impacts associated with the grazing of cattle: soil compaction and erosion. The first impact is caused as cattle walk around a pasture foraging for food. As the cattle graze they form interconnecting trails through the grass. These trails gradually are denuded of vegetation and become deeper, and over time compaction increases.

Erosion occurs after the vegetative cover has been lost. In order for the process of erosion to begin, two conditions must be met: 1) the soil must be dislodged through rain or other means, and 2) movement of soil down-slope must occur (usually by rain). The rate and amount of erosion on a trail will depend on the intensity of use, the slope, and soil type. In a naturally forested area, erosion is not a problem because the vegetation absorbs most of the impact of the rain. When rain does reach the soil, the organic layer provides pores for waterflow while the root system holds this layer together, thus preventing soil loss.

The present study took place on a degraded cattle pasture owned by Lynn Carpenter. It is located in Costa Rica near the Las Cruces Biological Station. This pasture had been abandoned for four weeks prior to my investigation.

There were three main areas within the pasture that I observed: 1) low hills that had experienced relatively little erosion, 2) a soil slump and, 3) a steep slope that resulted from the slump. Within these areas I identified three distinct microsites: severely

degraded cattle trails, moderately degraded cattle trails, and grassy areas with no trails. This amounted to a total of twelve sites.

There were three hypothesis that I hoped to test: 1) The more severely eroded the area, the more compacted the soil would be. 2) The more eroded the area, the slower the rate of infiltration. 3) The percent of water in the soil should be less in the more compacted soils.

Methods

I looked at two different aspects of soil condition to determine cattle impact, water infiltration, and soil compaction.

Two methods were used to gauge infiltration. The first involved using a 3 x 20 cm long PVC tube. With this I took three 5 cm deep core samples from each of the 12 sites studied. In the lab I saturated the soils by filling the tubes with water and leaving them overnight. The following day I added 150 ml of water to each sample and put them in a funnels placed on top of beakers. After twelve hours I measured the amount of water that infiltrated the soil and thus got the rate of water flow per 12 hours. Although this was a crude method that probably does not reflect true infiltration rates, it proved useful in comparing different areas within the pasture.

The second method used was to gauge infiltration through the use of the percent of water present at each site. One sample was taken at each site. This was employed to see if more degraded sites had a lower percentage of water than those of less degraded sites.

Compaction was also measured in two ways. The first was through the use of a penetrometer, a hand held tool used to measure the force needed to penetrate soil. Although this is a very quick and simple method, there is great variability in microsites within each site tested. For this reason I took a total of fifteen samples in each of the twelve sites in order to obtain an average value.

The second method used was to take cores to determine bulk density. This was done at two sites, one on a highly degraded trail on the low hill and the other within secondary forest. This was done to see what the differences are between a relatively undisturbed forest and a cattle disturbed site. Seven samples were taken from each site at increasing depths, from the surface to 45 cm below the surface of the soil.

Results

Infiltration rates ranged from 0 ml per 12 hrs to 120,000 ml per hour, with the higher rates tending to correspond to grassy areas (Table 1). The highest rates were found in the grassy area on the hill. Paths with moderate and severe erosion tended to have

considerably lower values. It was not apparent from my data whether rates were different between moderate and severely eroded trails or between the slump and the steep slope.

The percentage of water within the soil was highest in the grassy areas on the hill (40.9%) and slump (42.6%). The grassy area on the steep slope was unusually low (29.7%) and it is unclear if this was a measurement error or if this reflected true water content. In all areas the moderate and severely degraded trails had values ranging from 32 to 36 percent water (Table 2).

The penetrometer results for the hill and slump areas were as expected (Table 3). The force needed to penetrate the soil surface increased from the grassy areas to the moderately eroded trails to the severely eroded trails. Differences between the hill and slump at different microsites were unclear. The steep slope had different results. All three microsites were relatively similar. The reason for this appears to be due to the type of erosion occurring in this area. Since this is an extremely steep slope, the soil is eroding away at a faster rate than in other areas. Here there are actually small landslide like deposits in most of the eroded areas. This results in extremely soft soil that resembles that of the grassy areas.

The bulk density results were as expected (Table 4). The surface of the cattle trail had the highest bulk density of 1.22 g/cm^3 . At the forest's surface the bulk density was only $.90 \text{ g/cm}^3$. While the cattle trail's value decreased gradually over time to 1.07 g/cm^3 in the seventh core, the forested area's bulk density stayed about the same at all levels.

From these results it does appear that infiltration and compaction are significantly affected by the presence of cattle trails. It is less clear, however, if the region that the trails are in and their condition are important in determining the magnitude of these impacts. Further study is needed with a more advanced infiltration method and a larger sampling size for all tests. For any true determination of effects, a full analysis of the types of soils in each site is necessary. This study has, however, given a preliminary view of the effects of cattle on pastureland soil.

Table 1. Infiltration.

	Hill	Slump	Steep hill
Grass 1	1000.0	0.0	3040.0
2	12000.0	3000.0	280.8
3	120,000.0	2000.0	33600.0
Moderate erosion 1	0.0	0.0	0.0
2	2.5	0.0	370.0
3	6000.0	0.0	.6
Severe erosion 1	.5	1.2	no data
2	0.0	1.8	no data
3	20.6	.6	no data

Table 2. Percent Water.

	Hill	Steep slope	Slump
Grass	40.9%	29.7%	42.6%
Moderate erosion	33.4%	35.2%	32.2%
Severe erosion	33.7%	32.5%	35.7%

Table 3. Penetrometer.

	Hill	Hill avg.	Slump	Slump avg.	Steep hill	Steep avg.
Grass 1	.86	.61	.32	.45	.86	.64
2	.54		.40		.66	
3	.42		.62		.42	
Mod. eros. 1	1.3	1.14	1.14	.91	.74	.94
2	1.3		.62		1.20	
3	.82		.96		.88	
Severe eros. 1	3.28	2.81	1.10	1.47	1.04	.76
2	2.48		2.62		.72	
3	2.66		.70		.52	

Table 4. Bulk Density.

Hill	% water	Bulk Density g/cm ³
1	28.6%	1.22
2	no data	1.19
3	31.27%	1.06
4	32.75%	.99
5	34.47%	1.02
6	35.20%	1.01
7	36.25%	.97
Forest		
1	37.77%	.9
2	36.61%	.95
3	36.87%	.97
4	37.87%	.87
5	37.96%	.92
6	38.7%	.9
7	40.1%	.91

ARTIFICIAL PERCHES AND PERCHES WITH FRUIT AS TOOLS TO ENCOURAGE FOREST REGENERATION

Author: Bruce G. Ferguson

Resumen

Este estudio trata de refinar una metodología para aumentar regeneración natural por atraer agentes de dispersión de semillas a pasto con perches artificiales y con frutas. Parejas de perchas eran establecidos a intervalos de 10 m., empezando 10 m. desde un parche de bosque secundario y extendiendo 100 m. dentro del pasto. Trampas para semillas estaban puestos debajo de las perchas y observaciones visuales eran hechos para tres mañanas en sucesión. Uso de las perchas estaba poco, nada de la fruta era comido, y ningunas semillas eran encontrados en las trampas. Basado en estas resultados y observaciones suplementales, unas ideas para mejorar la metodología están sugeridos.

Abstract

This study seeks to refine a methodology to encourage natural regeneration by luring seed dispersal agents into pasture using artificial perches and fruit. Pairs of perches were set up at 10 m intervals, starting 10 m from a patch of secondary forest and extending 100 m into pasture. Tarps were placed beneath the perches to catch seeds and visual observations were made over three successive mornings. Use of the perches was light, none of the fruit was eaten, and no seeds were found on the tarps. Based on these results and supplemental observations, several suggestions for improving the methodology are made.

Introduction

Seed dispersal is a vital step in natural regeneration of forests in highly degraded areas (for more background see, "An examination of regeneration in an active pasture", La Selva section). Seed dispersal requires both a seed source (a sufficiently diverse patch of forest) and a seed dispersal agent (commonly wind, birds, bats or other animals) capable of carrying a seed from the seed source to the degraded site. Birds and bats, perhaps the most important seed dispersers in the tropics, may be reluctant to leave the safety of forest cover for open pasture. The purpose of this study was to test a methodology for using artificial perches and artificial perches hung with fruit to lure seed dispersers into a pasture. I also sought to determine how far these methods would draw dispersal agents into pasture.

Methods

My study site was located at Lynn Carpenter's farm, near the town of Agua Buena, at an average elevation of about 1070 m. I chose a north-facing slope with a fence line at the top and secondary forest bordering a stream at the bottom. On August 5th I set up 20 artificial perches in pairs 6 m apart with 10 m between pairs. The first pair of perches was about 10 m from the secondary forest and the last pair was 10 m from the fence line. Each perch was an oak branch about 2 - 2.5 m long with about 0.3 m below ground and a 0.5 m long cross piece lashed on about 1.5 m above the ground. I randomly assigned fruit to one of each pair of perches. I used half of a large exotic fig from the Wilson Botanical Gardens on each fruit perch throughout the experiment and added a banana on the morning of August 7th. I stretched a 1 x 0.65 m plastic tarp below each perch. Each morning on August 6th - 8th I checked the fruit for signs of feeding and the tarps for seeds that might have been excreted by dispersers visiting the perches and fruit. I observed the perches for 2.5 - 3 hrs. each morning and attempted to identify birds landing on them and time their visits.

I also attempted to identify other birds I observed in the pasture and the forest edge. On the 7th I hung a fig and banana just inside the forest edge and returned 24 hours later to see if they had been eaten. Additionally, for 24 hour periods beginning on the 6th and 7th I stretched a 6.4 x 2.3 m plastic tarp in the pasture and the forest, respectively, to measure "background" seed rain in each habitat.

Results

I found no signs of feeding from fruit on the perches or of bird droppings on the tarps below the perches on any of the three mornings. I also found surprisingly little interest in the perches or fruit on the part of birds during my morning observations (Table 1). Few birds used the artificial perches and there was no apparent preference for perches with fruit, nor did birds that landed on perches with fruit seem to notice the fruit. There seemed to be some preference for perches closer to the forest, but a clear pattern is not apparent from such a small data set.

I found no seeds on the background seed rain tarp left overnight in the pasture, while I found seeds of eight species on the tarp left in the secondary forest. Most of these seeds seemed to have fallen from the vegetation surrounding the tarp or to have been wind dispersed. The one bird dropping on the tarp was mostly insect parts. However, my observations of birds in the pasture and on the forest edge (but not on artificial perches) demonstrate that potential frugivores and seed dispersers are present in the immediate vicinity (Table 2). Furthermore, although the fig hung overnight (just inside the forest) it was untouched. The banana seemed to have been completely consumed with just a piece of peel remaining on the ground below.

Discussion

There are several possible explanations for the failure of the perches and fruit to attract more seed dispersers and the failure of the tarps to catch seeds: 1.) Dispersers may simply be reluctant to enter open areas despite the lure of fruit and perches. 2.) My artificial perches appeared to be competing with natural ones. I observed several birds perching on weedy pasture growth, though they did not seem to be the same species frequenting the forest edge. 3.) The fruit on the perches may be competing with the forest fruits that form local frugivores' search image. 4.) Different types of fruits may be more appealing to different birds and bats. The banana hung in the forest was eaten in preference to the fig, and other species may be still more appealing. 5.) Dispersers may take time to find and exploit new food sources and perches. My perches showed somewhat greater use on my final day of observation and this trend may have continued with more observation. 6.) Dispersal may be highly seasonal since birds are more diverse and abundant in Costa Rica during the northern winter. Furthermore, many trees fruit near the end of the dry season so there are probably fewer seeds available for dispersal in August. 7.) The tarps I had available to put below the perches seemed too small. Furthermore, there was rain every day that would have washed any seeds away from the slippery plastic surface.

Based on these considerations, I have several ideas to refine my methodology:

- Observe use of natural perches before setting up artificial ones. Artificial perches may only make sense where natural ones are unavailable.
- Experiment with perch height. Shorter perches may attract birds like the Blue-black Grassquit that seem to prefer low vegetation, while taller perches may be more noticeable to birds, such as parrots, that frequent tree-tops.
- Experiment with different fruits as attractants. Fruit taken from nearby forest may be a good choice.
- Try the experiment continuously throughout year.
- Use larger tarps and straight poles that are easy to center over the tarps. "Living fence-post" species may provide straight, durable perch poles, as well as improved microhabitats for seedling establishment.
- Develop a funneling seed trap that catches seeds on a screen so as not to lose seeds in the rain.

I believe that with such experimentation and refinement, an effective methodology can be developed for the use of fruit and artificial perches to encourage natural regeneration.

Acknowledgements

I would like to thank Lynn Carpenter for her advice and the use of her land and Brent Blair for helping set up the experiment.

Table 1. Observations Of Birds Coming To Perches. Perches Are Numbered According To Their Distance From Secondary Forest.

Date	Perch	Species	Time at Perch
August 6	60 west*	Unknown	1 min.
August 7	10 east*	Unknown	< 1 min.
August 8	30 east	Blue-black Grassquit**	5 min.
	100 east*	Unknown	1 min.
	20 east	Blue-black Grassquit**	17 min.
	20 east	Blue-black Grassquit**	8 min.

* Perches with fruit.

** These were probably the same individual, a male that seemed to be performing a mating display for most of his time at the perches.

Table 2. Birds Seen From Study Area, But Not At Artificial Perches.

Habitat	Species	Diet*
Edge shrubs and 2° forest trees	Yellow-faced Grassquit	Grass seed, berries, insects
	Scarlet-rumped Tanager	Fruits, berries, arthropods
	Red-crowned Woodpeckers	Arthropods, fruit, nectar
	Blue-gray Tanager	Berries, arillate seeds, nectar, arthropods, leaves
	a large flycatcher green parrots	Insects Fruit, nuts, seeds
Large pasture trees	green parrots	Fruit, nuts, seeds
Low pasture growth	Blue-black Grassquit	Grass seed, insects, berries

* Stiles, F. G. and A. F. Skutch. 1989. Birds of Costa Rica. Cornell University Press, Ithaca, New York.

Independent Field Problem

LEPIDOPTERA LARVAE-BEETLE INTERACTIONS ON *ZAMIA FAIRCHILDIANA*

Author: Keith Taulbee

Faculty: Gail Hewson

Resumen

Se hizo una análisis de la relación entre *Zamia fairchildiana*, las larvas de la Lepidoptera *Eumeaus minyas godoartii*, y un bicho no descrito de la familia Languridae. El número de individuos, su distribución espacial, y su comportamiento. Además, experimentos del campo y del laboratorio fueron hechos para examinar otros componentes de las historias de la vida de las larvas y los bichos. Este estudio provee solo una análisis inicial para estudios futuros acerca de este sistema que es poco entendido.

Abstract

The relationship between the cycad *Zamia fairchildiana*, the larvae of the Lepidoptera *Eumeaus minyas godoartii*, and an undescribed beetle of the family Languridae was examined. The number of individuals, their spatial distribution, and their behavior was recorded. In addition, field and laboratory experiments were performed to test other components of the life histories of the larvae and the beetles. This study provides only the initial framework for possible future studies of this poorly understood system.

Introduction

Eumeaus minyas godoartii larvae are gregarious upon the otherwise highly toxic leaves of the cycad *Zamia fairchildiana*. Like most cycads, *Z. fairchildiana* produces azoxyglycosides, which are highly toxic to humans, and have caused paralysis and death in cattle (Janzen, 1983). The larvae are able to eat all parts of the cycad, however, including the stem cone parts, and seed coats (Janzen, 1983), and they likely receive chemical protection from the plant as well, as evidenced from their pungent smell and bright coloration.

In addition to being able to eat the cycad *Z. fairchildiana*, the larvae are also able to eat the closely related *Zamia skinneri*, which is only located in the Atlantic side of Costa Rica's Continental Divide (Janzen, 1983). The level of herbivory can be intense, and some *Zamia* plants have been killed by over grazing.

At least one, and most likely two, species of Languridae beetles are often found in association with these larvae. The Langurids are a poorly understood group, especially in

the New World, and neither of these species have been described. These beetles are usually found on leaves or petioles that have been herbivorized by the larvae, and they are also seen touching the larvae occasionally. They also feed upon the surface of the pupae, and continue to feed even after the pupae have emerged (Hewson, pers. comm.).

The question remains, however, as to what type of relationship exists between the Langurid beetles and the butterfly larvae. Possibly, it is a type of mutualism, in which the beetles receive nutrients from the larval residues, and perhaps some type of chemical protection as well. In return, the beetles could be removing fungi and microorganisms from the surface of the larvae and pupae, increasing their viability. The other possibility is that it is a form of commensalism, in which the beetles receive all of the benefits, with the only harm to the larvae being the occasional annoyance of being touched by a beetle.

Study Site

The study was conducted at the Wilson Botanical Garden near Las Crusas, in the southwestern portion of Costa Rica, near the Panamanian border. Several *Zamia* trees in both the gardens and the secondary forest were chosen, based on the presence of beetles and larvae. The study was performed from August 4 through August 8, 1993.

Methods

Behavioral observations of the beetles and the larvae were recorded over a five day period. Each tree in the study area (see Appendix 4 for descriptions of trees) was observed once in the morning and once in the afternoon, for a period of 10 or 20 minutes. The 10 minute periods were in cases in which beetles were not present during the observational period, and the 20 minute periods were cases in which the beetles were present. The number of larvae and beetles, their distribution on the plant, and their behaviors during the observation period were recorded. Tables 3 and 4 contain a listing of all behaviors that occurred at any time during the observation period. Descriptions of larvae behaviors, beetle behaviors, and parts of the trees are listed in Appendices 1-3, respectively. Where it is appropriate, abbreviations from the appendices will be used in the paper.

On the first day of the experiment, 24 larvae were removed from the *Z. skinneri* plant, and 14 and 10 larvae, respectively, were placed on plants EA and EB. This was to determine whether or not a substantial beetle population existed in the forest, and how long it would take for these beetles to respond to the presence of larvae.

On the morning of August 5, nine beetles were removed from both the GA plant and the G plant. These were mixed together and randomly placed on two plants in the secondary forest, one in a well-shaded area (cycad S) and one near the edge of a path (cycad E).

During the morning of the 6th and the morning of the 7th, beetles from 6 plants were marked with acrylic paint and released. Each area received a novel color pattern, but due to the small size of the beetles, the beetles received the same marking at a given colony for both days. A marking was only considered successful if the beetle managed to fly away after marking. The number of marked beetles was recorded at each colony for each observational period following the original marking period.

On the morning of August 6, five larvae from the GA plant and the LS plant were collected and brought to the laboratory. On the first day, the GS larvae were placed on a young *Z. fairchildiana* frond, and the LS larvae were placed on a young *Z. skinneri* frond. Feeding patterns of the larvae were recorded, and after 24 hours, new young fronds of each species were added (the old fronds were removed), and the larvae were placed on the opposite species than the day before. The next day, a new frond of each species was added, and 6 beetles from EA were added to the cage, to determine whether or not they showed a preference for either cycad species.

Finally, in the field, three dead larvae from GB were ground into a paste and spread onto a leaf at EA, to see whether or not beetles were attracted to the larvae themselves, after it was observed in the field. In the laboratory, a dead larva from the LS plant was smeared on the *Z. skinneri* frond and a dead larva from the GA plant was spread on the *Z. fairchildiana* frond, to determine whether or not the beetles showed a preference for larvae depending on the cycad species upon which it feeds.

Results

The number of beetles had no correlation with the number of larvae on a particular plant. Rather, the presence of a plant within a well shaded area verses an open area was the strongest indicator of the number of beetles (Figure 1). The cycads EA, EB, and S, the three cycads found in shaded areas had significantly more beetles than the other plants, all of which were found in open areas ($P > 0.05$, comparison of means T-test).

Larvae tended to be clumped on brown leaves and along petioles or leaf bases (Table 1). They tended to aggregate in a tightly clumped area, usually on the same leaf, adjacent leaves, or the same section of the base or petiole (Table 1). Beetles tended to mass on leaves, leaf margins, and petioles that had been browned by herbivory (Table 2).

The most common activities of larvae were feeding and periods in which the entire population of a plant would alternately feed and go motionless simultaneously, described as cycling (Table 3). Larval behavior did not vary with the location of the plant, but they were slightly more likely to be motionless during the afternoon (Table 3). The most common beetle behaviors were "stop and go", feeding, and walking (Table 4). The beetles were found to be omnivorous, as they would feed upon leaf margins, larval frass, and even dead larva. Overall, diversity of beetle behavior was greater at the three shaded

locations (Table 4), but this was as much a factor of a greater number of beetles as anything else.

According to the mark and recapture data (Table 5), the greatest number of recaptures was at the S location, followed by the EA and EB locations. The number of marked beetles, as well as the total number of beetles observed at these locations during the recapture period was also highest at these three locations.

At several locations during the course of this project, one and possibly two other species of Langurid beetles were observed at the LS, EA, EB, and S locations, and they were most common at the EA, EB, and S locations. These beetles were also found to be omnivorous, and had similar behavioral repertoires to the other beetles. The main difference is that they tended to be found along the petioles of the plants most frequently.

Larvae showed no preference for either species of *Zamia*, as they would eat whichever species on which they were placed. Whichever group of larvae finished first would move onto the other plant and begin feeding. When beetles were introduced to the cage, they did not respond to either plant. Instead, they spent the majority of their time on the mesh of the top of the cage. One beetle was found on the brown leaf margins of each plant over the course of observations, but only for a brief time.

Beetles responded aggressively to the larval paste spread on plant EA, with several beetles actively feeding on the larva within minutes. In the laboratory, the one beetle was seen eating the crushed larva on the *Z. fairchildiana* plant, and one larva was seen eating the larva on the *Z. skinneri* plant.

Discussion

Beetles appear to be much more numerous in the well shaded areas of the forest, as shown by their greater numbers, as well as their greater behavioral complexity within the forest. The other, larger species of Langurid was only found in the forested area, with the occasional exception of the LS site. Adult butterflies, however, appear to be much more likely to lay their eggs on cycads within more exposed areas, as all of the well-shaded cycads within the study area were artificially created. This appears to contradict the hypothesis that the beetles provide an advantage to the survivorship of the larvae and pupae, by cleaning their surface of fungi and microorganisms. The beetles are clearly omnivorous, but even their consumption of the larvae does not rule out the possibility of mutualism, as they may reduce the possibility of the spread of disease.

The low percentage of marked recaptures, coupled with the rapid recruitment of beetles to areas in which the larvae were introduced, suggests that a large population of beetles is present in the forest, and that they are likely generalists feeders who occasionally return to the cycad. Whether their sporadic presence at a cycad is the result of limited nutritional value of the resource, or competition between beetles, remains

unknown. Perhaps a future study could attempt to determine the feeding patterns and home range size of the Langurid beetles.

Larvae appear to show no preference for the young fronds of *Z. fairchildiana* or *Z. skinneri*. Rather, larvae will consume whatever plant they happen to be on, and then they move to the nearest available plant. Beetles also show no apparent preference for either species, or for the larvae, alive or dead. However, the results of this experiment remain inconclusive, due to the unusual behavior of the beetles and the larvae in captivity, as they tended to avoid the fronds altogether more often than not.

Conclusion

Like many natural systems, the interaction between *Z. fairchildiana*, *E. minyas godoartii*, and the Languridae beetle is far more complex in less disturbed environments. Whether or not the system is a mutualistic relationship, or simply a form of commensalism in which the beetles are the sole beneficiaries, was not determined by this study. It has been observed, however, that pupae that are visited regularly by beetles have a higher emergence rate than pupae that are not visited by beetles (Hewson, pers. comm.). If the system is mutualistic, any reduction of the forest cover in which the beetles live would be detrimental to both species.

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Table 1. Spatial Distribution of Larvae.

Time	Date	GA	GB	LS	E	G	EA	EB	S
AM	8-4	GL, BL, P,B				BL1			
PM	8-4	BL3, P		P		BL1	BL1, P	BL1	
AM	8-5	BL, P3, B	BL3	B,P		P1	P1, BL	P1	
PM	8-5	B3	BL3	BL1	BL1	BL1	P1	BL1	BL1, P1
AM	8-6	B,P3,B L4	BL3	BL1	BL1	BL1	BL1	BL1	BL2
PM	8-6	P2, BL3	BL3	BL1	BL1	BL1	BL1	BL1, P1	BL1, P1
AM	8-7	B1, BL1	BL3	BL1	P1	B2	P1, GL1	BL2, P1	BL1, P1
PM	8-7	BL1, B1	BL3,*	BL1	BL1	B2	P1, BL1	BL1	BL2, P1
AM	8-8	BL2, B1, BL2		BL1	P1	BL1	BL1	BL1	B1
PM	8-8	B1		BL1,*	P1	B1	BL1	BL1	B1

Key:

Number - Number of those structures on a given plant on which larvae were present.

* - Larvae were found dead during observational period.

See Appendix 3 for a description of plant part abbreviations.

Table 2. Spatial Distribution of Beetles.

Time	Date	GA	LS	EA	EB	G	E	S
AM	8-4	BL,P				BL		
PM	8-4	BLM, GL	BLM, B,P, GLM	P,BL, BLM, GLM	BL			
AM	8-5	BLM, B,P, BL	B	BLM,P GLM, BL,GL	BLM, BL,P	BLM		
PM	8-5	GL,P	P	BLM, BL,P	BLM, BL,P			BL,P
AM	8-6	P	P	BLM, BL,P	BLM,P BL,GL	P		BLM,P BL,GL
PM	8-6	P		BLM,P BL	BLM,P BL			BL
AM	8-7		P	BLM,P	BLM,P BL			BLM,P BL
PM	8-7	GL	BL	BLM,P GL,BL	BLM,P GLM, BL	BL,P		BLM,P BL
AM	8-8	P		BLM, BL,GL	BLM,P GLM, BL	BL,P		BLM,P GLM,B GL,BL
PM	8-8	BLM,P GLM		BLM, BL	BLM,P BL	BL	BL	BLM,P GLM,B GL,BL

Key:

See Appendix 3 for a description of plant part abbreviations.

Table 3. Listing of Larval Behaviors.

TIME	DATE	GA	GB	LS	E	G	EA	EB	S
AM	8-4	Cr,F R				C			
PM	8-4	Cr,F		C,R		C	R,F	R,F	
AM	8-5	Cr,F R,C	F	Cr,M		F	Cr,F R	Cr,F R	
PM	8-5	F	M	C	M	F,M	F,M, R	M	F,M
AM	8-6	F	M	F,M	F	Cr,F	Cr,M	C	F,R
PM	8-6	F,R	M	M	F,M	M	F	F,R	M
AM	8-7	Cr,F	M,*	M	M,C	Cr,M	Cr,C	Cr,F R	Cr,CR
PM	8-7	Cr,F		M	M	M,F	F	M	Cr,M F,R
AM	8-8	Cr,F		M	C	F	F,M	M	F
PM	8-8	F		M,*	F	F	F	M	Cr,F

Key:

* - Larvae found dead during observational period.

See Appendix 1 for a description of larval behaviors.

Table 4. Listing of Beetle Behaviors.

Time Date	GA	GP	LP	LS	EA	EB	G	E	S
AM 8-4	T,W, F	SG					AD		
PM 8-4	SG,F W	SG		AD,W T,F	SG,W EF,T F	AD,T W			
AM 8-5	EL,W T,F	SG	SG	F	EL,W EF,T SG,F AD	EF,F SG,T W	AD,F		
PM 8-5	AD,F W			F	SG,T W,F	SG,F EF,W			AD,F SG,W
AM 8-6	SG			F	SG,F EF,W AD	SG,F W	SG,W		EF,W SG,F T
PM 8-6	SG,T				SG,W EF,F AD	SG,F T,W			SG
AM 8-7			SG	SG	SG,F W	SG,F T,W			SG,F AD,W T
PM 8-7	AD		SG	W	EL,F SG,W	SG,F AD,W			SG,F AD,W T
AM 8-8	SG,F		SG		SG,F AD	SG,F W	F,W		SG,F AD,W EF,T
PM 8-8				SG,F AD,W	SG,F	AD,W F	AD,F W	SG,F W	SG,F AD,W EF,T

Key:

See Appendix 2 for a description of beetle behaviors.

Table 5. Mark-Recapture Data.

Location	# Beetles Marked	# Marked Beetles Recaptured	Total # Beetles Counted During Mark Recapture Period
GA	3	1	8
LS+LP	7	0	12
EA	12	3	49
EB	10	3	43
S	9	5	77
G	2	0	5

Appendix 1

Descriptions of Larval Behaviors

Feeding (F) - Larva mouthparts moving, body often writhing slightly. When many larvae are feeding on the same plant, they produce an odor that resembles sweaty feet.

Motionless (M) - Larvae are not moving.

Cycling (C) - Larvae follow a cycle of alternately feeding and going motionless. When it occurs, it tends to follow a cycle of approximately 20 minutes.

Rearing (R) - In response to a touch by a beetle, a larva will quickly pull away from the beetle, and will slightly raise that portion of its body.

Crawling (Cr) - Larvae move along plant.

Appendix 2

Descriptions of Beetle Behaviors

Stop and Go (SG) - The beetle stops at a location, feeds or is otherwise motionless for 10 - 60 seconds, and then walks for a short distance before stopping again.

Walking (W) - Beetle seen rapidly walking along plant.

Touching (T) - Beetle touches larva, and can be seen moving its mandibles and/or touching its front legs to the larva, which it then brings to its mouth.

Feeding (F) - Beetle seen feeding, either through direct contact with its mandibles, or by touching with its legs first, and then touching its legs to its mouth.

Arrival-Departure (AD) - Beetle flies away from or onto a plant.

Eating Frass (EF) - Beetle seen eating larval frass balls.

Eating Larva (EL) - Beetles seen feeding upon dead larva.

Appendix 3

Descriptions of Cycad Parts Mentioned in Study

Base (B) - Base of the frond, below the leaflets.

Petiole (P) - Petiole within the range of the leaflets.

Brown Leaflet Margin (BLM) - Leaflet darkened by herbivory

Green Leaf Margin (GLM) - Leaflet untouched by herbivory.

Brown Leaflet (BL) - Leaflet darkened by herbivory.

Green leaflet (GL) - Leaflet unaffected by herbivory.

Appendix 4

Descriptions of Cycad Locations

Garden A (GA) - Within the garden grounds. Little shade.

Garden B (GB) - Approximately 50 m from GA. Essentially the same conditions.

Emerged Pupae (EP) - Approximately 50 m from GA. Slightly more shaded than GA or GB. Contains the husks of 25 emerged pupae.

Live Pupae (LP) - On the other side of the garden, in the fern section. Totally non-shaded area with nine developing pupae.

La Selva Cycad (LS) - A *Z. skinneri* cycad about 5 m from the LP plant. Also non-shaded.

Experimental Cycad A (EA) - In a well-shaded area within secondary forest.

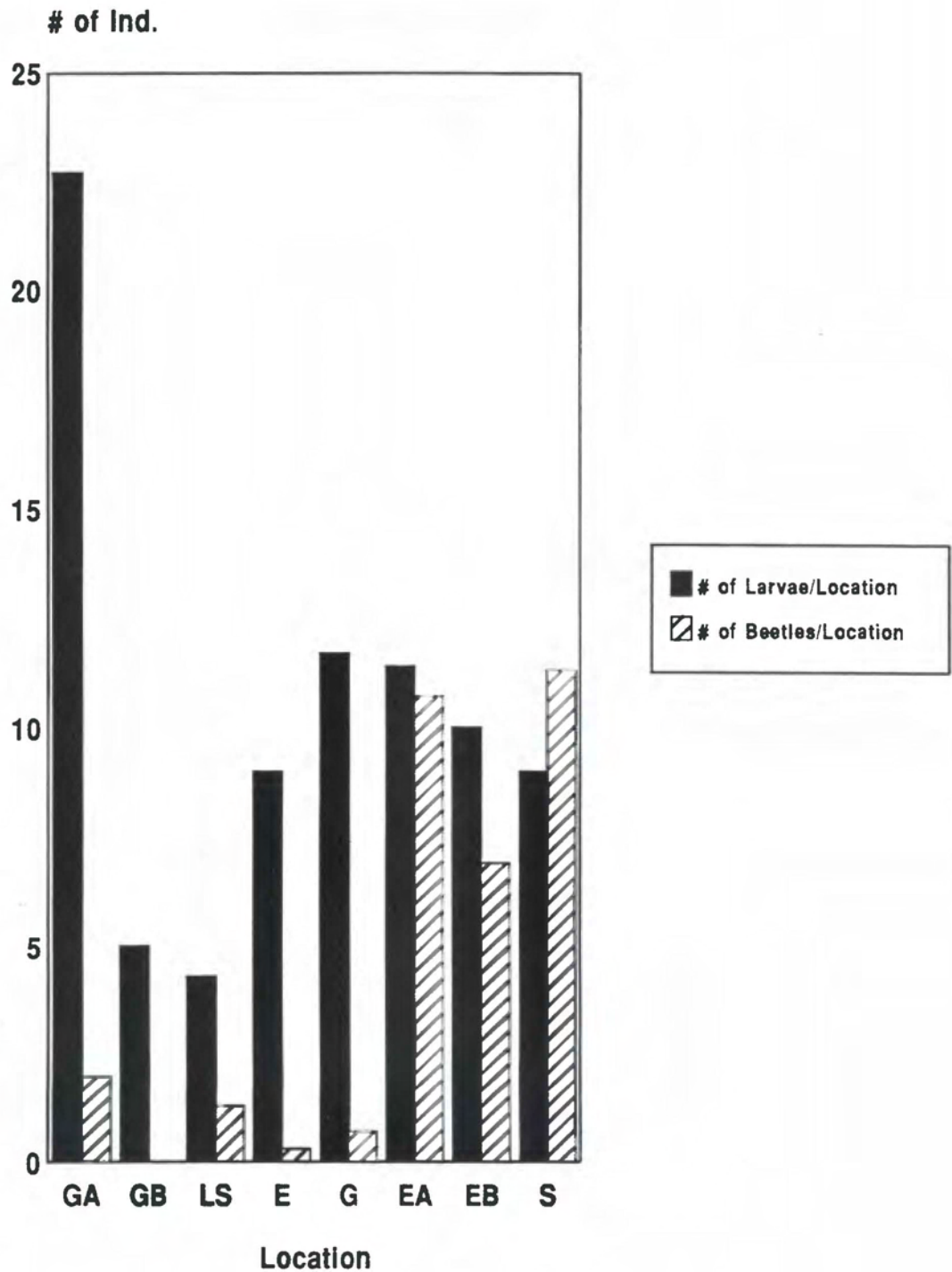
Experimental Cycad B (EB) - About 10 m from EA. Basically the same conditions.

Edge (E) - Along the side of the river trail, within the secondary forest. Receives a fair amount of sunlight.

Shade (S) - Several hundred meters within the secondary forest. Very well-shaded.

Gap (G) - Within the secondary forest, on the edge of a recent gap created by a fallen tree. Approximately 250 m from S.

Figure 1. Average Number of Beetles and Larvae at Each Location.



See Appendix 4 for a description of locations

**CLIMATIC CHANGES ON COTO BRUS: STATEMENTS AND
EVIDENCES FROM METEOROLOGICAL STATIONS ON
CLIMATIC AND ENVIRONMENTAL CHANGES**

Author: Pantaleo K. T. Munishi

Abstract

This study was done in Coto Brus county with an objective of getting an idea on peoples perception on climatic changes over the area, and attempted to analyze some available meteorological data in order to determine the existence of any climatic/weather patterns over the area. All people interviewed expressed a perception of climatic changes in terms of decreased rainfall, increased temperatures, and lengthened dry season. The analysis of yearly variations of rainfall data from San Vito (1954 - 1982) showed that the rainfall is variable from year to year. However, there is a tendency of relatively lower rainfall years (below average) after 1960. Based on the P/PE ratio, no year shows to approach the conditions for a dry year (i.e., P/PE ratio < 0.5). The year 1968 and 1960 had the lowest and highest rainfall, respectively. Periodic variations (1954/58 - 1979/82) show the rain season to have a slightly decreasing rainfall from 1954/58 - 1969/73, while 1964/68 and 1974/78 approach dry year conditions. Trend analysis would probably give a fair trend of decreasing rainfall from 1954/58 - 1978/78. From Wilson Botanical Garden, rainfall data (1988 - 1992) showed high variations in amount of rainfall. The number of rain days decreased tremendously from over 200 days per year in 1988 to less than 140 days per year in 1990. During the same period, the total annual rainfall decreased from above 400 cm per year to below 320 cm per year. In relative terms, 1989 and 1990 would have been dry years for the area. Rainfall distribution for a particular month varied in intensity, duration, and starting date in each year. Although there was no clear trend of rainfall patterns on the two stations, the variations in rainfall distribution, amount, duration, and intensity over months, periods, and years, this may mean much to individual farmers who deal with the weather on practical terms.

Introduction

Most people tend to take for granted the moderate nature and relative stability of the earths climate. During these modern times, human societies have experienced little else of climatic changes due to the prevailing interglacial periods (World Resource Institute, 1990). However, the earth's climate has changed dramatically in the past. Early human societies experienced a colder climate - the Ice Age Period. In still earlier periods, the earth was ice free, and far warmer than today. Today, a new concern of human activities altering the atmospheric composition is to be added on the natural climatic variations.

Weather differences mostly depend on the amplitude of the oscillation of certain weather parameters including mostly insolation, atmospheric heat, wind, precipitation, and cloudiness (Coen, 1983). These variations generate a very diverse weather in Costa Rica. The local weather and its effects are made even more diverse through complex interactions with microtopographic relief and the vegetation cover. Two different regimes of rainfall occur in Central America, Costa Rica inclusive. The atlantic side has the most rain during December and January, while the pacific side has almost no rain during the same period. On inland areas, rainfall patterns are a mixture of the two. Normally, the average temperature of the warmest month and coolest month in Costa Rica do not differ by more than 5°C at a given site (Coen, 1983).

The analysis of climatic changes over a given area is a complex process, especially when considering areas with diverse climate/weather patterns as most of Costa Rican regions. On the other hand, although climatic studies are long term, short term studies can be important in assessing the magnitude of some major variables. Therefore, the assessment of localized values of climatic parameters such as rainfall and temperature patterns are essential and of practical importance.

Many people who live in different counties of Costa Rica say that the climate has changed during recent years, attributing this to forest clearance. Such allegations have also been given by long time residents of the western Usambara mountains of Tanzania (Hamilton, 1989). Some of these people in Costa Rica are farmers who have to deal with the weather on practical basis. But on the other hand, individual perceptions and evidences about climate (anecdotal evidences) are to be treated carefully. They might be liable to bias through selective recall and sometimes deliberate for personal reasons (Hamilton, 1989). In this study several statements on climatic changes from different people questioned around Las Cruces - Coto Brus are presented, and an attempt is made to analyze some of the available meteorological data from San Vito and Wilson Botanical Garden at Las Cruces.

The objective of this study is to attempt to identify the existence of (if any) climatic/weather patterns or fluctuations over the area through the analysis of rainfall data.

Materials and Methods

The study site is Coto Brus county (San Vito and Wilson Botanical Garden). This area is on the pacific side of the country. San Vito is at about 890 meters above sea level, latitude 08° 5'N, and longitude 82° 59'W.

Data Collection and Analysis

Rainfall data were obtained for San Vito from the National Meteorological Institute of Costa Rica (Instituto Meteorologico Nacional) for the year 1954 - 1982. The data were divided into five year periods. The mean ratio of precipitation to potential

evapotranspiration (P/PE) was used in analysis. In this analysis, it is assumed that a ratio of less than 0.5 for any period will reflect a dry year/period. These ratios were plotted against their respective periods for the dry season (January), the middle of the rain season (May), and the peak of the rain season (October). The annual rainfall totals were also plotted against their respective years.

Results

Statements on Climatic Changes

These statements are recorded with as little prompting as possible in order not to bias any information given. Wherever possible and mostly, the statements are reported the way they were structured and given by the person interviewed.

1. Dr. Luis Diego (Director, Wilson Botanical Garden).

During the 1950's, according to many people, we used to get roughly something like only a week of dry season over this area. Forest clearance, as speculated by many people, has taken place very rapidly and a possible consequence among other reasons is a lengthened dry season. For example, in the years 1988 - 1992, there have been over 90 dry days per year, which is about 3 dry months per year.

2. Don Gomez Mora (A farmer for about 20 years in the area).

Since we came here from Guanacaste, some 20 years ago, there has occurred a lot of changes in climate. By that time there was too much rain. There was no real dry season. Coffee was growing normally well, and everybody talked about coffee. There was a lake at a place I am using as a pasture, which is now completely dry. The dry period has now become long and starts earlier. Coffee now flowers and ripens earlier due to high temperature.

3. Don Gomez Sanches (A farmer for about 13 years).

I came here 13 years ago. When I arrived here, compared to this time, there used to be full time rain, and it was colder than now. Nowadays you can have a dry period up to more than two weeks continuously without rain.

4. Don Luis Cruz (A farmer).

I have been here for 10 years. In the past we had rain nearly everyday. Today, it is warm and rainfall is less. I am, for example, surprised that today it is almost four days without seeing a heavy rainfall in this time of the year. This was not the case in the past. These changes have greatly affected coffee production due to poor flowering and development, especially when it does not rain as it is expected.

Analysis of Meteorological Data

San Vito - Yearly variations (1954 - 1982).

Figure 2 shows that rainfall at San Vito is variable from year to year with no clear trend/pattern. However, there is a tendency of years with relatively lower rainfall (below average) after 1960. The years 1960 and 1968 had the highest and lowest rainfall, respectively, over the period. Based on P/PE ratio, no year shows to approach the conditions for a dry year.

San Vito - Periodic variations (1954/58 - 1979/82).

The peak of the rain season shows a slight decrease in rainfall from 1954/58 - 1979/82. For the dry season, based on the P/PE ratio, the year 1964/68 and 1974/78 seem to approach dry year conditions (Figure 1). Generally, if trend analysis is done on these data, a possible fair trend of decreasing rainfall from 1954/58 to 1979/82 would be observed. However, from this analysis there is not a clear trend in rainfall pattern, but more or less periods of increased and decreased rainfall.

Wilson Botanical Garden - Yearly variations and monthly distribution of rainfall.

The Wilson Botanical Garden data show big variations in rainfall. The number of rain days decreased tremendously from over 200 days per year in 1988 to less than 140 days/year in 1990. In the same period, the total annual rainfall decreased from above 400 cm per year to below 320 cm per year. In relative terms, 1989 and 1990 would have been dry years for the area (Figure 7 and Table 1). Rainfall distribution over the period (1988 - 1992) for different months vary from year to year (Figures 3 and 4). For each rainfall occasion, the starting date and intensity vary in each year for any particular month. For example, the year 1988 and 1991 seemed to have a higher intensity at different rain occasions during October (Figures 6 and 9), while 1992 show higher intensities in April and August (Figures 5 and 8), and year 1992 show higher intensity in January. It is important to note that the differing intensities and rainfall occasion may relatively mean dry periods, depending on the farmers experience, perceptions, and expectations at such particular times of the year.

Conclusion

Generally, there are no periods of serious drought for the two stations, otherwise there exists periods of low and high rainfall. At the same time, rainfall patterns show no clear trend. However, with trend analysis, probably a trend could be established for San Vito with a decreasing rainfall from 1954/58 to 1979/82. These results for San Vito and Las Cruces Wilson Botanical Garden are a probable reflection of other stations in the

whole county and the country. Although there is not a clear trend of rainfall patterns over the two stations, the variations in rainfall distribution, amount, duration, and intensity over months, years, and periods may mean much to individual farmers who deal with the weather on practical terms.

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Table 1. Las Cruces Biological Station, Five Year Rainfall Data.

Month	Avg. No. of Rain Days	Rainfall (cm)				
		1988	1989	1990	1991	1992
Jan.	4.8	3.5	4.2	4.2	13.2	4.3
Feb.	2.8	2.0	0.5	7.4	1.3	12.6
March	6.0	6.5	8.1	12.5	2.6	0.4
April	10.6	35.6	7.1	19.4	12.7	49.8
May	17.2	27.7	39.2	40.1	53.0	22.3
June	16.2	34.1	27.4	39.4	25.8	38.7
July	15.0	46.5	37.3	30.0	13.0	16.9
Aug.	21.8	86.2	47.4	36.9	42.2	57.3
Sept.	23.2	70.3	69.8	34.4	39.3	56.7
Oct.	23.2	88.3	47.7	69.2	49.7	53.6
Nov.	25.0	31.0	30.0	44.6	32.8	29.5
Dec.	9.0	11.8	17.2	10.4	25.6	8.1
Totals		443.5	335.90	321.50	311.20	350.2
Mean		36.95	27.90	26.79	25.93	29.18
Rain Days		202	147	134	161	182

Source: Wilson Botanical Garden, 1993.

Table 2. Mean Annual Rainfall and PE by Period and Month, 1954/58 - 1979/82, San Vito, Costa Rica.

Period	Parameter	Month												Period Mean
		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
1954 - 1958	R'Fall (P) (mm)	113.8	66.1	106.9	186.0	433.8	387.0	377.0	422.9	481.0	750.6	441.1	178.3	
	P/PE	0.81	0.50	0.67	1.18	2.93	2.80	2.69	2.95	3.87	5.77	4.28	1.35	2.25
1959 - 1963	R'Fall (P) (mm)	78.9	106.9	123.5	263.0	565.1	400.9	375.8	414.8	575.4	713.2	547.1	196.3	
	P/PE	0.56	0.81	0.78	1.67	3.81	2.94	2.68	2.90	4.23	5.48	5.30	1.48	2.62
1964 - 1968	R'Fall (P) (mm)	64.9	125.0	11.6	127.5	519.9	439.5	372.7	426.2	382.2	666.6	449.9	137.5	
	P/PE	0.46	0.95	0.07	0.81	3.51	3.23	2.66	2.98	3.00	5.12	4.36	1.04	1.78
1969 - 1973	R'Fall (P) (mm)	120.0	49.5	126.6	210.6	335.4	369.8	250.5	461.8	425.3	552.7	401.1	137.4	
	P/PE	0.85	0.37	0.80	1.34	2.26	2.71	1.78	3.22	3.43	4.25	3.89	1.04	2.09
1974 - 1978	R'Fall (P) (mm)	42.6	49.9	89.5	187.6	467.6	387.0	252.5	362.6	519.9	630.6	469.9	148.0	
	P/PE	0.30	0.38	0.56	1.19	3.15	2.84	1.80	2.53	4.19	4.85	4.56	1.12	2.20
1979 - 1982	R'Fall (P) (mm)	96.2	52.0	79.4	286.7	530.5	401.9	303.0	331.1	518.5	552.7	415.2	170.5	
	P/PE	0.68	0.32	0.50	1.82	3.58	2.95	2.16	2.30	4.18	4.25	4.00	1.29	1.82
Month Mean	PE (mm)	140	131	158	157	148	136	140	143	124	130	103	132	
	R'Fall (P)	87.8	70.1	95.8	213.6	471.5	398.0	320.7	405.0	477.2	646.9	455.6	161.9	
Overall Mean	P/PE	0.62	0.53	0.60	1.36	3.18	2.92	2.29	2.83	3.84	4.97	4.42	1.22	
														2.30

**Figure 1. Rainfall Pattern by Period: 1954 - 82,
San Vito, Costa Rica.**

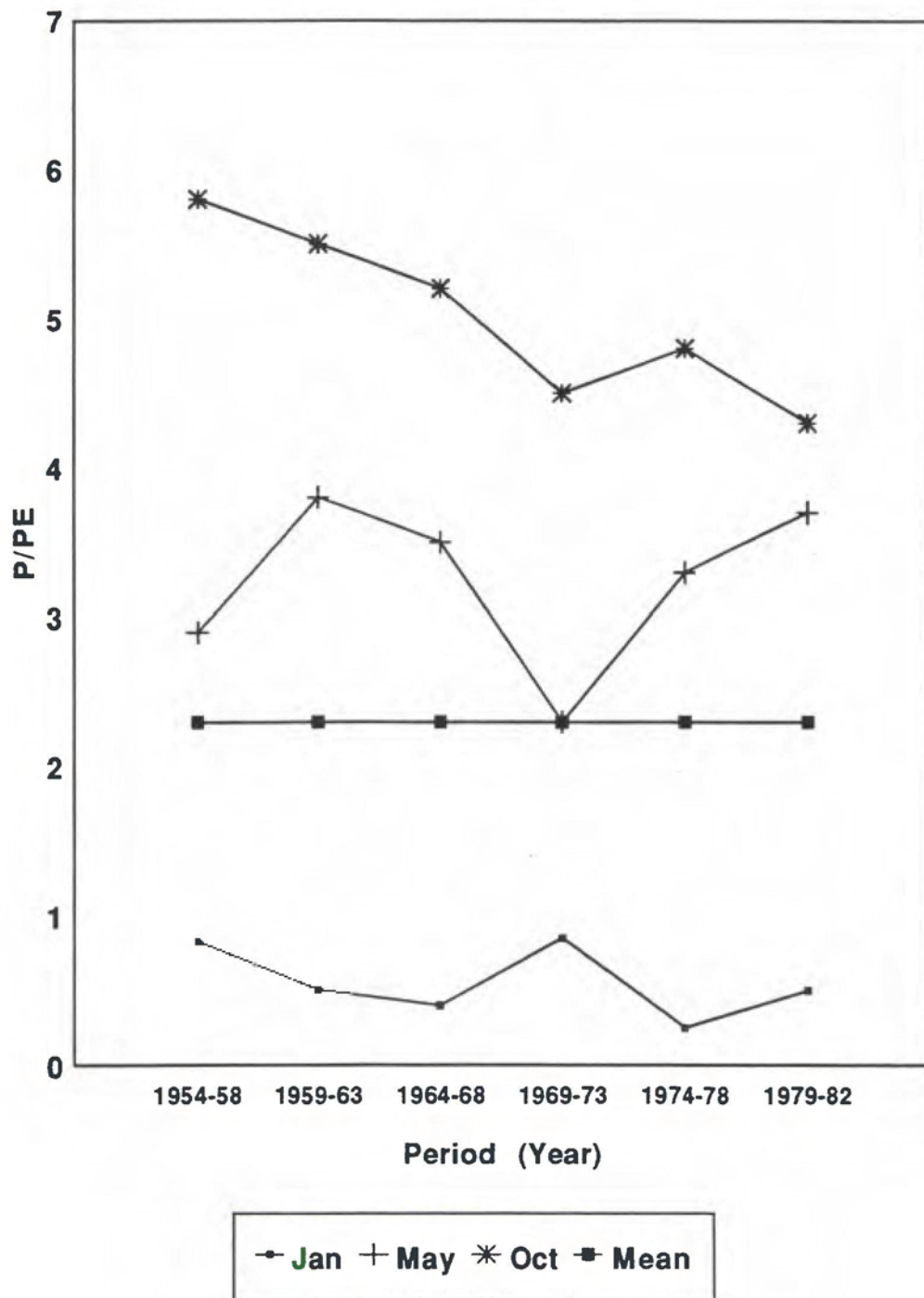


**Figure 2. Annual Rainfall Pattern 1954 - 82,
San Vito, Costa Rica.**

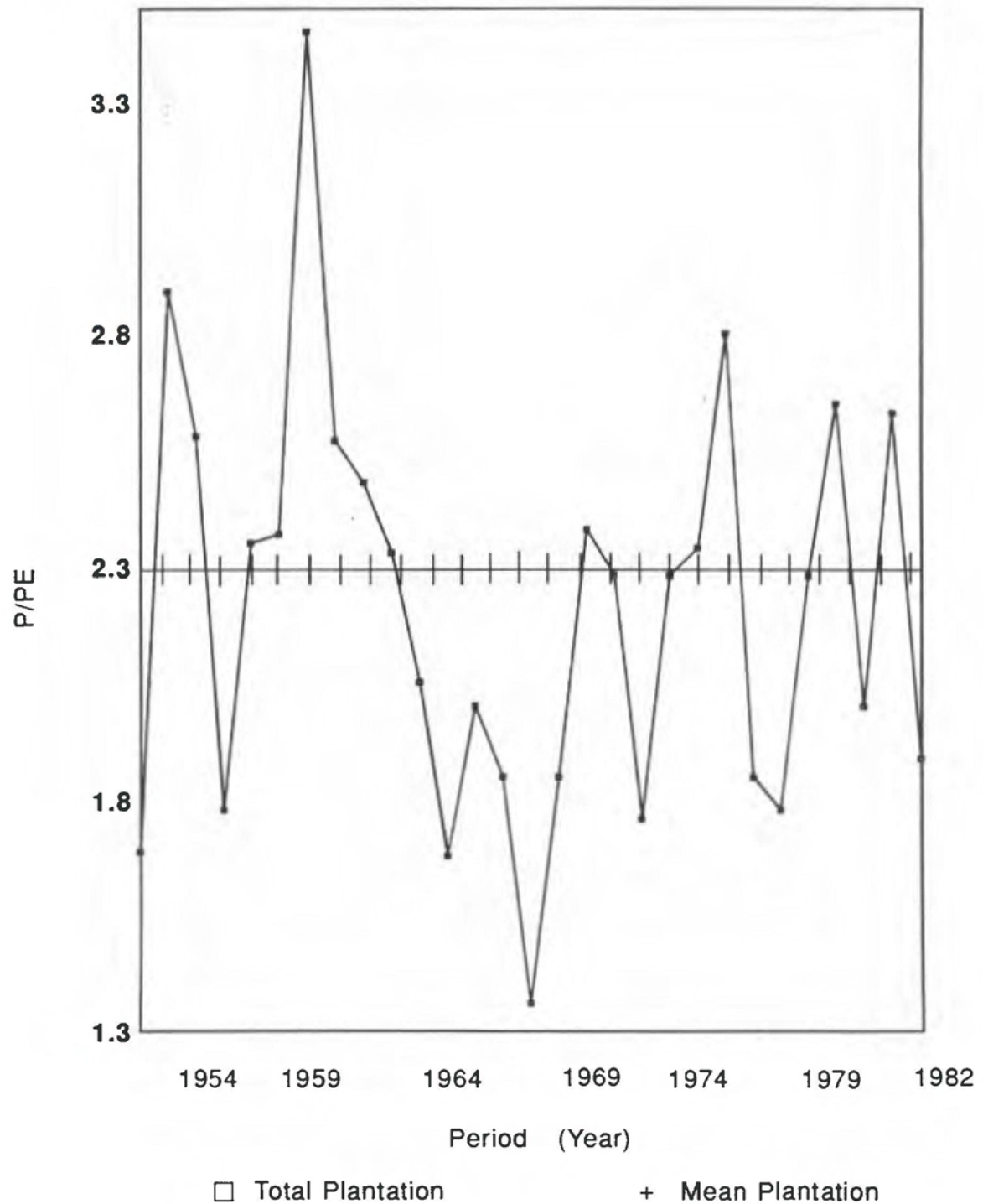


**Figure 3. Rainfall Distribution Comparison,
Wilson Botanical Garden, January, 1988 - 92.**

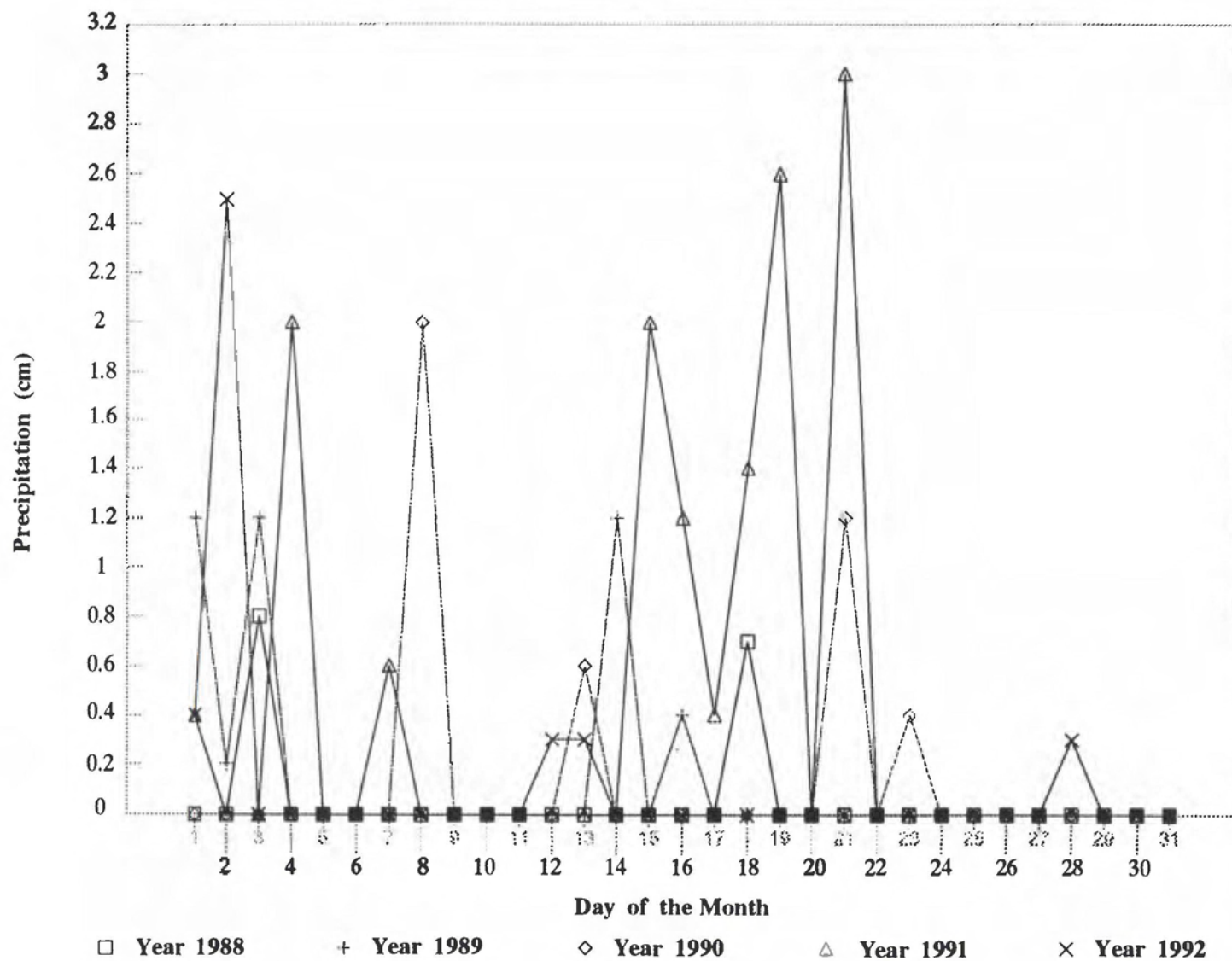


**Figure 4. Rainfall Distribution Comparison,
Wilson Botanical Garden, April, 1988 - 92.**

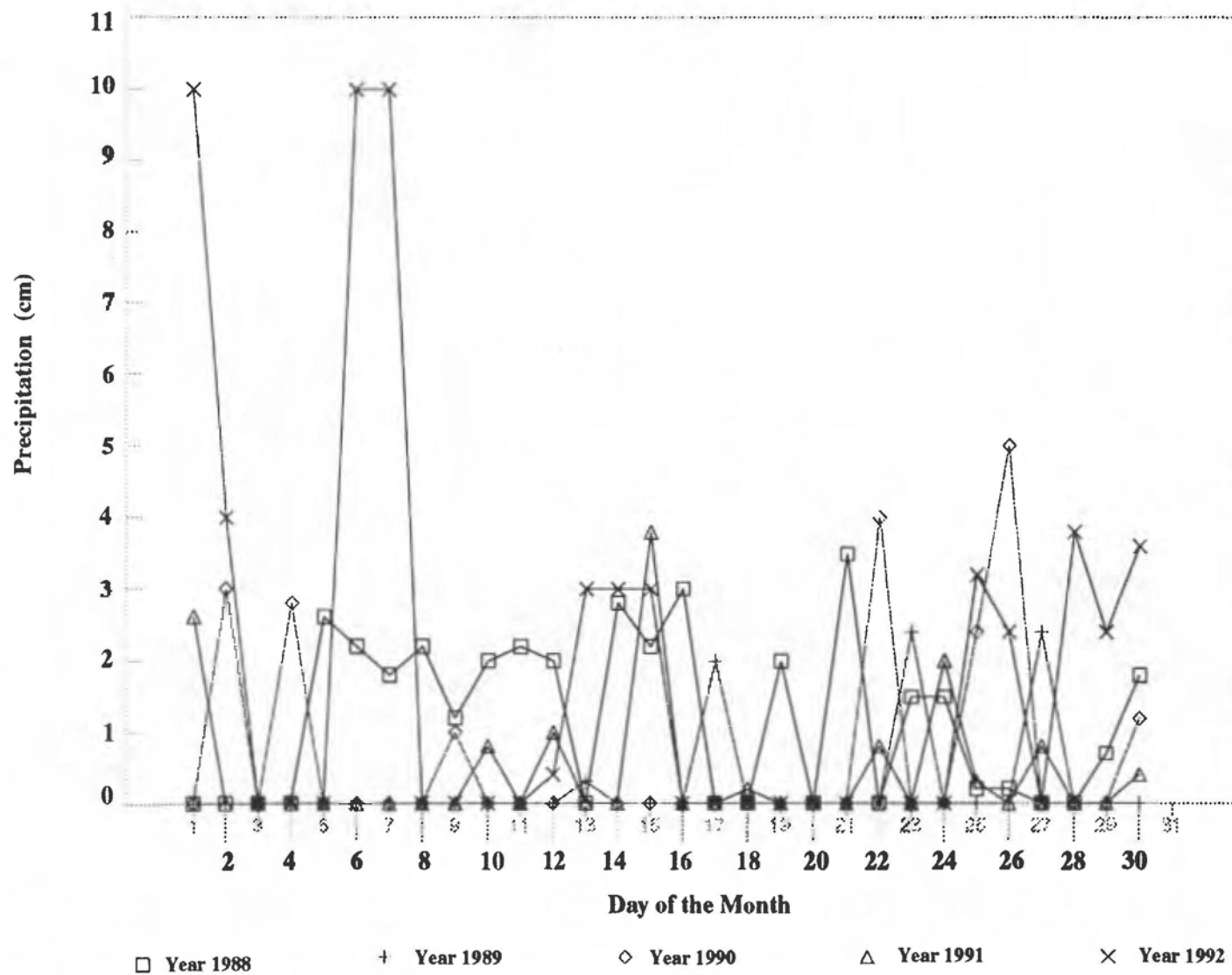


**Figure 5. Rainfall Distribution Comparison,
Wilson Botanical Garden, August, 1988 - 92.**

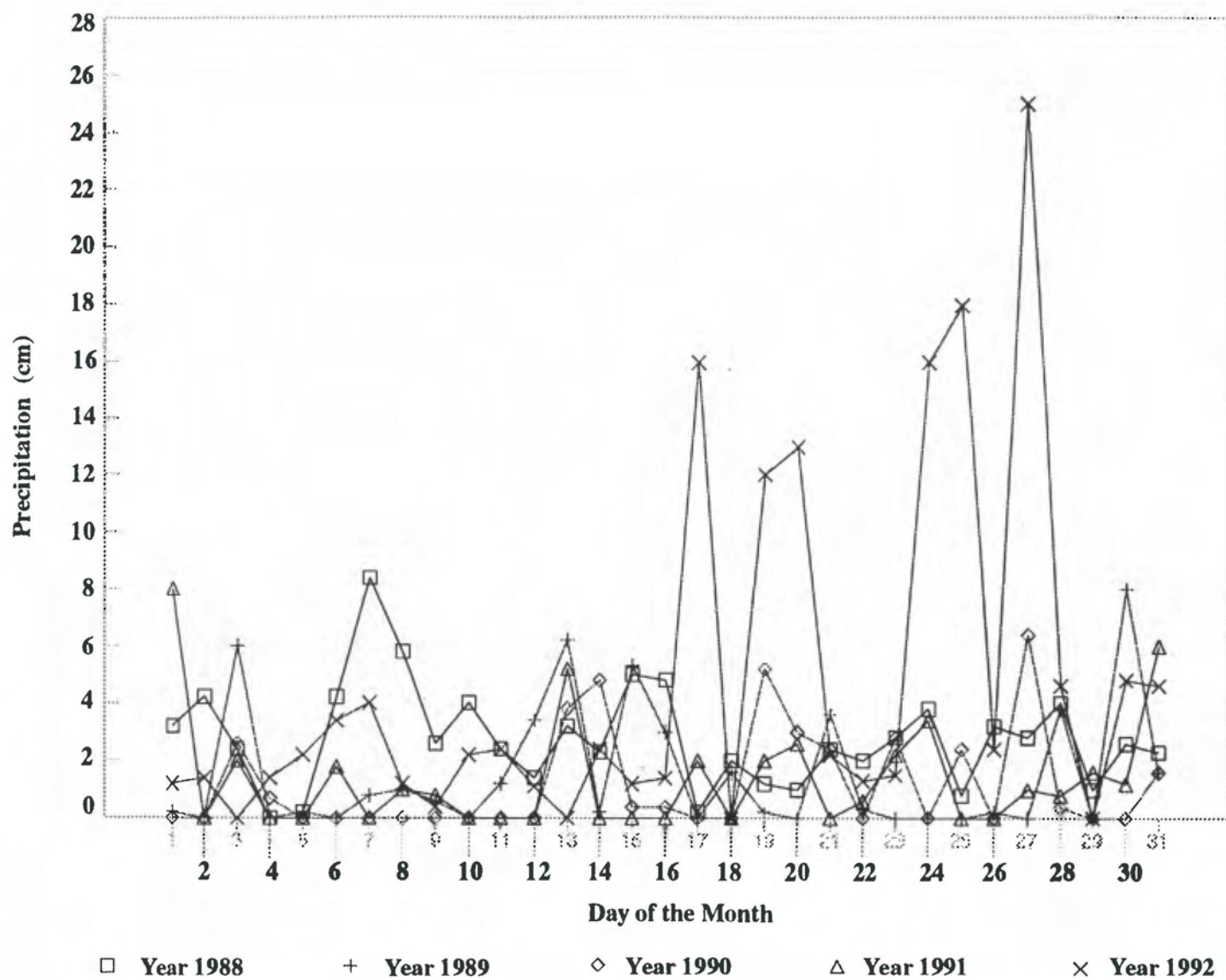


**Figure 6. Rainfall Distribution Comparison,
Wilson Botanical Garden, October, 1988 - 92.**

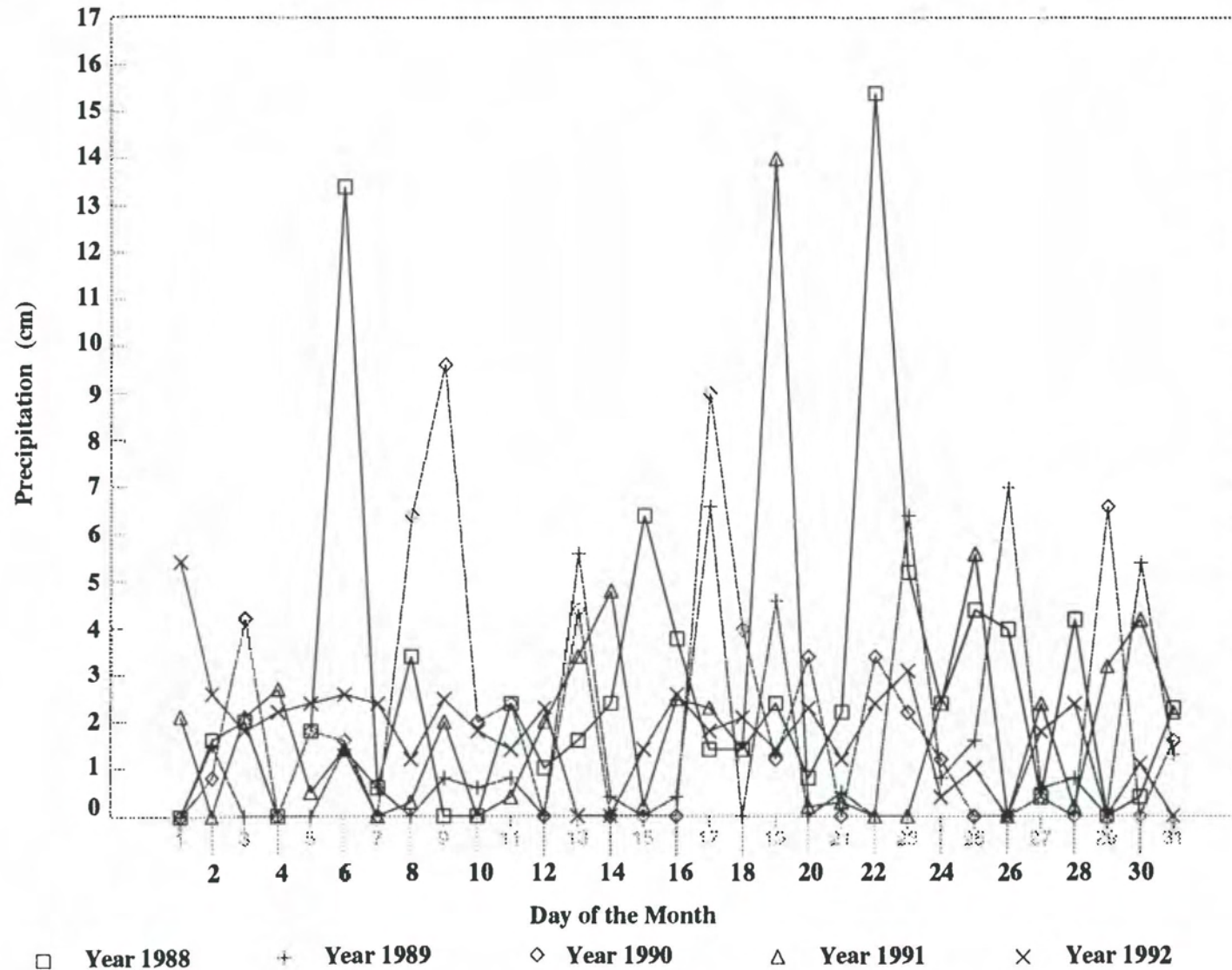


**Figure 7. Number of Rain Days/Year
Wilson Botanical Garden, Costa Rica, 1988 - 92.**

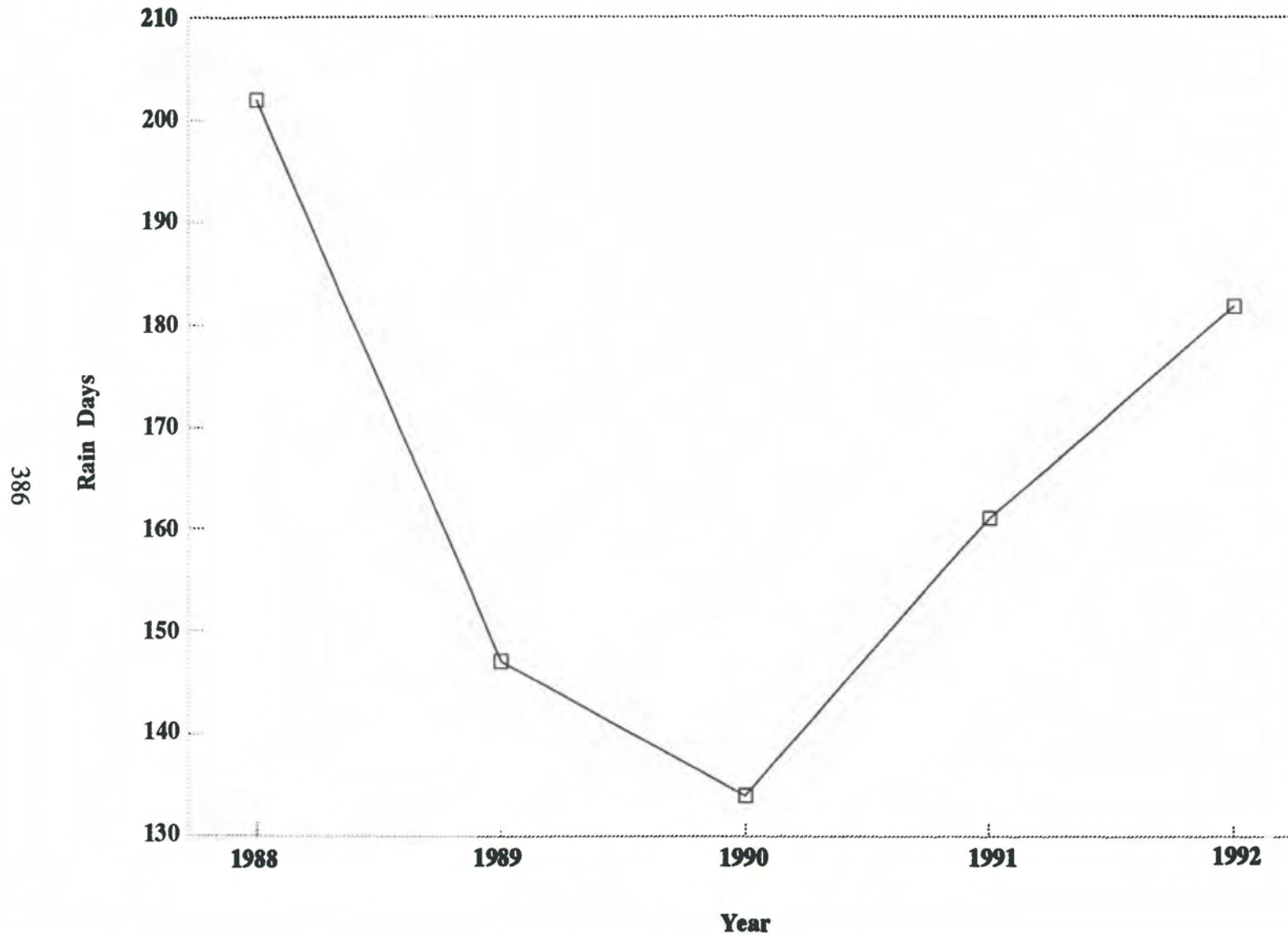


**Figure 8. Rainfall Distribution Comparison,
Wilson Botanical Garden, April, 1988, 90, 92.**

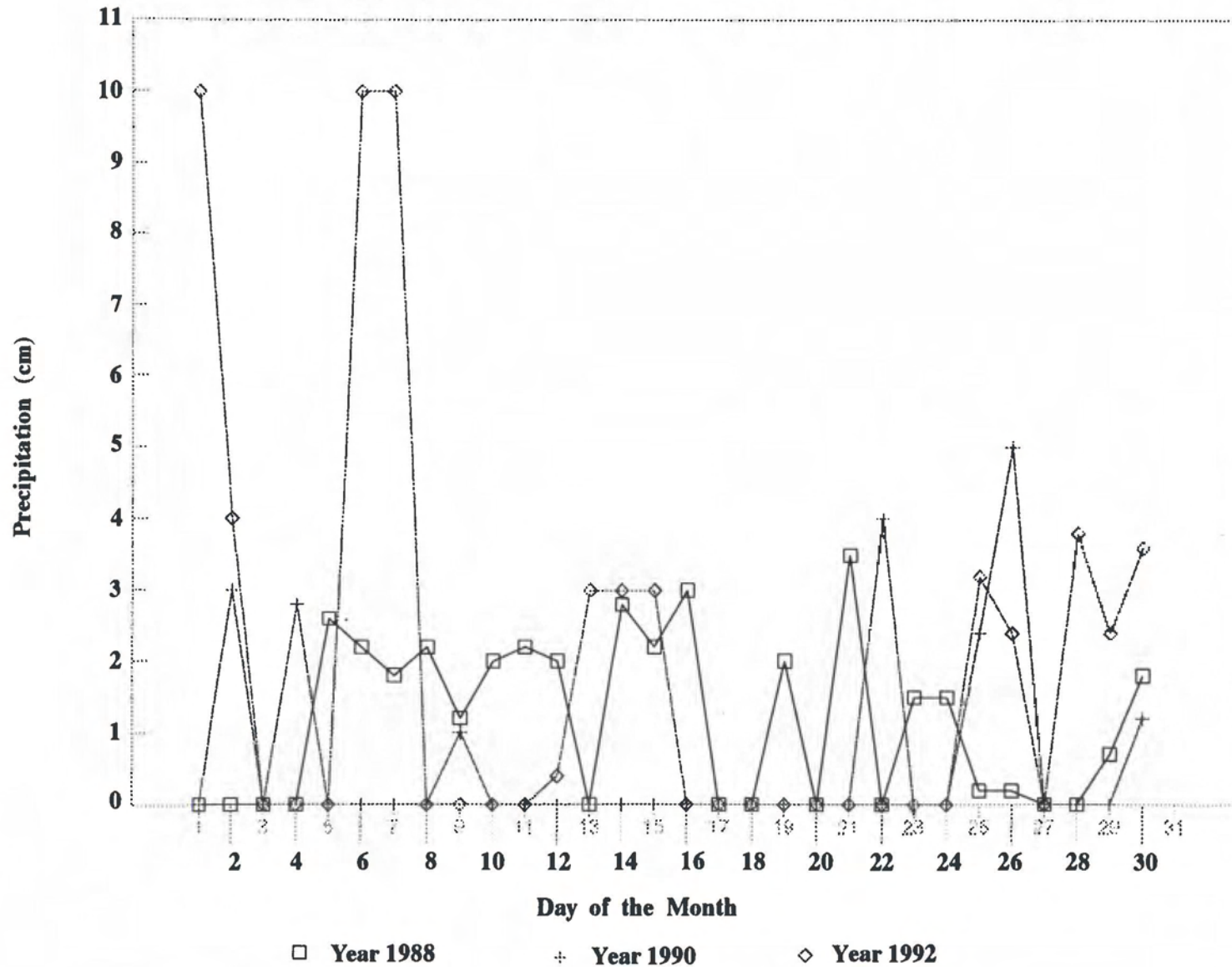
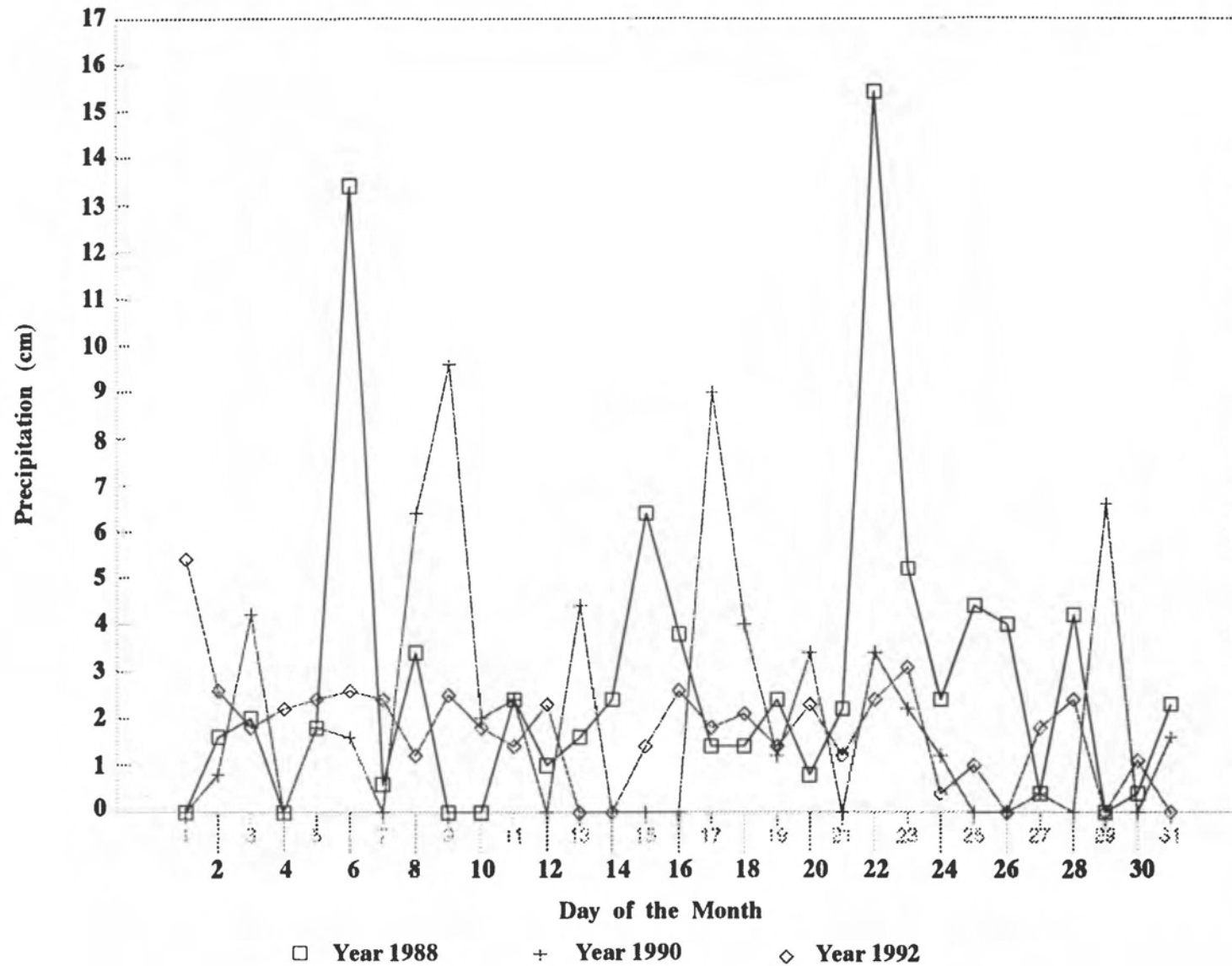


**Figure 9. Rainfall Distribution Comparison,
Wilson Botanical Garden, October, 1988, 90, 92.**



"MONTES BUENOS" AND "MONTES MALOS": THEIR RELATION TO "TIERRA BUENA" AND "TIERRA MALA"

Authors: Lucy Buchan, Jagdish Krishnaswamy, and Nick Shorr

Abstract

Under low nutrient conditions, some plants are particularly strong nutrient accumulators. The slash-and-mulch system of Frijol Tapado taps these nutrient reserves by growing beans directly in the cut mulch. Tapado farmers often distinguish 'good' from 'bad' fallow species and associations. Current agronomic research in Coto Brus attempts to increase the efficiency of this system by identifying fallow species that are superior accumulators of nutrients, especially P. They obtain their plot trial candidates from lists of plants that Tapado farmers claim as 'good'.

This study gathered a list of 'good' and 'bad' weeds from farmers in an under-surveyed region of Ultisols. Criteria for 'good' and 'bad' were elicited. Individuals of species so judged were collected and identified. Soil samples were taken from under 'good' and 'bad' vegetation patches, in otherwise similar micro-environments, and tested for pH and available P. No significant difference.

Introduction

Fifty percent of farmers in Costa Rica currently use the Frijol Tapado (FT) system of agricultural production, a system that has significant ecological and socio-economic benefits. FT is a traditional planting method in which fallow landcover is cut and seeds are hand broadcast on the resulting mulch. The mulch layer serves the functions of both fertilizer and herbicide, and to some extent, pesticide as well. The mulch provides ongoing nutrient input necessary for plant growth, limits weed emergence and is a medium for the insect diversity necessary for natural checks on pests. Since no artificial inputs are applied and weeding is minimal, labor is critical only at planting and harvest time. Farmers take advantage of this and diversify their activities at the time when off-farm income generating activities are abundant. Perhaps, most importantly, it is the source of critical subsistence crops. By securing the subsistence base while freeing labor for additional income, they can minimize economic risks and insure basic survival needs. FT is economically sustainable for resource-poor farmers. In contrast, Frijol Espeque (FE) is a high input system of bean production requiring that land be cleared, row planted, and maintained with fertilizer, herbicide, and pesticide. Therefore, it is a much more labor and capital intensive system than FT.

In Acosta and San Vito alone, approximately 90% of bean production uses FT. High rainfall and steep slopes characterize the San Vito area. The greater ecological

sustainability of FT over FE is particularly significant under such conditions. The mulch protects the soil from the erosive impact of heavy rainfall while the cleared land under FE frequently suffer from significant soil erosion. Such erosion, combined with agrochemical runoff, leads to polluted waters downstream. Soil loss also has powerful economic effects: degraded lands yield less; large farmers convert these lands into pasture, leading to further degradation; small farmers go into debt and lose their land altogether.

Having recognized some of the ecological and socio-economic advantages of FT over FE, current researchers (Martha Rosemeyer, Ken Schlater, and Jim Kettler) in Coto Brus have become interested in this system. They recognize that its continued viability depends on meeting two challenges: 1) the agroecological one of adequate fallow-length in a context of reduced land-availability; and 2) the economic one of achieving returns to investments comparable to those for competing land uses. To these ends they are seeking ways to increase the rate of nutrient accumulation in the fallow. They are engaging in a number of on-farm experiments examining soil effects of fallows of 'good' and 'bad' weeds as designated by farmers in the county.

The soils of the study area are Ultisols, which are prone to low availability of P especially under acidic conditions. Low pH causes Iron and Aluminum (Al) to become active, and P is "fixed" as unavailable iron and aluminum phosphates. Exchangeable Al is especially a good "fixer". Aluminum is more active and soluble at pH below 5.5 (being precipitated as Al phosphate at and above 5.5), although significant amounts of available P may be present even at lower pH due to the slowness of the soil processes. In addition, other transformations of soil phosphorus are also pH dependant. The other factor that controls availability of P is organic matter. Al forms strong complexes with organic matter and there is lesser amounts available for "fixing" P. In general, pH above 5.5 and higher amounts of organic matter are conducive for availability of P for plants. In addition, in Ultisols between 60 to 80% of P may be associated with organic matter (Sanchez, 1976). Certain plant species native to such areas, where available P may be limited, are known to be superior accumulators of P. The search for P accumulators is a central part of the current experiments of FT research in Coto Brus.

Aims and Hypotheses

We were told by Martha Rosemeyer and Ken Schlater that there had been little "good weed/bad weed" interviewing in an area of Ultisols and suggested visiting San Gerardo de Limoncillo, just such an area. To assist the ongoing research effort, we decided to go there 1) to ask farmers which volunteer vegetation they considered particularly good or particularly bad for making FT and why; 2) to take samples of these indicated plants and associations and have them identified for comparison with plants designated as such elsewhere; and 3) to take soil samples from beneath patches of both 'good' and 'bad' weeds to test them for differences in P, pH, and organic matter.

We wanted to test two null hypotheses. First, that we would find no difference in levels of available phosphorous, organic matter, and pH for soils located in fallows identified by farmers as 'good' and 'bad'. Second, that species composition in farmer-identified 'good' and 'bad' fallows would show no difference.

Methods

Over the course of several days we visited and spoke with ten FT farmers near San Gerardo de Limoncillo. As we walked through their fields and fallows (charrales) we asked them to point out which 'weeds' (montes) they considered 'good' or 'bad' for FT cultivation. In each case, we asked them in what ways the plant was good or bad. We collected samples of plants they distinguished in the charral which were later keyed by Luis Diego Gomez at Las Cruces.

After developing a list of good and bad species from farmers, we sampled vegetation for species composition in different aged fallows, described by one of the FT farmers, Jorge Borbon, as "good land" and "bad land". Samples were collected using a quadrant sample in 1 meter square plots. Samples were collected at two heights, above and below 60 cm. In plots containing more than 20% of a single species, (per visual estimation), the percent groundcover was noted instead of the number of individuals. In each plot, two samples were collected above 60 cm, and one below. Unfortunately, we were limited by time and did not obtain a good one year fallow to compare with our bad one year fallow.

In order to determine whether differences actually exist between soils beneath 'good' and beneath 'bad' weeds and weed associations, we had to control for other environmental factors. To achieve this we sampled the soil in 'sets'. Each set consisted of at least two composite samples within a few meters of each other (to attempt to control for soil heterogeneity), in the same charral (fallow age), at similar slope position. At least one of the composite samples in each set was taken beneath representative clusters of 'good' species or species associations and at least one from beneath 'bad' species. The soil was collected from the top 10 cm. The assumption was that processes that most influence P availability would be active in this organic rich layer. All soil samples were within a two km² area.

In the laboratory, the soil samples were sieved, dried and tested for available P, pH (1:2.5) and organic matter. Unfortunately, the soil organic matter test had to be abandoned at the final stage due to technical problems. The test for available P was the resin anion exchange based spectro-photometric method, which was recommended by researchers at Las Cruces OTS station.

Results

Our central question for farmers was "which weeds are good for frijol tapado"? Most of our research centered around the meaning of "good" and "bad" in this context, but we also learned something about the semantics of 'charal', 'montes', and 'monte'. A charal means a stretch, a piece of fallow. We never heard any of the farmers say 'barbecho', perhaps a more 'technical' term. 'Montes' are plants of secondary growth, volunteers, 'weeds'. We rarely heard the word 'maleza' used. A 'monte' can either be: a) an individual 'weed'; b) a cluster, a stretch, an association of them; or c) 'the bush' in its more inclusive sense. In this last meaning an etymology suggests itself: monte is 'mountain', with its echoes of the untamed nature of volunteer vegetation.

Though our primary purpose at the beginning was the extent of correlation between farmers' indications that a plant was good and its P contribution, we knew they were not directly aware of phosphorous contribution to mulch or soil, so we always asked in what ways they considered a plant good. The most common response was that it indicated good land for tapado ('muestra la tierra buena'). We thought this conflated several possible factors which we tried to untangle in subsequent questions. On the one hand these sites may be 'good land' because of either underlying soil or resulting mulch. Although the mulch of several plants was described as 'puro abono' (pure fertilizer), this distinction was never made. In a related sense, these plants may either be more abundant on soils of higher fertility prior to their existence or their presence may actually improve the soil. On only one occasion did we receive more than a shrug in response to this question of causal direction. Sr. Rojas said he believed both Paira (*Melampodium spp.*) and Girasol (*Helianthus* spp.) actually improve ('mejora') the soil in which they grow. (The question of causal direction will be returned to with regard to fallow management.)

There were two other interesting notions of plant effects on soil. A number of volunteers were considered bad because their roots grab ('amara') the soil and "make it hard". While some others "make it soft". Good soil was plainly described as black and soft, bad soil as red and hard.

Although the farmers did not make distinctions where we sometimes wished they would, they made a great number that we had not expected. They happily unpacked a whole range of attributes contributing to their blanket label of 'bueno' or 'malo', beyond the relative fertility of mulch/soil (see Table 1). These most commonly included:

- a) Ease of cutting. Good weeds grow upright and have fairly thin stems; bad ones have lower, sprawling growth habits, become dense mats or have spines, etc.;
- b) Length of time remaining 'dead' after cutting. Good weeds stay dead longer; bad weeds resprout rapidly during the course of bean production;
- c) Size of leaves. Good weeds have big leaves, offering more biomass ('abono') to the mulch; bad weeds, less;

- d) Root structure. Good weeds have either limited, non-binding roots or actually 'loosen' ('suelta') the soil; bad ones have thick masses of roots that can 'grab' ('amara') the soil;
- e) Relative competitive ability with beans. Bad weeds compete strongly with beans, even 'strangle' (**) them;
- f) Seed abundance. Bad weeds produce large amounts quickly; and
- g) Speed of regeneration after harvest. Good weeds, though delayed in resprouting or germinating over the course of bean growth and maturation, re-emerge strongly after harvest and are ready to offer their various benefits to the next tapado season in a relatively short time.

Comparison of the vegetation samples between the good and bad 5 year fallows showed that in only one case, Leguminosae #3, was there any overlap in species composition (see Tables 2 - 7). In the one year 'bad' fallow (P5) there were only two 'good' individuals (one of Tuete, and one of Jaral). There were no other contradictions between farmer's good/bad designations of individual plants and the good/bad species sampled in plots designated by farmers as good and bad monte.

The available P levels (Table 8) for the soils were higher than those of comparable Ultisols in other regions (Sanchez, 1976) and certainly higher than what is considered optimum for beans (Sanchez, 1976), although in those regions, the beans were growing on the soils, unlike the Tapado system. The available P levels for those soil samples above pH 5.5 (mean = 5.13) was higher than the mean P for all the samples, possibly indicating a pH effect, even though for the entire pH range, available P was not correlated strongly with pH.

A correlation of available P with class of soil ('good'=1, 'bad'=0) did not yield any relationship. Perhaps more interesting relationships could have emerged if sufficient samples were taken within a particular fallows to allow statistical robustness. The absence of soil organic matter data made the study of soil-plant relationships difficult, since organic matter in such soils is crucial for storage and transformation of nutrients, cations and anions. It is possible that some of the weed species in each successive fallow year accumulate P and may be more useful when they are slashed and are made part of the mulch. Thus, weed species other than those that are Nitrogen fixers may be important for the Tapado system, since P is more limiting in these soils.

It would be interesting to measure P content in living tissues of 'good' and 'bad' plants just before the slash occurs and in their mulch at different stages of decomposition. This would yield a much better picture of 'good' and 'bad' weeds and their relation to nutrient flows. In addition, some of these P accumulators may actually be associated with soil patches poor in P, where they may have a competitive advantage. Some may have significant Mycorrhizal associations.

Discussion

What does it mean to "indicate good soil"? All but one farmer did not really distinguish between cause and effect here: the association between a plant or cluster of plants and a land quality is enough. It is enough when one wants to know which area of charal is the best site for the next tapado, which sites to continue avoiding or remove from the system entirely and clear for pasture. It may not be enough if a farmer is interested in actually increasing the speed of adequate nutrient accumulation ('abono') in a charal, or of improving the quality of his charal. The relative advantage of FT versus FE is determined in part by land available for adequate fallow. As population pressure increases demands on land, there is a trend toward smaller landholdings and intensification of land use. The effect of such pressures is to decrease the fallow-length. Since sufficient fallow-length is at the heart of the FT system, the current trends in population and land-use challenges the basis of this system.

Though it seemed that farmers were not very interested in the direction of causality in a plant-soil association, the attributes of good and bad volunteer plants were far more complex than we had expected. Rather than dismissing these other attributes as irrelevant to the central research enterprise of identifying superior nutrient accumulators, perhaps research should include examination of the competition, soil density and management effects indicated by these other criteria of 'good' and 'bad'.

As adoption of FE is becoming more prevalent, so is the rate of land degradation increasing.

The conditions favoring FT are when land is available that does not have to be directly engaged in production, when cash resources are low, when sources of inputs and markets are not easily accessible, when high off-farm labor is available to farmers, and in areas with heavy rainfall and steep slopes. Conditions encouraging FE are when land is less available, when competition for other land uses is greater, when access to cash, inputs, markets, and labor is good.

Land availability

Labor: Shortage of available labor also influences the shift of land use in to pasture because it is a less labor-intensive activity. Another complication in land use is the perception that profitability of bean production is declining (Bellows, 1992). The effect of this seemingly unfounded perception is to shift land use out of bean production and into pasture (Ibid, 1992).

A fourth factor influencing land use is the recent drop in coffee prices. This situation has caused farmers to reduce the amount of land devoted to coffee cultivation and diversify crop activities. The observed trend is for an increase in vegetable

production and pasture. As mentioned, the labor for pasture is minimal, therefore, vegetable production is more likely found where there is no shortage of labor.

Government policies, particularly those effecting agricultural extension and agricultural aid to farmers, have been very influential in determining land use and agricultural cropping systems. Government programs provide farm loans and market development to encourage resource-poor farmers to adopt the input-based agricultural systems.

The manner in which agricultural research is conducted has also heavily influenced land use. The FE system was developed on experimental research plots located on lands that are unrepresentative of the majority of those under bean production, namely, flat, more fertile lands versus steeper sloped, less fertile lands. Under the former experimental conditions, the FE system has been shown to increase productive yields, but such research was not conducted on the type of lands cultivated by the majority of bean growers.

Realization of this institutional bias toward the less sustainable environmental and economic FE has led to research interest in improving the comparative advantage of FT with FE by increasing its efficiency. There are two aspects to such research, one focusing on increasing crop productivity through minimal amounts of purchased nutrient inputs, the other focusing on managing the natural fallow more intensively through close examination of natural processes and farmer practices.

In a few instances, it appeared that farmers believed that certain species actually improved soil and FT yield. Given the constraints on land availability pushing farmers into intensification of land use, there appears to be great potential for research on how to enhance a non-input based system, i.e., natural weeds, to rehabilitate degraded soils or restore soil fertility for FT with minimal fallow lengths. Research should enter where it appears that farmer's knowledge reaches a limit. Keeping in line with the on-farm research approach (Shaner et al., 1982; Chambers et al., 1985), there seems to be great potential for research to utilize farmer's knowledge about weeds.

The first step would be to select weeds that farmers considered best or worst soil indicators, especially any that they had more insight into vis a vis their effect on soil properties. Research could be conducted both on-site in field conditions, preferably as part of a farmer's normal crop management, and in controlled plots, that might be monitored closely by a 'researcher'. Analysis could operate at both a molecular chemical level as well as a macro-biological level. Above and below plant biomass could be analyzed for nutrient content to determine their contribution to nutrient levels in mulch.

It would also be important to study rates of decomposition and possible presence of secondary compounds and levels at which such would become damaging to either crops or associated good 'weeds'. Analysis of root structure and its potential effect on physical soil structure would be another important aspect of research. Rate of growth of different

species, both in isolation and in various associations with other species, would be necessary to determine which combinations of species would produce the highest amount of biomass while taking into account other factors mentioned above. This focus would also determine ability of plants to compete in different plant associations. The possibility and ease of seed collection of desirable species for management would be necessary, including optimal methods of dispersion. For plants rooting by rhizome and/or adventitiously, research would also need to examine optimal means of propagation. Throughout all of this research, the context of returns to labor for the farmer would need to be of paramount concern.

This scenario would achieve both production goals and environmental goals - both in terms of conservation of resources (soil and water), as well as contributing to increasing vegetative cover, maintaining maximal vegetative diversity. It might even be considered as an initial stage in managed reforestation - the first step to improving soils, to be followed by introduction of tree species, and eventually the system might evolve into a managed forest, sections of which are slashed and mulched on a rotational basis and intercropped with FT.

FT is just one example of a tapado system, but we have heard, though not seen, that it is possible to use the principles of tapado for other crops. Using a tapado system and participatory research approach holds much potential for developing agricultural systems that are at once environmentally and economically sustainable and could work towards goals of habitat preservation.

This OTS course has exposed us to problematical aspects of input-based agriculture. As researchers with particular interest in applying our work, we are faced with the issue of how to disseminate our results to target populations. Often, not only are research questions developed without consulting target populations, but results are typically alienated from the researcher's context when they are applied in extension work. One solution to this dilemma is to more closely tie research to both farmer's sites and insights, and avert the alienation and distortion of research.

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Table 1. List of Good and Bad Weeds as Identified by at Least One Frijol Tapada Farmer.

Common Names	Species	Family	# Responses	# Indivs Indicating Additional Criteria
Good Weeds:				
Tucte	Veronia spp.	Compositae	4	1
Mosote	Cosmos caudatus	Compositae	4	2
Platanilla	Heliconia spp.	Musaceae	4	-
Paira	Melampodium spp.	Compositae	5	2
Jaral	Calea urticifolia	Compositae	4	1 E,G,N
Burio	Hampea apendiculata	Tiliaceae	4	2
		Malvaceae		
Zacate peludo	Panacoideae spp.	Gramineae	3	1 M
Jaboncilla	Phytolaca spp.	Phytolacaceae	2	
Zacate amargo	Axonopus spp.	Gramineae	2	1
Piper/Pipiazu	Cucurbita mixta	Cucurbitaceae	2	
Calinguero	Melinis minutiflora	Gramineae	2	
Hoja Ancha	Setaria vulpiseta	Gramineae	2	
Bad Weeds:				
Escobilla	Sida spp.	Malvaceae	4	3C 1I
Helecho	Pteridium spp.	Pteridiceae	5	2M,1C,1G
Tarquesa	Scleria spp.	Cyperaceae	3	
Dormilona	Spilanthes spp.	Compositae	3	1C
Colechibo			2	
Alambrillo	Borrena suaveolens	Rubiaceae	2	1C

Table 1 continued.

**Mixed
Responses:**

Muriseco	<i>Bidens pilosa</i>	Compositae	3B 5M	1E,M 3M,L
Verejena			2B	1M

Key to Column 5:

"Good" Monte:

E = easy to cut

G = grows quickly

N = does not grow back rapidly or strongly

M = 'makes the soil good'

"Bad" Monte:

G = 'grabs' soil; compacts

C = competes with good monte

I = indicator species of bad monte

L = plant grows low to the ground and is hard to cut

S = spiny and difficult/unpleasant to cut

Key to Column 4:

B = Bueno/Good

M = Malo/Bad

Table 2. Vegetation Above 60 cm in Monte Malo, 5 Year Fallow, Sample P2.

#	Common	Family	Species
Indivs Name			
5	Bracken Fern	Pteridiceae	<i>Pteridium aquiligrum</i>
4		Compositae	<i>Baccharis spp.</i>
2	Escobilla	Rubiaceae	<i>Sida spp.</i>
2		Graminae	
1			<i>Vismia guianensis</i>
1		Apocinaceae	<i>Vincetoxicocum spp.</i>
1		Graminae	
1		Leguminosae 1	
1		Compositae 4	
1		Compositae	<i>Melampodium spp.</i>

Table 3. Vegetation Below 60 cm in Monte Malo, 5 Year Fallow, Sample G2.

#	Common	Family	Species
Indivs Name			
6		Euphorbaceae	<i>Phyllanthum spp.</i>
5		Compositae 4	
2		Rutaceae	<i>Xanthosoma mexicana</i>
2		Leguminosae 1	
2		Compositae	<i>Melampusium spp.</i>
1		Leguminosae 2	
2		Graminae	
2		Acanthaceae	
1		Leguminosae	

Table 4. Vegetation Above 60 cm in Monte Bueno, 5 Year Fallow, Sample P3.

#	Common	Family	Species
Indivs Name			
2		Euphorbeacea	
1	Platanilla	Heliconiaceae	<i>Heliconia latispatha</i>
1		Rhamnaceae	<i>Govinia monoica</i>
1		Pteridaceae	<i>Densteteae obtusiloba</i>
1		Compositae	<i>Mikania spp.</i>
1		Compositae 2	
1		Compositae 3	

Table 5. Vegetation Above 60 cm in Monte Bueno, 5 Year Fallow, Sample P4.

#	Common	Family	Species
Indivs Name			
2		Pteridaceae	<i>Densteteae obtusiloba</i>
2		Compositae 1	
2		Compositae 2	
1		Rubiaceae	<i>Faramea spp.</i>
1	Platanilla	Heliconiaceae	<i>Heliconia latispatha</i>
1		Convolvulaceae	<i>Ipomoea spp.</i>
1		*Leguminosae 3	
1		Rhamnaceae	<i>Goviania monoica</i>
1		Vitacea	<i>Vitus spp.</i>
1		Apocinaceae	<i>Colubrina spp.</i>

* denotes the individual that appeared in both the 'good' and 'bad' charrals.

Table 6. Vegetation Above 60 cm in Monte Bueno, 1 Year Fallow, Sample P5.

#	Common	Family	Species
Indivs Name			
16	Cana agria	Melastomataceae	
4		Compositae	<i>Melapodium perfoliatum</i>
3	Tuete	Compositae	<i>Vernonia spp.</i>
3		Rubiaceae	<i>Faramea</i>
3		Compositae 4	
2		Euphorbiaceae	<i>Phyllanthus spp.</i>
1		Rubiaceae	<i>Richardia spp.</i>
1	Lantana	Verbenaceae	<i>Lantana camara</i>
1	Gavilana	Compositae	<i>Neurolina lobata</i>

* 75% of the species composition was *Gramineae Panicoidum spp.*

Table 7. Vegetation Below 60 cm in Monte Bueno, 1 Year Fallow, Sample G3.

#	Common	Family	Species
Indivs Name			
22	Muriseco	Compositae	<i>Bidens pilosa</i>
9		Acanthaceae	<i>Vletchum brownii</i>
3		Leguminoseae 1	
3		Gramineae 1	
1		Gramineae 2	
1		Rubiaceae	

List of Lectures

Title of Lecture	Speaker	Student Reviewer
Environmental Education and Conservation Planning	Gerardo Barboza	Liz Marshall
Anthropological Entomology	Jeff Bentley	Keith Taulbee
Soils of Costa Rica	F. Bertsch	Donald Mee
Acid Rain	Dr. Bruck	Ellen Pedersen
Integrated Pest Management	Hernán Camacho	Ankila Hiremath
A Case Study of an IPM Project	Hernán Camacho	Chris Picone
Fundecor	Froylan Casteneda	Jagdish Krishnaswamy
Photosynthesis and Growth of Understory Plants in Response to Light Variation	Robin Chazdon	Pamela Stedman
An Introduction to Aquaculture	Bill Deutsch	Jill Fischer
Water Quality	Bill Deutsch	Jagdish Krishnaswamy
Aquatic Ecology in the Context of Tropical Managed Ecosystems	Bill Deutsch	Nabiha Megateli
Organic Farming	Luis Eladio	Pamela Stedman
The History of Agricultural Development	L. Fournier	Keith Taulbee
Biotic Units	Luiz Diego Gomez	Lucy Buchan
Production Economics	Upton Hatch	Brent Blair
A Round Table Discussion on Sustainability	Upton Hatch	Donald Mee
Resource and Environmental Economics	Upton Hatch	Pantaleo Munishi
Introduction to Boscosa	Jose Joaquin Campos	Norm Bourg
Geography of Costa Rica	Oscar Lucke	Christopher Rosin
Mammals of Palo Verde - Especially Opossum (<i>Didelphis Virginiana</i>)	Monica Marquez	Laura Howard

Banana Plantations	Alex Martínez	Jill Fischer
Proyecto de Desarrollo Rural Integrado Osa-Golfito	Ana Mesa	Bruce Ferguson
History of Conservation in Costa Rica	Julian Monge	Cecelia Smith
Fungi	Greg Mueller	Laura Howard
Body Condition Score in Dairy Cows	Wayne Odegard	Ellen Pedersen
Sustainability of Dairy Farming in the Tropics	Wayne Odegard	Pantaleo K. T. Munishi
An Introduction to Portico	Rudolfo Peralta	Ankila Hiremath
Water Quality/Drinking Water	Cathy Pringle	Liz Marshall
Functions of Biological Corridors	Jaime Rau	Cecelia Smith
National Parks of Costa Rica	Jose Maria Rodriguez	Liz Marshall
Costa Rican National Parks	Jose Maria Rodriguez	Lucy Buchan
Dairy Industry of Costa Rica	Augusto Rojas	Amelia Oliver
Introduction to Coto Brus	Martha Rosemeyer	Lucy Buchan
The Frijol Tapado System	Martha Rosemeyer, Darryl Cole, and Ken Slater	Amelia Oliver
Inbio	Elvira Sancho	Bruce Ferguson
Organic Agriculture	Shogo Sasaki	Christopher Rosin
Forest Growth Simulation	Lloyd Simpson	Brent Blair
High Altitude Ecology	Carlos Valerio	Laura Howard
Life Zones of Costa Rica	Carlos Valerio	Norm Bourg
Reproduction Strategies of Araceae	Carlos Valerio	Christopher Rosin
Pasture Ecology and Management	Edzard Van Santen	Jeff Zimpfer
Research Methods in Agronomy	Edzard Van Santen	Nabiha Megateli
Integrated Pest Management	Mike Williams	Jeff Zimpfer

Lecture Abstract

ENVIRONMENTAL EDUCATION AND CONSERVATION PLANNING

Speaker: Gerardo Barboza

Abstract by: Liz Marshall

Costa Rica alone harbors 5% of the earth's flora and fauna. Palo Verde National Park, a tropical dry forest in the Guanacaste region, has more than 12 different ecosystems, a large diversity of insects, and a wide variety of larger animals including coati, black and green iguanas, deer, and howler monkeys. The marsh is a resting point for many migratory birds during the dry season, and nearby Isla de Pajaro is one of the most important bird rookeries in Costa Rica. Threats to the park include questionable land management practices, pesticides, forestry and unplanned irrigation systems.

Costa Rica's enormous diversity makes it a prime target for ecotourism development. Sixty percent of the people who arrive in Costa Rica are interested in its natural history, and tourism is the country's second largest source of foreign exchange. Some of the positive effects of ecotourism are the encouragement of conservation culture and the attraction of people from outside of Costa Rica. Ecotourism is also a means of diversifying income and of taking advantage of local resources, both cultural and environmental.

There are negative impacts as well, however, such as the environmental impact on fragile environments such as Isla de Pajaro and the Barro Honda caves. Four beaches in particular -- Ostional, Grande, Nancite and Naranjo -- exhibit different degrees of human impact. All four beaches are important sea turtle nesting sites. Playa Nancite is closed to tourism and suffers minimal disturbance. Ostional has a legal program for harvesting sea turtle eggs that seems to have cut down on the illegal harvesting pressure. MIRENEM has tried to control tourism's impact at Playa Grande, but it has been largely unsuccessful, as the turtles are likely to return to water after even the slightest disturbance. Access to Playa Naranjo is very difficult, so the impact is controlled naturally.

Other negative effects of tourism include cultural impacts and displacement of small local landowners who sell out to foreigners.

There has been a lot of effort in Guanacaste to encourage tourism; the government is providing training for service personnel, improving the transportation infrastructure through the area, and has just recently initiated a program to encourage small-scale land development. There is great potential for ecotourism development in the area, but it must be carefully managed to avoid these negative impacts.

ANTHROPOLOGICAL ENTOMOLOGY

Speaker: Jeff Bentley

Abstract by: Keith Taulbee

Both farmers and scientists have contributed significantly to advances in agriculture. However, scientists often forget that farmers have been around for far longer, and many of the current agricultural problems the world is facing are the result of overuse of pesticides and fertilizers invented by scientists. Many of the recent advances in organic farming, agroforestry, and crop rotation have actually been practiced by farmers around the world for centuries. However, farmers do not know everything about agriculture, and in some cases scientists can contribute significantly to agricultural efficiency and production. This interaction between farmers and scientists was the intention behind farmer participatory research, in which farmers and scientists worked together, combining their areas of expertise.

Farmer participatory research may have sounded like a good idea in theory, but to date, it has not produced anything of significance. This is the result of a multitude of factors, nearly all of which stem from a lack of communication. Furthermore, anthropologists have a tendency to assume that farmers, and other native peoples, have all of the answers. On the other hand, agricultural scientists think that they also have all of the answers. The truth, of course, lies somewhere in-between.

One way to see how small farmers and scientists view the world is to arrange the known world in terms of whether or not something is important, and whether or not something is easy to see. Phenomena such as soil, yield, weeds, and bees are both easy to see and are important. As a result, farmers tend to have as much of an understanding of these issues as agricultural scientists. Other phenomena, that is also important, but which is very difficult to see, such as pests and plant diseases, are much better understood by agricultural scientists, and is an area in which they can have much to offer the small farmer.

Although generally thought of as conservative, farmers are constantly innovating, and if given sufficient background information regarding those things which are not easy to see, but which are important, farmers will begin trying new strategies of pest control, hybridization, and other techniques to improve their productivity. This is the interface in which farmer participatory research can be most effective. Rather than stressing the typical application of petroleum based fertilizers and pesticides, which increase the resistance of pests, agricultural scientists could begin to implement courses which, while introducing farmers to basic ecological concepts, do not try to force feed farmers with what the agricultural scientists perceive to be the best way to do things. Scientists must also be willing to learn from farmers, and to have the patience to not encourage wholesale change, if it conflicts with the farmers traditional belief system.

This strategy has been successfully employed in Honduras, through a series of three day long courses. During these courses, the farmers attend lectures, play games, sing songs, and conduct field work which increases their knowledge of the agroecosystem, and the importance of natural predators, parasitoid wasps, and microbotic organisms which the farmer would not otherwise notice. The courses are kept interesting, and repetition is avoided at all costs, to maximize retention. Although these causes have only been in existence for a few years, they appear to be incredibly successful.

Farmers and scientists each possess knowledge regarding agriculture. In some areas farmers may know more, in some cases scientists may know more, and in other cases, each may be equally knowledgeable. Farmer participatory research, once hailed as the solution to the world's agricultural problems, has yet to contribute anything of significance. However, short causes like the one in Honduras may be an important first step in bridging the communication gap which has so hindered the movement in the past.

SOILS OF COSTA RICA

Speaker: F. Bertsch

Abstract by: D. Mee

Despite popular belief that tropical soils tend to be of a similar nature (i.e., highly weathered, nutrient poor), they are in fact as diverse as those in temperate regions. The characteristics of a soil depend on several factors, the most important of which are: parent material, relief, weather, soil organisms, and the age of the soil.

Soils with similar characteristics are often grouped together so that generalizations can be made. There are a variety of taxonomic systems used throughout the world. The USDA soil classification system is used in Costa Rica. Soil depth, texture, consistency, chemical properties, and the presence of rocks are characteristics used in determining a particular taxa.

Of the eleven soil orders in the USDA system, eight are found in Costa Rica. These are: Alfisols, Andisols, Entisols, Inceptisols, Mollisols, Sopodosols, Ultisols, and Vertisols. The more predominant of these orders can be grouped into four broad categories for field recognition and management purposes.

The first group is the Alluvials found on 20% of the land in Costa Rica. This group is comprised of Entisols (lacking definite horizons) and Inceptisols (having A and B horizons). These are young fertile soils with a high proportion of exchangeable bases. They are found throughout the country.

The next group in Andisols make up 16% of the area. These are easily compacted soils of volcanic origin. Because of amorphous clays such as allophanes, these soils tend to fix phosphorus, making it unavailable to plants. These soils are found in the volcanic central highlands.

Vertisols making up only 2% of the land area are important because of their importance to rice farming. These are stable mature soils with a high content of vermiculitic clays capable of considerable shrinking and swelling. Because of their cracking nature, these soils are self-inverting. They generally have a high pH and a high level of exchangeable bases, especially calcium. They are commonly found in depressions in the northwest part of the country.

The final group is red clays which occupy 33% of the land. These are Alfisols and Ultisols. They are highly weathered clays with a low pH and high levels of aluminum in monomeric or sesquioxide forms. They are common in the lower altitudes.

ACID RAIN

Speaker: Dr. Bruck

Abstract by: Ellen Pedersen

Industrialized countries have observed the death of trees in natural forests in the past 10 - 15 years. Several theories ranging from global climate changes and insect attacks were tested in order to explain this sudden mortality of apparently healthy forest in the U.S. and Europe. Chemical analysis showed changes in soil and air composition, whereas physical analysis of the trees showed a decline in biomass and reduction of growth rate accompanied by chlorosis of the needles in the last 30 years. The low pH values in the clouds surrounding the trees were proven to be the cause of this mortality and was caused by human pollution.

Eastern european countries face similar but extremely higher pollution and tree death rates, aggravated by their political and economical instability. No immediate solution was proposed by Dr. Bruck more than the suggestion of the establishment of nuclear power plants, which would not even be considered by countries with unlimited supply of cheap brown coal that "needs" to be exploited. The general perspective was negative, although realistic.

INTEGRATED PEST MANAGEMENT

Speaker: Hernan Camocho

Abstract by: Anila Hiremath

The Integrated Pest Management (IPM) program in Canton Acosta is a pilot project, started in collaboration with the European Economic Community (EEC), to try and eradicate the Mediterranean fruit fly, a pest of citrus. The objectives of the project are to try and demonstrate the ecological and economic feasibility of IPM as an alternative, low-impact technology.

IPM attempts to minimize the use of conventional chemical pest control by incorporating biological control methods based on an understanding of pest population dynamics, pest-parasitoid interactions, etc. There are several aspects of chemical pesticide use that make IPM an attractive proposition. These include:

1. the buildup of pest-resistance to the pesticide applied,
2. the creation of secondary pests,
3. pest-resurgence,
4. the accumulation of chemical residues in the food chain,
5. trophobiosis (the detrimental effect of pesticide use on plants), and
6. the high costs involved.

Of these, two in particular were important in motivating IPM research in Costa Rica. One of these was the rise in prices of chemical pesticides. The other was the result of various studies conducted in the mid '80s which showed that the levels of chemical residues in food crops were higher than the recommended standards. They also showed that more than 70% of all human fat-tissue sampled registered the presence of chemical residues.

Another factor that was instrumental in stimulating IPM research was the development at this time of fruit-growing as an alternative to cattle-farming. In particular, citrus was promoted to take advantage of the opening in the world market created by the frost-induced failure of citrus in the United States. With the rise in citrus cultivation came the problem of the Mediterranean fruit fly, an exotic pest. In 1986 the damage to citrus caused by the fruit fly was calculated to be 34%.

The Mediterranean fruit fly is one of several fruit flies in Costa Rica. All are Dipterans, in the family Tephritidae. Together they represent three genera:

1. *Ceratitis capitata*. The Mediterranean fruit fly. A pest of citrus.

2. The genus *Anastrepha*, has more than 90 species, of which four are pests:

- i. *A.obliqua*. A pest of mango.
- ii. *A.striata* . A pest of guava.
- iii. *A.serpeentina*
- iv. *A.fraterculus*

3. *Toxotryphana curvicauda*. A pest of papaya.

With the exception of the Mediterranean fruit fly, which is an exotic pest, all the other species are native to the neotropics. That is one of the reasons behind the attempts to eradicate the Mediterranean fruit fly while seeking only to control and not to eradicate the other species. Another reason is to meet the quality control standards for the export of citrus.

A CASE STUDY OF AN IPM PROJECT

Speaker: Hernàn Camacho

Abstract by: Chris Picone

Europe, Japan, and the U. S. depend on countries like Costa Rica for fruit imports during the winter season in the Northern Hemisphere. However, this coincides with Costa Rica's dry season, when the exotic Mediterranean fruit fly, *Ceratitis capitata*, is a pest. Unlike its native counterparts, *Ceratitis* populations peak from January - May, when citrus and mango production is highest. Thirty-six percent of the citrus crop was lost in 1986. In that time, citrus received little chemical inputs because coffee was the focus crop. With the drop in coffee prices, pest management of citrus has been encouraged. The EEC has thus helped to fund an IPM program in the Acosta area.

First, male pupal flies are sterilized by radiation and released into agricultural zones. Every week during the year, one bag with 3000 flies is applied per hectare. The sterile males should outnumber fertile males, dominate mating, and reduce the next generation. Each bag is currently subsidized by the EEC, but when subsidies cease, a bag will only cost U.S. \$1.50.

Secondly, two parasitoid wasp species are cultivated in the lab and released when *Ceratitis* populations are peaking. One ant-like wasp attacks pupa, while the other deposits its eggs into fly larvae.

The program has taken off with small farmers in the Acosta region. To begin, it is critical that farmers are well organized and cooperate because a regional approach is necessary for success. Thus far, 50% of Acosta is involved, yet 100% of the area is covered by the program. Eight years have passed since the program was initiated, and now only 1% of the fruit crop is lost to the Mediterranean fruit fly.

FUNDECOR

Speaker: Froylan Casteneda

Abstract by: Jagdish Krishnaswamy

The foundation for the Development of the Central Volcanic Mountain Range (FUNDECOR) is a Costa Rican, non-profit, non-governmental organization supporting and promoting the conservation and sustainable use of the natural resources in the specific region. It has received financial aid from USAID to fund its activities and overhead costs.

Based at Puerto Viejo, the organization actively supports the Costa Rican Ministry of Natural Resources in preserving and managing the protected areas in this region. This support includes technical and training components. In addition, Fundecor is active in management of Buffer Zone areas, by financing forest management, reforestation and agro-forestry. This is to address the need to meet the growing demand for timber without degrading natural forest patches. One of the strategies adopted is acting as a technical advisor for private forest owners and as a liaison between logging contractors and these private holders. This encourages adoption of non degrading or sustainable practices, including well designed access roads. Also, many campesinos own forest land, and being short of hard cash, are forced to sell logging rights cheaply to unscrupulous logging agencies. Fundecor intervenes and recommends loggers to such land owners.

Fundecor is also involved in reforestation with native species, and is collaborating with OTS on much needed research. Fundecor attempts to help private land owners initiate reforestation or agro-forestry, and gradually decreases subsidies to avoid too much dependance.

The conflicting policies of IEDA programs cause problems and often promote deforestation and land degradation. Fundecor is attempting to gradually wean private forest holders, and those with marginal land suitable for forestry, from adopting degrading land use.

PHOTOSYNTHESIS AND GROWTH OF UNDERSTORY PLANTS IN RESPONSE TO LIGHT VARIATION

Speaker: Robin Chazdon

Abstract by: Pamela Stedman

Robin Chazdon, a researcher at La Selva, spoke about the response of understory plants to the variations in light on the forest floor. Full sunlight only occasionally reaches many plants in the understory, in relatively brief moments referred to as sunflecks. The amount of light reaching the forest floor in some places can be as little as 1% of the light hitting the canopy. It can be expected that plants will have developed an appropriate photosynthetic response to their environment. Several studies were discussed in the lecture. However, the technology for studying photosynthetic responses of plants in the field to variations in light has only recently become available, and many further studies remain to be done.

The first study examined the variation in light intensity across various habitats at La Selva. Photosynthetic photon flux density varied by three orders of magnitude from the forest floor, to gaps of 200 m² and 400 m² to a cleared area. This would seem to confirm the importance of sunflecks.

The second study looked at photosynthetic rates of understory plants responding to sunflecks of various durations. It was found that higher levels of photosynthesis are reached with each sunfleck -- when they occur in rapid succession -- until an equilibrium level is reached. Initial response is low because the plants have not been fully induced. However, there is also a lag in response to the dark periods -- that is, the plant will continue photosynthesizing even after the sunfleck is over. In this way, plants adapted to the understory may be taking greater advantage of the brief moments of sunlight than would be expected.

The third study looked at spatial differentiation among species, based on variations in light. It was found that, in a cleared area, there was a strong relationship between light and photosynthesis equilibrium levels. This tight relationship was not found in a dark ravine, indicating that plants in the darker areas have a photosynthetic capacity which is not fully employed.

The fourth study compared growth of two piper species under different light conditions--a small forest gap and a large gap. *Piper arieianum* is common in the understory and *Piper santafelicis* is common in more open areas. The gaps presented a range of light conditions, with peak radiation in the center and less at the edges. The understory species did not seem to take advantage of the increased levels of light, whereas

Piper santafelicis showed higher growth rates in the brighter areas. Light, therefore, seems to be a greater controller of growth in *P. santafelicis* than in the understory species, *P. arieianum*. No control was carried out in a fully shaded area to confirm piper arieianum's growth capacity in low light areas.

The study of response to light flecks, and the role of canopy density and openings, may have important implications for agroforestry, forest management, and forest regeneration, given its implications for species selection and growth rates.

AN INTRODUCTION TO AQUACULTURE

Speaker: Bill Deutsch

Abstract by: Jill Fischer

To begin his presentation Bill Deutsch mentioned that while a fisherman is a hunter, the practice of aquaculture, despite the reliance on water, more closely resembles conventional agriculture than it does fishing. He demonstrated this point through the vocabulary utilized by those who practice aquaculture. The fish are referred to as seed, the ponds are fertilized to encourage the growth of plants in the ponds, and when the fish are large enough to be sold, they are harvested. The characteristics of aquaculture also simulate conventional agricultural practices. Pests and predators are eliminated from the ponds, as in an agricultural system. Just as the grain, the fish are selected for specific traits, such as size and color. And, the pond gradually moves toward a monoculture system.

Just as in farming, there are different levels of aquaculture intensity. The least intensive system is known as a capture fishery. This type of aquaculture is usually practiced along the coast utilizing the distinct water levels of the tides to temporarily capture fish. Thus, only the desired quantity needs to be collected. This system is one of few inputs, no feeding is required; and, there is no change in the water quality, as new water enters the system with the changing of the tide.

Aquaculture can also be a semi-intensive or intensive system. In such cases, the fish are in an enclosed area; fertilizer (to encourage the growth of the naturally existing flora to serve as a source of food, and to increase the level of oxygen in the water) and food are added to the system in varying degrees, depending on the level of intensity of the aquaculture.

Just as any other farming system, aquaculture has limitations. As the intensity of the system increases, the first main obstacle to overcome is the lack of dissolved oxygen in the water, which occurs most frequently in the early morning. However, when introducing oxygen into the system to compensate for the early morning deficit, the quality must be monitored. If large quantities of dissolved oxygen are added to the water during hours of bright sun, plankton may begin to consume the introduced oxygen intended for the fish; and thus, quickly reach a level of supersaturation. Therefore, to avoid such adverse effects on the system (and to save money on electricity bills), it is recommended that oxygen be introduced only for a few hours in the early morning. The second major obstacle to more intensive aquaculture is the buildup of ammonia. Ammonia is the material excreted which is a result of the breakdown of proteins in fish

food. Because the fish are kept in relatively small areas, high levels of ammonia in the water can become toxic to the fish.

Deutsch stressed that aquaculture is not only important in terms of generating income, but also as producing high quality protein with minimal impact on the agroecosystem. Fish are the most efficient source of animal protein, in terms of the ratio of inputs to the output of protein. Furthermore, aquaculture can be practiced in many areas, even on relatively infertile lands, and is merely another by-product gained from a watershed.

WATER QUALITY

Speaker: Bill Deutsch

Abstract by: Jagdish Krishnaswamy

Water resources often reflect the health and state of degradation of a watershed. This is because land use and changes thereof in the watershed ultimately may cause corresponding changes in water quality, whether in terms of physical, chemical or biological parameters. It is important to distinguish these changes over and above (or below) those that are due to natural processes, and ensure that any temporal trend is significant. The natural variability including seasonal trends, stream flow related and those due to instrument or data recording errors need to be subtracted before one can establish actual anthropogenic induced changes. It is also necessary to obtain baseline data from a watershed similar in all other respects but without the land use or activities that one is concerned about.

It is essential to recognize that pollution in the watershed can be both non-point and point source based. Agro-chemical use and erosion are typically non-point whereas an effluent discharge is usually a point source. One approach to water quality assessment is costly, laboratory based and skill intensive. The other is mobile, simpler, portable kit based. The latter is accessible to non-specialists and is useful in generating awareness, even though it is not very precise or accurate for some parameters.

It is not necessary to test for all possible chemical and physical parameters, and very often parameters such as pH, temperature, dissolved oxygen, total hardness, and total alkalinity can reveal a whole range of commonly encountered processes in natural waters, polluted or otherwise. This can then form the basis for selection of a more detailed laboratory based sampling and testing program, if required.

AQUATIC ECOLOGY IN THE CONTEXT OF TROPICAL MANAGED ECOSYSTEMS

Speaker: William Deutsch

Abstract by: Nabiha Megateli

The 90's are like a second wave of environmental holism predated by the 60's. Water is the grand integrator of focus for land-use conflicts and resolution at the watershed level. Auburn University is at the forefront of international aquatic ecology and aquaculture research and education. Of the 100 graduate students, 50% are international.

"Poverty won't Save the Planet"

Ninety five appropriate technology aquaculture projects are in progress in the world, including Panama, Guatemala, Ecuador, Philippines, Burkina Faso, Zaire and Rwanda. With small scale subsistence farmers in mind, integrated agri-aquaculture systems are being designed to provide efficient production of high quality protein and alternative income to farmers as part of the USAID CRISP program. Typically, thalapia mono/polyculture ponds of 3 to 4 meters are being combined with water harvesting and agro/silvo/forestry projects. Careful attention must be paid to mosquito larvae and snail population monitoring for the prevention of malaria and schistosomiasis.

Rapid bioassessment techniques are being developed that can be understood and used by local people. Stream water quality indices based on aquatic macroinvertebrates are assisting in monitoring and assessment of the effects of non-point and point pollution sources. Using these bioassessment techniques, Alabama citizen groups of both children and adults are monitoring stream impacts of organic loading from agricultural systems. In addition, easy to use colorimetric water test kits for measuring temperature, pH, dissolved oxygen, turbidity, and alkalinity have been made available.

Despite imperfect data, these groups, having now grown to 70 in number, could break into the typical political clout and information cycle. If a thousand fold magnified, citizen data collection, dissemination and use could not only change the lifestyles of members but also result in major policy changes at the local level. University environmental extension can thus be considered vital particularly for non-point source pollution abatement.

In our search for the conservation of biodiversity and economic development, the Holistic Research Model may be helpful. At the center is the gray ball is all of what humans want: quality of life, landscape conservation, production, etc. All the multicolored balls representing interdisciplinary generalists should contribute with and not exclude single colored balls. Ultimately the painful process of the entire context and our goals should speak to us all.

ORGANIC FARMING

Speaker: Luis Eladio

Abstract by: Pamela Stedman

Luis Eladio, together with his brother, is practicing organic farming of vegetables on his land in the Central Valley. They share a one and a half ha. IDA plot, which they have held for x years. Eladio took part in an intensive course in organic farming techniques two years ago taught by the Japanese development agency, and is putting those techniques into practice on his farm. He explained the processes he is using and the problems and benefits of organic vegetable farming.

This particular organic farming system was developed by the extension agent from the Japanese development agency, based on traditional Japanese techniques and local climate, topography, crops, windbreaks and soil qualities. All inputs from fertilizers to pesticides are organic. Two fertilizers are used, one a compost of cow manure, sawdust, soil and crop residues, and the other, more frequently used, called Bokachi, which is a fermented mixture of charcoal, rice husks, chicken manure, molasses and yeast. Insect repellent is made from chilis, garlic and oil. Biodegradable soap is used to kill other insects.

Luis Eladio estimates that the cost for organic farming are about the same as they are for conventional systems. However, he can expect to receive a higher price for his produce from buyers who prefer organically grown vegetables. For example, a national chain, Mas X Menos, to which he sells some of his produce, has recently begun selling organic produce.

Lecture Abstract

THE HISTORY OF AGRICULTURAL DEVELOPMENT

Speaker: L. Fournier

Abstract by: W. Keith Taulbee

Costa Rica has undergone four major agricultural periods during the course of its history. These four periods, the pre-Columbian, colonial, early republican, and the Twentieth Century, have both shaped and been shaped by many extraneous factors, such as the political structure, the growth of national infrastructure, and the rate of deforestation.

During Costa Rica's pre-Columbian period, beginning with the earliest human settlement, the country was characterized by a high diversity of indigenous peoples, as it lies within the region which linked the Mayan and Andean cultures. Primarily, these people were fisher-hunter-gatherers who practiced a system of shifting cultivation, and whose population was concentrated within the fertile, temperate central valley. A wide variety of cultigens were utilized, including cassava, yucca, palms, various fruits, and cocoa, the seeds of which also served as currency.

Although the traditional belief holds that pre-Columbian people lived in total harmony with nature, evidence of localized deforestation within the central valley suggests that the human population of 27,800 had nearly reached carrying capacity. However, by the beginning of colonization, 96% of Costa Rica was still covered by forests.

The colonial period began in 1522 when Spanish settlers established permanent colonies in the central valley. They largely displaced the indigenous form of agriculture with a more intensive system, and imported such European grain crops as corn and wheat, and imported European livestock such as cattle, pigs, and chicken. This required the clearing of large expanses of forest, and the indigenous people who had not been either enslaved or killed by disease were forced into the more marginal highlands.

Due to the decimation of the indigenous population, Costa Rica's population remained low throughout the colonial period, with a total population of only 15,538 in 1622, rising to 52,591 by 1801. The percentage of forested land also remained high, with 88% covered in 1802.

The early republican period began with independence in 1821, and is characterized by the beginning of two major export crops, coffee and bananas. Coffee was first planted in Costa Rica in the 1820's, but in 1860 direct trade with Europe began. This event was both a signal for the beginning of international trade and entrance into the world economy, as well as the start of a cultural exchange with Europe. Banana plantations were first

established in 1883, as the result of a land grant issued to the chief engineer of Costa Rica's railroad, to the Atlantic Ocean. Finally, Costa Rica began to manufacture more goods during this period, and in the latter part of the 1800's, it began creating its technological and educational infrastructure.

Even though the country's population grew from 70,000 in 1821 to 303,000 in 1900, Costa Rica was still largely forested. By 1900, 82% of Costa Rica remained covered with forests.

The Twentieth Century has been a period of tremendous agricultural change, as well as a period of tremendous challenges. The population has grown to 3.25 million, with the largest portion of that occurring within urban areas. A rapid increase in the amount of land converted to pasture has left only 31.8% of Costa Rica's lands covered with forests. Soil erosion from deforestation, and contamination of lands long used as banana plantations, have created additional environmental problems. The Costa Rican government has taken steps to address these problems, such as in the creation of governmental agencies which manage and regulate agriculture, and the funding of governmental and university projects which address the issues relating to sustainable agriculture.

Agriculture in Costa Rica has changed dramatically over the course of its history. Most of that change has occurred in a very short period of time, and the rate of change appears to be accelerating. These changes have transformed Costa Rica from a tree-covered, isolated land into a significant agricultural exporter, which has become integrated into the global economy.

BIOTIC UNITS

Speaker: Luiz Diego Gomez

Abstract by: Lucy Buchan

The concept of mapping biotic units was initiated by Holdridge in 1947. His Life Zone Concept was used to predict successional and climax vegetation based on temperature, altitude, rainfall, and evapotranspiration. This system has been used for many years, primarily in Costa Rica. Recently, it was revised to incorporate additional factors and refine some of the information used when Holdridge developed the system in 1947.

When Holdridge developed the system, the technology used to collect data was not as accurate as that used today. In many cases, the data used by Holdridge was found to be as much as 100% inaccurate. Another drawback to his system was that the data did not account for seasonal variation, nor was the concept of evapotranspiration well developed. To address these shortcomings, the system was revised in 1986 by Luis Diego Gomez and Wilberth Herrera Soto. The revised system accounts for seasonal changes in temperature and rainfall to allow for a more dynamic interpretation of vegetation. The description of plant communities has similarly evolved away from the relatively static concepts of successional and climax vegetation, influenced by the ideas of Clements. Other factors incorporated into the revised system include hydric balance in soils, plant radiation due to albedo, and faunal indicators such as amphibians, butterflies, and birds. The faunal species chosen are those that are highly sensitive to environmental change rather than those capable of adapting to such change. This distinction is crucial because unless species are sensitive to such changes, they will not serve as good indicators of vegetation succession in response to environmental change.

The revision to the Holdridge system, as it applies to Costa Rica, was completed in 1990 and published as a map with an extensive key in 1993. The system has also recently been revised to cover the South American continent.

PRODUCTION ECONOMICS

Speaker: Upton Hatch
Abstract by: Brent Blair

Whether a product is produced by a purely profit seeking individual or company will depend upon the economic profit that can be made by its production. The level of production will depend upon the input-output relationship of the particular product. This can be graphically seen in an input/output curve. Such a curve represents the relationship between the input of resources towards production and total output of the particular product. The precise level of production will occur at a point between the "inflection point," which is the point on the curve that has a slope of one, and the point where additional inputs will result in no further increase in output. This point of "total product" has a slope of zero.

To find the exact level of production the cost of production and price of the product must be determined. The economic optimum will occur when the return of an additional unit of output just exceeds the cost of an additional input. This analysis assumes that the product being produced is the product most suited for the site.

The opportunity cost is the foregone profit by the best use that was not chosen. If an individual produces a product that is less profitable than an alternative product, the opportunity cost of producing the current product will be greater than profit being made. Such an individual would be expected to change to the more lucrative product.

To determine the profitability of producing a product in real world situations is generally quite complicated. For this reason there have been several methods devised to analyze these situations. One method commonly employed is a "cost benefit" analysis that takes into consideration key parameters such as investment costs, labor costs, and cash flow. It then provides income above variable cost and the net-returns to investment. The costs employed and benefits determined in this analysis are averages and, therefore, may vary from year to year.

A second method used is termed a "cash flow" analysis. This method uses similar parameters as the previous one, but looks at costs and returns from a yearly point of view. Here it is possible to visualize when net returns will be positive or negative from year to year.

Although both methods are potentially quite complicated when using many parameters, the process can be greatly simplified through the use of computer software devoted to this purpose.

A ROUND TABLE DISCUSSION ON SUSTAINABILITY

Moderator: Upton Hatch

Participants: Class

Preparation of notes: Donald Mee and Upton Hatch

1. Definition of sustainable agriculture:

Sustainable agriculture provides a consistently high-quality supply of food in an environmentally sound, economically viable and socially equitable manner over the long term.

2. Changes or limitations in the scientific technique used in the group field problem on sustainability:

- a. assess pesticide damage or impact of conventional practices on water quality;
- b. improve sampling in terms of time, geographic coverage, soil depth, and number of samples;
- c. collect background information on past land use;
- d. assess level of nutrients in water from runoff;
- e. use several insect trapping techniques so as not to bias type of insects sampled;
- f. evaluate aggregate impacts, not just individual fields, especially aggregate environmental impact;
- g. evaluate conventional and organic practices in intercropping or multiple cropping situations;
- h. attempt to compare to natural areas;
- i. investigate impacts on households, especially health impacts of pesticide applications;
- j. evaluate consumer acceptance of products from alternative systems, especially export markets;
- k. determine source and dependence on input supplies;
- l. measure residues in food;
- m. develop understanding of household decision-making, especially motivation and information sources;
- n. improve randomness of sample;
- o. consider relative risk of alternative production systems; and
- p. assess marketing incentives, especially product differentiation and economies of size.

3. Tradeoffs between conventional and organic systems (**dairy**, vegetables, and coffee):

<u>Conventional</u>	<u>Organic</u>
less perceived yield risk	better soil processes
higher profit	possible increase in insect diversity (alpha or beta)
higher environmental costs	less price risk, lower cost
more dependent on input supplies and output markets	lower yield (in the beginning, with increases through time)
	better use of natural processes
	requires more skill, knowledge and management

4. Limits to adoption:

- a. extension agents and information dissemination;
- b. consumer markets and development of specialty markets;
- c. land tenure;
- d. size as proxy for access to financial resources, information, and management skill; political power to affect policies;
- e. government agricultural and trade programs, especially preferential credit programs and commodity programs;
- f. innovativeness or newness of organic practices;
- g. peer pressure or acceptance by neighbors;
- h. input supply infrastructure, especially seed, fertilizer and pesticide, that encourages sales of commercial inputs;
- i. chemical dependence or treadmill, difficulty of transition; and
- j. needs of urban consumer, ability of organic practices to meet consumer needs at a reasonable price.

NATURAL RESOURCE AND ENVIRONMENTAL ECONOMICS

Speaker: Upton Hatch

Abstract by: Pantaleo Munishi and Upton Hatch

Basic principles of property rights, externalities and environmental problems were presented. Efficient property rights structure, externalities, common property, public goods, and imperfect market structures were discussed both theoretically and empirically.

Economic efficiency criteria can assist in making rational decisions between economic and environmental considerations. An environmental problem exists when resource allocations are either inefficient or expected to leave future generations worse off. These problems occur when economic or institutional factors cause decisions by individuals to differ significantly from collective decisions. Often this divergence results from property rights. The four characteristics of an efficient property rights structure are: universality, exclusivity, transferability, enforceability. All resources must be privately owned, all entitlement specified. All benefits and costs accrued as a result of owning and using the resource should accrue to the owner only. All property rights must be voluntarily exchanged among individuals. Property rights should be secure from involuntary seizure. Many environmental problems result from the lack of one or more of these characteristics.

Externalities exist when exclusivity of property rights is violated. There are two types of externalities: technical and market. Technical externalities involve physical impacts on another party whereas market externalities occur simply through price impacts. The bee producer next to an orchard is the classic example of a positive, technical externality and a large, new industrial plant locating in a small town would illustrate a market externality. The former example involves the physical effects of improved pollination in contrast to the latter where wages and land prices might be affected. The common strategy to address externalities is to internalize the social or public cost.

Common property, open access resources are those that are not exclusively controlled by a single entity. Access is not restricted; thus, use is on a first-come basis. Many fish and wildlife resources are over-exploited because the asset value of conservation is lost to the individual.

Public goods are those that are not exclusively controlled by a single agent, are fully accessible to all interested persons, and which exhibit consumption indivisibilities. Consumption is indivisible when one person's consumption of a good does not diminish the amount available to others. Biological diversity and clean air are examples. Public goods have free rider problems and are generally under-supplied. In field research, it is

very difficult to illicit the value an individual places in the good and there are few market transactions from which to estimate the public good's value.

Environmental problems and resource misallocation also occur when one party in the exchange of property rights is able to exercise excessive market power. Monopoly is the clearest example; however, oligopoly and other imperfect market structures are common in resource markets. The price will be higher and the quantity lower than that which would occur in a competitive resource market.

The divergence of the social and private discount rate for evaluating the impact of future flows of benefits and costs is a potential source of resource inefficiency. Efficient resource allocation requires that firms use the same rate to discount future net benefits as society. The divergence results from different perceptions of risk and different planning horizons. Public investments face very little, if any, risk; private decision makers face considerable risk. Private investment decisions tend to be viewed with shorter planning horizons, resulting in higher private discount rates. Higher discount rates will favor investment with lower initial investment and higher immediate returns. Many public projects involve large investments that produce returns over a very long period.

INTRODUCTION TO BOSCOSA - JOSE JOAQUIN CAMPOS

Speaker: Jose Joaquin Campos

Abstract by: Norm Bourg

BOSCOSA, the Program for Forest Management and Conservation on the Osa Peninsula, began as a project of Fundacion Neotropica and World Wildlife Fund's Tropical Forestry Program. The program's main objective is to maintain forest cover on the Osa peninsula by managing natural forests, especially those surrounding Corcovado National Park. BOSCOSA has seven areas of activity: 1) Forestry and Forest Management; 2) Reforestation; 3) Agriculture; 4) Ecotourism; 5) Training and Marketing; 6) Research and Information Management; and 7) Environmental Education.

The program has a number of ongoing projects in the above areas. Research is being done on ways to add value to soursop and pejibaye crops. The "paraforester" training program has taught local people forest management and monitoring techniques so that they can then assist small landholders and farmers in managing their forests. BOSCOSA has also conducted a Rapid Ecological Assessment of the entire Osa peninsula, which discovered a new tree genus and a new plant species, *Osa pulcra*. Environmental education is being promoted through the Tropical Youth Center, a Danish-funded institution which offers education programs free to local children and also admits international students.

Some statistics on the Osa peninsula give insight to the challenges facing forest conservation there. Only 5% of the land is held in title and over 12,000 people reside in the area. Most of these people arrived 10 - 15 years ago when the banana industry declined in the Golfito region. Seventeen Guaymi Indian families also live on the peninsula. An imminent threat to natural forest on the Osa is Ston Forestal Corporation's nearby paper pulp factory, which has large Gmelina plantations and is encouraging the planting of this species on private land. BOSCOSA is trying to develop policies for good land use by developing a comprehensive land-use plan for the peninsula, as well as assisting farmers with getting title to their land.

GEOGRAPHY OF COSTA RICA

Speaker: Oscar Lucke

Abstract by: Christopher Rosin

Oscar Lucke introduced the geography of Costa Rica as the conjunction of evolving land use policy and macro economics. Lucke argued (in a vein current in geography) that the geography of a country -- and therefore its landscape -- is the product of the interplay of various physical and social factors. Current land use in Costa Rica reflects the available resources, perceptions of their use, and the paternalistic relationship between government structure and rural populace.

The principal impact of these factors in the Costa Rican countryside is extensive deforestation. Lucke suggested that deforestation resulted from the country's emphasis on an export economy. This was reflected in the extensive production of coffee, bananas, and cattle for export markets. (Lucke foresaw a similar impact created by ecotourism.) All of these agricultural practices necessitated vast transformations of land from forest. The destruction of forest was justified by the need for export capital and the pursuit of wealth. When government policy reacted to the deforestation, its actions were limited to mitigation efforts. Lucke also criticized government policy for its top-down approach and lack of local participation.

Lucke insisted that a need for environmental planning existed. Costa Rica, he claimed, occupied a valued position in the world's ecosystem. His claim was based on the country's large biodiversity and its position linking the continents of North and South America. The means of achieving an acceptable plan lay in evaluation and planning that respected local perceptions. It would be necessary to recognize the cultural diversity of Costa Ricans (as well as their neighbors) in this process.

Lecture Abstract

MAMMALS OF PALO VERDE - ESPECIALLY OPOSSUM (*DIDELPHIS VIRGINIANA*)

Speaker: Monica Marquez

Abstract by: Laura Howard

Palo Verde Opossum Biology

The opossum is marsupial, nocturnal, solitary, polygynous and omnivorous. They are dimorphic with males being bigger and having larger canines. Females give birth twice a year (once during the dry season and once during the wet season). Females may bear 20 - 25 young per birth, yet only 7 or 8 generally survive to adulthood. High infant mortality is expected as each offspring must locate one of 13 teats from which to feed. Opossums disperse at three months of age and females are philopatric whereas males disperse from their natal territory. Males generally have territories two to three times as large as female territories.

Monica Marquez studies the reproductive biology of *Didelphis virginiana* and is currently testing the sex ratio variance hypothesis put forth by Trivers and Willard in 1972. This hypothesis states that strong (energetically fit) females should produce more sons and weaker (physiologically stressed) females should produce more daughters. Previous research on the opossum has shown that when the diet of female opossums is supplemented, these females will produce male biased litters. At Palo Verde there is a pronounced wet and dry season influencing the availability of resources. The cycle of scarcity and supply of food and water resources may physiologically strain the females causing them to produce more male young during times of scarcity.

The opossums at Palo Verde would be expected to exhibit a pattern of male biased litters. One might reason that during the wet season females gestate for two weeks and lactate for three months. The female will have little time to replenish energetic losses before reproducing again in the dry season. The strained physiological condition of the female entering the dry season may be further exacerbated by lack of available food and water. Thus, due to physiological stress, females fertilized at the end of the dry season would be expected to produce male biased litters.

During 1992 Monica trapped opossums at Palo Verde for 6 months. During this period the sex ratios of the litters produced remained equal, thus there failed to be a marked increase in the production of males. At this time, the opossum of Palo Verde fail to support the Trivers and Willard hypothesis.

BANANA PLANTATIONS

Speaker: Alex Martínez

Abstract by: Jill Fischer

Cueste lo que cueste. Whatever it costs to produce bananas in Costa Rica, right? That is how ABAS (Asociación Bienestar Ambiental Sarapiquí) representative Alex Martínez perceived the policy of the multinational banana corporations.

Martínez began to paint a negative picture of the banana plantations with the economics of the business: there are many benefits, as well as handsome profits, generated by the plantations, however, they only accrue to the foreign owners.

The environmental impact of banana production is also far from positive. Each year 25,000,000 plastic bags coated with pesticides are thrown away by the multinationals. Yet, the bags are not essential to the production of the fruit; rather, their use is primarily to prevent insects from damaging the appearance of the bananas. Those same chemicals run off into nearby rivers, and therefore, indirectly affect the health of the watershed and its users. This was exemplified by a recent fish kill in the Matina River, which was attributed to the runoff loaded with nematicide, most likely from a nearby banana plantation. Agro-chemicals have also been determined to be the cause of plantation workers health problems. Some have lost fingernails as a direct result of contact with the chemicals. Others who have worked with DBCP - a chemical that has been outlawed in the USA because of its detrimental side effects - have become sterile.

In the 1980s the Costa Rican political parties began to take a stand on the issues of the use of pesticides by, and the expansion of, banana production. As a result, the banana companies are now immune to regulation. After the Matina River fish kill, the plantation in question was exonerated. Furthermore, when confronted with the chemically-induced sterility in plantation workers, the banana company was not forced to compensate the injured parties.

Despite all of these negative effects created by the banana plantations, many people of the region feel that life without bananas would be a nightmare (pesadilla).

PROYECTO DE DESARROLLO RURAL INTEGRADO OSA-GOLFITO

Speaker: Ana Mesa

Abstract by: Bruce Ferguson

The Proyecto de Desarrollo Rural Integrado (PDRI), initiated in 1987, was proposed by the Costa Rican government in response to the withdrawal of the banana companies from the Zona Sur. The return of the bananeros to the Limón region (which they had abandoned in 1931) left the Zona Sur paralyzed by massive emigration and unemployment. Under an agreement with the Costa Rican government, the European Community provides funding and technical assistance for the project to improve agricultural production, infrastructure (especially drainage), capacitación, and housing in a 30,000 ha. area that includes 1500 families. PDRI has already reached 1000 families on 11,000 ha.

A major focus of PDRI is aiding people in the transition from salaried agricultural workers in an enclave economy to independent producers. IDA tried just providing people with land but many lack basic construction, agricultural and business skills. In addition to these social problems, the bananeros left behind improperly drained land with high copper levels from fungicide use. As a result of such difficulties, land ownership is becoming concentrated as people sell out to their neighbors. PDRI is working to rehabilitate the land and develop a better system of land distribution and titling.

The project is working through cooperatives and producers' organizations to aid people in the conversion to independent production. PDRI acts as an umbrella organization for 18 organizations of agricultural producers. Such organizations are the only way small producers can compete in the marketplace. PDRI provides credit and helps these organizations market their products. They have done pilot studies on production and marketing of about twenty crops and have produced soil maps to help people determine appropriate land uses. The project covers basic grains, permanent crops such as oil palm and cacao, and double purpose cattle.

The first phase of PDRI is coming to an end, but funding has been secured for another three years. It is hoped that national organizations will be attracted to the project to continue the work already under way and expand the area of coverage.

HISTORY OF CONSERVATION IN COSTA RICA

Speaker: Julian Monge
Abstract by: Ceal Smith

Humans have manipulated the environment of Costa Rica ever since their arrival here 25,000 years ago. Although the pre-colonial human population is believed to have been less than 30,000 people and forest removal was only 1%, more area per capita was removed than in modern times. Colonial policies encouraged forest clearing for agriculture and pasture. Nevertheless, conservation measures were implemented as early as 1775 and during the 1880's numerous laws were enacted to protect the environment, although they were rarely enforced. Monge discussed important Costa Rican naturalists and conservationists and their role in the history of conservation in Costa Rica. Important institutions such as the National Museum (1887), School of Parasitology (1950), and the National Park System (1960's) were established. It was emphasized that Costa Rica's reserve system is very young, having only been in existence since the 1970's, at a time when the rate of deforestation was second highest in the world. International support and the work of foreign biologists have been very important in the history of conservation in Costa Rica.

FUNGI

Speaker: Greg Mueller

Abstract by: Laura Howard

Traditionally, estimates of the number of fungal species approached 250,000 species. However, recent calculations of the number of fungal species estimate that 1.5 million species may exist. On the average, 1,100 new species of fungi are discovered each year, thus creating a backlog of taxonomic work. Currently, the prospect of medicinal uses for fungi has fueled a new interest in the study of fungi, particularly tropical fungi. Not surprisingly, large pharmaceutical companies are supporting bioprospecting of tropical fungi.

Forest fungi can be characterized as decomposers, pathogens, or mutualists. Decomposers breakdown organic material and make micronutrients available for uptake by other organisms. Pathogens typically cause plant and animal diseases. Mutualistic fungal associations may be termed either endo- or ecto- mycorrhizal. Endomycorrhizae penetrate the plant root cortex and facilitate the movement of phosphate and nitrogen. Ectomycorrhizae fail to penetrate the cortex, yet may facilitate the passage of water and nutrients to a plant via association with its roots.

Many fungus-animal-plant interactions exist in nature. For example, spotted owls rely on decaying trees (or snags) for nesting areas. Trees may become habitable for spotted owls after infection with a specific fungus. Flying squirrels eat the fungal spores and facilitate the dispersal of the fungus. Once established, the fungus begins the process over again.

Renewed interest in the study of fungi may bring funds into Costa Rica. Perhaps graduate students from the University of Costa Rica might be encouraged to participate in research and collaborative efforts. The basic questions that remain unanswered for the fungi include the following: What is a species of fungi? What is considered an "individual"? Where are the various species distributed? These questions and many more will continue to foster the study of fungi.

Lecture Abstract

BODY CONDITION SCORE IN DAIRY COWS

Speaker: Wayne Odegard

Abstract by: Ellen Pedersen

Body condition and reproductive status of cows in a herd are some of the variables that determine milk production. Body condition score is a tool to evaluate the status of a **dairy**; individual cows are compared to a standardized, race specific chart containing a sketch of pin and hook bones. Values ranging from 1 to 5 are attributed to each individual according to the amount of fat covering the bones: (1) very thin: bones extremely visible due to stressed or starving conditions, (2) thin: bones still visible, (3) average: normal, (4) fat: added fat on bones, and (5) very fat: bones not visible, fat deposit on flanks.

Dry seasons in the tropics introduce variables to this system, since healthy cows usually lose weight during several months of the year. Over-fat cows may present the "death cow syndrome". Cows with undesirable scores should be culled (eliminated in one or another way from the herd).

Insects, as transmitters of diseases, can be the cause of loss of weight in cows. Mastitis is a common disease in the tropics. It can be avoided by sanitation, disinfection of utters, proper machines (if applicable), segregation of infected animals, prophylactic therapy, and culling chronically infected cows.

Lecture Abstract

SUSTAINABILITY OF DAIRY FARMING IN THE TROPICS

Speaker: W. Odegard

Abstract by: Pantaleo K. T. Munishi

There are a number of milk producing animals differing from country to country. These include: cow, goat, buffalo, sheep, camel, and yak.

There are several prerequisites for efficient and successful milk production in the tropics. These include:

- trained personnel at all levels,
- large volumes of milk and supplies of milk,
- supply of high quality feeds,
- high yield per cow,
- control of cattle diseases and parasites,
- sanitation and health regulations, and
- realistic pricing.

Alternative Dairy Production Systems in the Tropics

1. Less confinement of animals and greater use of pasture

Advantages of this alternative include:

- lower incidence of diseases,
- less use of antibiotics and other chemicals,
- less capital intensive,
- less labor required, and
- possibly a more human system.

2. Controlled environment system (Dry lot or Confinement)

Advantages of this system include:

- permit larger operations,
- permit greater control of the cow's environment, and
- productive and profitable under favorable economic conditions, but more vulnerable.

Sustainability of Dairy Farming

For dairy farming to be sustainable, it must fulfill the following conditions:

It must be environmentally sound. For example, a system that pollutes water is not sustainable.

It must conserve the natural resources, soil and water inclusive.

It must be able to provide an adequate, safe, and healthful milk at a reasonable cost.

It must be commercially competitive and sustainable.

Constraints to Milk Production in the Tropics

The most important constraint to milk production in the tropics is mastitis, which may be of different types. The control of this disease is necessary to ensure the sustainability of milk production in many tropical areas.

AN INTRODUCTION TO PORTICO

Speaker: Rudolfo Peralta

Abstract by: Ankila Hiremath

Portico is a Costa Rican company which was founded in 1982 as a manufacturer of wood products, mainly doors. The company exports between 40 and 50 thousand royal mahogany (*Carapa guianensis*) doors a year. In the initial years more than 90 percent of the exports were to the United States. Since 1990 Portico has also been exporting to the United Kingdom, France, Italy and Mexico. The company has about 750 employees and an annual income of 7 to 10 million dollars.

In 1987, foreseeing a shortage of timber to meet their demands, Portico decided to buy 5,000 ha. of *Carapa*-dominated swamp forest in the Tortuguero plains and to manage it on a sustainable yield basis. The forest (which we visited after the introductory talk) is dominated by *Carapa guianensis* and *Pentaclethra macroloba*. Together the two species constitute more than 50% of the species with basal area greater than 30 sq.m. At present, only *Carapa* is harvested. With the development of laminated board technology, the company hopes in the future to be able to use *Pentaclethra* also.

As part of the management plan, the company conducts detailed surveys in each forest section. All trees are marked and classified as one of the following:

- *trees to be harvested (dbh greater than 70 cm),
- *young trees which need protection during directional-felling,
- *shade trees that require to be left standing, and
- *trees that need to be left as seed trees.

This also helps in the planning and design of internal skid trails in a manner that minimizes damage. In addition, silvicultural techniques are employed to facilitate the growth of desirable trees. These include the cutting of vines and the girdling of over-mature trees (dbh greater than 28 cm.) that are competing with young *Carapa* trees. Permanent plots are left undisturbed in each forest section to serve as a baseline for comparison.

Studies have shown that logging, followed by silvicultural treatment, leads to a 55% opening of the canopy. In comparison, logging alone (i.e., without silvicultural treatment) leads to a 35% canopy opening, while the natural forest has a 20% canopy-open structure. The greatest growth increment in young trees is observed in areas with the 55% canopy opening. Following logging, it has been observed that there is a 50% reduction in biomass, a 30% reduction in tree density, but no alteration in the number of

species. Earlier, some trees with dbh greater than 70 cm, which were regarded as possessing a superior genotype, were left standing to serve as seed trees. However, it was later found that these trees accounted for only about 22% of the regeneration that was observed, since *Carapa* is reproductively mature by the time trees reach a dbh of 30 cm. Therefore, the selection for seed trees is now based on their being evenly distributed, rather than on their size.

Surveys of the age class distribution of *Carapa* have led to projections that the forest should be able to sustain a harvest of 30 cu.m. per ha. with a 15 year rotation period if the current harvesting protocol is maintained. It was also stressed that the company's policy was to limit production to a maximum dictated by the forest. An increase in demand for wood, as has occurred in the last few years, is being met by imports from elsewhere (e.g., Red Oak from the United States).

WATER QUALITY/DRINKING WATER

Speaker: Cathy Pringle
Abstract by: Liz Marshall

In 1986, several streams in La Selva were found to be very phosphorous-rich, with levels at 60-300 mg/l. One of these rivers was the Quebrado Salto. This concentration was highly variable, and to determine whether this variability reflects surface level phenomena or subsurface weathering of primary minerals, a transect of wells perpendicular to the Salto River was drilled. The results suggested that there are two different sources of water; a nutrient-rich water welling up from below, and a nutrient-poor water derived from runoff. Chlorine, a conservative mineral, had a concentration distribution similar to that of phosphorous.

The ecological performances of nutrient-poor and nutrient-rich waters vary, because phosphorous stimulates algae growth, which supports the rest of the ecological web. Slide setups in different streams found that the nutrient-rich streams were saturated with phosphorous, chlorine, and nitrogen. Addition of phosphorous to nutrient-poor streams, on the other hand, stimulated chlorophyll A accrual, indicating that such streams are phosphorous-limited.

A survey of areas around the dormant volcano Mt. Barba in Braulio Carillo National Park indicates that these waters are geothermal waters that emerge at 2000 meters above sea level as acid sulfate waters. As this water runs underground to La Selva, however, it changes to sodium chloride bicarbonate springs. There are three vectors of water movement: upward convection of magmatic water, lateral subsurface flow, and evaporation and wind transport. Only the first two are applicable to La Selva's waters.

Surveys of Costa Rica and Central America indicate that these nutrient-rich geothermal waters are common to both.

Water Quality

Deforestation in Costa Rica causes severe erosion, which clogs rivers, destroys fisheries, and contaminates drinking water with sediment. The village of Puerta Vieja, near La Selva, has an additional problem -- they have contaminated their drinking water with fecal coliform bacteria from cows. They now pipe water from a geothermal spring 14 km away in Braulio Carillo. This water is nutrient-rich and, therefore, a low-quality drinking water. As the population in the area expands due to burgeoning banana plantations, it will be a challenge to meet increasing water quality demands.

FUNCTIONS OF BIOLOGICAL CORRIDORS

Speaker: Dr. Jaime Rau

Abstract by: Cecelia Smith

A biological corridor is a linear habitat whose primary function is to connect two or more significant habitat areas. The 5 main functions of corridors are to facilitate migration, propagation, genetic interchange, movement in response to environmental change and natural disasters, and recolonization. Corridors are used differently by "passage species" and "corridor dwellers". Some habitats such as greenbelts, buffers, biogeographic landbridges, migratory waterfowl refuges, underpasses and tunnels, may function as biological corridors. The potential disadvantages of corridors include: increased dispersal of diseases, pests, exotic species, and other undesirable species; outbreeding depression, increased susceptibility to fire and other abiotic disturbances, increased exposure to predation (including poaching and hunting), and costs and conflicts with conventional land use preservation. "Line corridors" are narrow, have homogeneous species composition, and are composed of edge species. "Strip corridors" are wider with heterogeneous species composition and are used by interior dwelling species. "Stream corridors" can be of either type. The potential advantages of corridors include: increased immigration to connecting reserves resulting in an increase in species richness and genetic diversity, reduced inbreeding depression and decreased probability of extinction; providing increased foraging area for wide-ranging species, predator-escape cover for movement between patches, provision of a mix of habitats, alternative refuge and the preservation of "greenbelts" in urban areas.

NATIONAL PARKS OF COSTA RICA

Speaker: Jose Maria Rodriguez

Abstract by: Liz Marshall

The rate of deforestation in Costa Rica has traditionally been very high. Due to improved health care, the population growth rate has also been very high, and in the 1950s was the highest in the world. This combination of forces threatens Costa Rica's infamous biodiversity.

Costa Rica's first forestry law was passed in 1969. This law regulates tree-cutting, establishes four categories of wildlands, and creates the forestry service. There are currently five categories of wildland -- national parks and biological reserves (administered by the National Park Service), wildlife refuges (Wildlife Service), and protected zones and forestry reserves (Forestry Service). These areas represent 21% of Costa Rica's land area.

The level of protection varies among the categories. National parks and biological reserves have been very successful in avoiding squatters and deforestation, but the other zones are not well protected. In 1987 they reviewed wildlands policy and decided it would be more efficient to decentralize decision-making, consolidate responsibility into one agency, and to promote improved relations with communities surrounding the parks. This review gave rise to the "conservation unit" management plan, which identifies 7 large management areas, each of which encompasses a number of other protected areas. The management plan resembles the biosphere reserve concept.

The National Park Service was established in 1970 and grew quickly until the economic crisis of 1980. NGO's proliferated in the late 80's, and Costa Rican parks finally received major foreign financial assistance.

Park management priorities list resource protection first and public use second. However, public use creates several management problems that are not compensated for by the entrance fee; raising the fee and charging foreigners and ticos differently requires legal adjustments that have not yet been made. The future of Costa Rica's parks may rely, in part, on removing the legal obstacles and increasing the cost of use to generate a larger source of revenue.

Lecture Abstract

COSTA RICAN NATIONAL PARKS

Speaker: Jose-Maria Rodriguez

Abstract by: Lucy Buchan

The Costa Rican National Park system was created by the 1969 Forestry Law with the purpose of protecting and managing wildlands. The law created four categories of wildlands: national parks, biological reserves, wildlife refuges, protection zones, and forest reserves. To date, the law has resulted in the creation of 16 national parks and 9 biological reserves. On paper both the law and the wildland system sound impressive, but as Rodriguez noted in his talk, what is expressed on paper often sounds better than the reality of such descriptions. According to Rodriguez, the national parks and biological reserves are relatively well-protected in comparison to the wildlife refuges and the forest reserves. This is significant in light of the fact that collectively, the wildlands system only comprises 9% of all the land in Costa Rica, and of this total, biological reserves only comprise 1%.

In 1987, the government conducted a review of wildland management and concluded that a major impediment to management was the lack of communication between government agencies responsible for wildland management. The recommendations were to decentralize decision-making, thereby enabling local managers to have greater influence in management decisions, and to incorporate the needs of local people living on Park boundaries into management decisions. The institutional response to this review was to create "conservation areas" -- units of management taking into consideration natural and cultural resources on a landscape level.

This concept was based on the model provided by the United Nations Biosphere Reserve. The establishment of the conservation areas was an attempt to facilitate communication between wildland units within similar biogeographical units. Each conservation area was assigned a steering committee composed of individuals representing natural resource agencies, NGO's, and business interests. These committees were intended to create a forum for extra-park interests to participate in management decisions. In reality, however, Rodriguez says that this mechanism has not been effective. The committees rarely meet and have little influence on wildland management decisions. The relative ineffectiveness of the committees, and hence, the areas themselves, can partially be attributed to the fact that they are not mandated by law, only by presidential decree. The decree only states that both new and existing wildlands should be legally affiliated, and communicate management decisions through committees. Therefore, there are no clear guidelines for how the areas are to be formed; no plans to assist decision-makers in the process. The dearth of such guidance has greatly impeded implementation of the concept.

Rodriguez discussed the macroeconomic situation in Costa Rica in the early 1980's by way of partially explaining why the wildland management units were having difficulty fulfilling their charter. The 1980 - 1983 "debt crisis" caused an 80% reduction in funds available to the national parks for purchase of land and any activities related to park maintenance. It also resulted in a 15% reduction in staff. In this resource-poor environment, wildland management became more difficult.

This drastic cut in financial resources forced the wildland units, in particular, the national parks, to seek outside sources of funding. By 1984, the national parks had procured \$50 - 75 million in donations. Some of this was targeted to obtain lands to link La Selva to lowland wildland units near the northeast Atlantic coast. USAID earmarked \$22 million for this project, and MacArthur Foundation committed \$1 million, provided that matching funds were available. Such efforts reflect the relatively recent focus of the national parks to procure and protect lands adjacent to and linking protected areas.

In the past six years visitations to the national parks have increased 25% annually. Approximately 50% of all visitors are foreign to Costa Rica. This trend poses some hope for the management of wildlands, because it represents an important economic activity, however, it also portends increased impact on the natural resource base.

DAIRY INDUSTRY OF COSTA RICA

Speaker: Augusto Rojas, Director of the Experimental Station

Abstract by: Amelia Oliver

The **dairy** industry is an important sector in the Costa Rican economy. As a milk consumer, Costa Rica consumes 188 liters/yr, exceeding other Central American countries such as Guatemala (80 l/yr) or Nicaragua (40 l/yr). Holstein cows dominate milk production, representing 70% of total milk production. Costa Rica is a milk product exporter and joins the ranks of Uruguay and Argentina as leading Latin American milk producers.

The primary function of the experimental station is to maintain a tight relationship with private industries using research, teaching, and extension as the channels to the dairy sector. The focus is on sustainability. Currently, the dairy industry depends on subsidized corn and wheat from the United States rather than investigating alternative crops, a practice which jeopardizes a sustainable dairy industry. Land prices also challenge the future of the **dairy** industry. Increasing urbanization is putting upward pressure on land market prices, resulting in sales of dairy land to alternative activities and the intensification of **dairy** production. High labor costs decrease the demand for labor-intensive systems resulting in a trend toward dairy systems practicing semi-confinement of the cows.

To address these current trends in Costa Rica, the experiment station is aiming to increase the efficiency of the land dedicated to the dairy industry and to decrease the need for outside feed and fertilizer. The principle projects of the station are currently: pejibaje, banana peels, and peanut foliage. Fermented banana peels are an abundant source of protein for feed, containing 6 - 8% protein. Rotted pejibaje fruit, from the pejibaje palm, another possible feed source, contains 60% starch, 10% lipid, and 6% protein. *Arachis pintoides*, a ground peanut, provides an alternative grazing source for Costa Rica. Considering that 85% of dairy production cost are spent on feed, half of which is feed concentrate, these three options utilize tropical products and decrease the corn/wheat dependency while decreasing the costs of cattle production and increasing per animal production.

INTRODUCTION TO COTO BRUS

Speaker: Martha Rosemeyer

Abstract by: Lucy Buchan

Overview

The county of Coto Brus is located in the state of Puntarenas, covering 93,000 hectares and supporting a population of 35,000 people. The region's main agricultural crop has been, and still is, coffee. However, due to the depression in coffee prices, coffee cultivation is slowly decreasing. The region has experienced relatively high rates of emigration, as a result of this price decrease. People are moving to the Atlantic region to engage in the banana production industry, or to the United States, primarily in manual labor. The average temperature is 22°C, and annual average rainfall is 3600 - 4000 mm. Three major botanical units are found in the region: Las Tablas, La Amistad, and the Guayami Reserve. Thirty three percent of the county is forested under different levels of protection.

History

In the Pre-Columbian era populations centered in several major villages. The Guayami began inhabiting the area in 1910. In the 1920's an invasion effort by Panamanians was aborted by the U.S. Army. By the 1940's the government had invited Italians, Yugoslavians, and other Mediterranean/Eastern Europeans to settle in the region to help establish national territorial rights. This colonization effort quickly established infrastructure in the region. The region was heavily dominated by these European settlers until the 1970's when the number of Costa Ricans began to increase relative to other ethnic groups.

Land-Use

Agriculture in the region has been dominated by coffee (10,000 ha) and beans (2,900 ha). Other major crops include macadamia nuts (467 ha), corn (425 ha), sugar cane (200 ha), tequisque (200 ha), avocado (22 ha), citrus (20 ha), guanabana (10 ha), and a more recently expanding vegetable market: tomatoes (15 ha), peppers (10 ha), asparagus (20 ha), and miscellaneous others (3 ha). Reforestation through 1990 accounted for 1,500 ha, and 1,050 in 1993 alone. The total area in forest as of 1980 was 39,300 ha.

Land Tenure

Data from 1963 and 1979 illustrate that the trend in land tenure has been for number of landholdings in the small to medium size categories (less than 50 ha) to increase and for number of holdings greater than 50 ha to decrease.

THE FRIJOL TAPADO SYSTEM

Speakers: Martha Rosemeyer, Darryl Cole, and Ken Slater,
with demonstrations by Lionel Gomez

Abstract by: Amelia Oliver

Background

The frijol tapado system is a traditional, prehispanic, agricultural production system which still produces 50% of Costa Rica's beans and 90% of the beans in the Coto Brus region. It is a slash-mulch system which historically has been used for other crops besides beans. The presence of mulch in the system provides nutrients important to tropical soils, where biomass is the principal nutrient source. The system relies on short rotations: 2 - 3 years of fallow following 2 years of cultivation. The beans most appropriate for this system are bush-climbing varieties which will grow out over the mulch and then use secondary growth for climbing. Frijol tapado requires relatively few inputs, as compared to the espequeado system, which is another prominent bean production system but is more input intensive.

Steps of the frijol tapado system:

- 1) choose a site within a secondary growth area (at end of rainy season),
- 2) cut parallel aisles with a machete, 2-5 m apart,
- 3) scatter beans on both sides of aisles,
- 4) cover beans by cutting remaining vegetation,
- 5) recut vegetation into smaller pieces and spread evenly,
- 6) leave 85-95 days,
- 7) pullout beans into bundles and leave to dry 2-8 days, and
- 8) harvest by gathering and beating beans stalks.

Steps of the espequeado system:

- 1) prepare plot 7 days before planting, using herbicides,
- 2) plant beans, using a pointed stick, 2-4 seeds/hole (30-50 cm between rows and 15-30 cm between plants),
- 3) apply fertilizer once seeds have germinated,
- 4) apply fungicides, insecticides, and herbicides as necessary, and
- 5) harvest.

There are many advantages of the frijol tapado system compared to the espequeado system. It is a system which has evolved and has been perfected throughout generations.

It makes efficient use of the soils and land available in the region. Its impacts on the environment are less severe, as it does not promote erosion, nor does it depend on agrochemicals which are expensive and deter biodiversity. The mulch layer decreases the incidence of disease, weeds, and insects, while providing valuable nutrients. The fallow aspect of the system further contributes to overall biodiversity and condition of soil. This system also demonstrates high returns to labor.

There does exist some weaknesses of this system. Overall, yields are generally lower than the input-intensive espeqeadado system. The important fallow periods may cause land constraints. In rare cases there have been problems with slugs.

There exist interesting implications to the slash-mulch system regarding the type of secondary growth used as mulch: good versus bad weeds. This system tends to make use of many good weeds which contribute to production of beans by providing nutrients and biomass. These weeds generally decomposes easily, regenerate quickly, and offer other uses to humans. Bad weeds, on the other hand, compete with the beans and do not decompose easily.

Ongoing and Prospective Research

Effects of fallow on production, soil condition, and weed varieties in the frijol tapado system

Production plateaus comparisons between the two systems

Production comparison between the two systems based on land quality. Usually the espeqeadado system dominates higher quality lands

Phosphorus levels in the soils of the frijol tapado system

Differences in the root structures of the beans in the two systems

Economic analysis of the frijol tapado system

Further Readings

Rosemeyer, Martha and Leon Victor Barrantes. 1991. Frijol Tapado en Laderas: El mejoramiento de un sistema tradicional. Ponencia para conferencia sobre ensayos internacionales de frijol.

Rosemeyer, M. E. and S. R. Gliessman. 1992. Modifying Traditional and High-input Agroecosystems for Optimization of Microbial Symbioses: A Case Study of Dry Beans in Costa Rica. *Agriculture, Ecosystem, and Environment*, 40:61-70.

INBIO

Speaker: Elvira Sancho

Abstract by: Bruce Ferguson

In 1988 the Costa Rican government established a biodiversity planning commission charged with developing a strategy to save representative samples of ecosystems, undertake a systematic inventory of the nation's biodiversity, and use that biodiversity sustainably. The Instituto de Biodiversidad (INBIO), a private non-profit, was created by the commission in October, 1989. INBIO's non-profit status allows it greater flexibility and fund-raising ability.

INBIO's top priority is to inventory Costa Rica's arthropod and plant species. To accomplish this goal, INBIO is training 100 "parataxonomists." Twenty women and twenty men have already completed five to six months of training in sampling techniques and natural history and are collecting for INBIO. All are literate and some have finished high school. They are hired to collect samples near their homes and to return to INBIO for two or three days a month for feedback. Parataxonomists collect about 80,000 specimens per month, and have already accumulated a total of 1.5 million, of which only about 10% have been fully described. About 1500 plant samples are collected every month, and about 80% of those have been described. Each specimen is labelled with a bar code for entry into a database. Technicians then sort the material, generally to the genus level. Completion of the biodiversity inventory is expected to take ten years.

Biodiversity has both intellectual and economic uses. The former include science, education and conservation, and the latter industrial and agricultural applications. "Biodiversity prospecting" describes the process of screening millions of species for possible chemical or biotechnological application. In 1991, INBIO received a MacArthur grant for biodiversity prospecting. INBIO supports research at Costa Rican universities involving extraction of chemical extracts from plant specimens.

In September, 1991, INBIO signed a two year, non-exclusive biodiversity prospecting contract with Merck, Sharpe and Dome pharmaceuticals. There was no precedent for this type of agreement and it continues to be controversial. There is great concern that profits from the arrangement will not be distributed equitably. Merck paid \$1,135,000 up front for INBIO's services, and will share an undisclosed percentage of profits from any product developed as a result of the relationship. INBIO will then share half of that percentage with MIRANEM for parks. Under the contract, INBIO supplies Merck with selected plant and insect samples. Merck searches the samples on a largely random basis and pays universities for extract processing of the samples. INBIO has also entered a contract with a British company to develop pesticides from plant extracts. Initial results for seeds of a dry forest tree appear promising.

Although INBIO was not intended to be a model program, it has signed agreements with agencies in Mexico, Kenya, the Philippines, and other countries that are interested in creating similar programs. INBIO has received support from the UN to train Latin American decision makers in the preservation and use of biodiversity.

Lecture Abstract

ORGANIC AGRICULTURE

Speaker: Shogo Sasaki

Abstract by: Christopher Rosin

Shogo Sasaki introduced the topic of organic agriculture with a film produced in Japan. The film introduced the living soil as the basis on which organic agriculture is built. Soil organisms from plants, to mycorrhizae, to bacteria were described and photographed as sometimes invisible factors of agricultural production.

Sasaki preceded to present a series of slides covering his work as an extensionist with vegetable farmers in the Zarcero region of Costa Rica. He described the process of soil building using compost and bocaci (a fermented biological fertilizer). He also discussed various means of pest control using plant extracts. The viability of the program he introduced to the Zarcero farmers was presented in an economic analysis of inputs and returns. Sasaki claimed that the organic farmers were earning up to three times as much as the conventional farmers.

Sasaki concluded his talk with a discussion of his future plans. Four Japanese extension workers are expected to receive training from Sasaki in January of 1994. Each worker will eventually be assigned to climatically variable areas of Costa Rica where they will develop organic agriculture programs suitable to those climates.

FOREST GROWTH SIMULATION

Speaker: Lloyd Simpson

Abstract by: Brent Blair

Traditionally, the logistic mode of population growth has been used in fisheries, forests and other managed ecosystems that are being harvested. This model assumes that there is no difference in ages of the resources being used and that all individuals within the system act in the same way. Forests are neither steady state nor determinate but rather quite dynamic.

George Mason, in 1970, created a computer growth model (Jabwa) that more accurately reflects this diversity by randomizing certain components. It uses, as variables, the growth rate, maximum size and maximum diameter of a particular species. With this information an unique growth curve can be created for each. This curve reflects how a tree species would grow under ideal circumstances. From here it is possible to "degrade" the growth by manipulating variables such as moisture, competition, nutrient availability and temperature. Although any growth model is never perfect and is never in a final form due to periodic new information, this model has proven, in practice, to work well for temperate forests.

Recently there has been great interest in the global carbon cycle, due to its importance in global warming. Unfortunately, the values that are often used are extrapolated from smaller studies focusing on temperate regions. Such areas have relatively few species and are quite different from those in the tropics where many species and the bulk of tree biomass exists.

In 1990 Lloyd Simpson and George Mason began to develop very basic biomass equations for Costa Rican trees. In addition, they have begun to use the growth simulation model for tropical trees. Due to the large number of species in the tropics, it has been necessary to limit the number included.

Although this exploration is in its early stages, it should be possible to use the new model (Selvita) to predict effects of cutting regimes, herbivory and other treatments, as well as that of global warming on tropical tree ecosystems.

HIGH ALTITUDE ECOLOGY

Speaker: Carlos Valerio

Abstract by: Laura Howard

Altitudinal changes in temperature, altitude, and atmospheric pressure influence both the growth and survival of various organisms. In the temperate zone, organisms living above the timberline exhibit slower metabolic rates, larger body sizes and hibernate during the winter. However, in the tropics while many organisms above the timberline (3,000 m) also have slower metabolic rates, they differ in being smaller and exhibiting torpidity. Above timberline, evaporation pressure decreases and UV radiation intensifies. As a result, organisms living above timberline may find shelter and morning heating critical to their survival.

In the tropics, elevations above 3,000 m constitute paramos. Cold temperatures and wet, humid conditions predominate in paramos. Similar to those found in the Andes, the paramos of Costa Rica are dominated by shrubs and grasses. Historically, the paramo life zone encompassed solely the Talamanca range (Chirripo). However, recent findings support the classification of paramo for high elevations in the Cerro de la Muerte region.

Until recently, scientists believed that frequent fires in Cerro artificially lowered the treeline, thereby enhancing the paramo. If human influences maintained the paramo, then the Cerro paramo could not be considered a true paramo. However, Nancy Horn has found evidence of fires in the paramo occurring approximately 4,000 years ago. Subsequent data provided by a core taken in Chirripo (1992) shows the presence of fire 8,000 years ago. Since fires seem to have played an important role in paramo maintenance for over 8,000 years, one may classify Cerro and Chirripo as true paramos.

Although similar to the paramo, the paramillo differs in several important ways. Paramillos are found below 3,000 m and are maintained by a fire regime. The paramillos of Costa Rica include Poas, Irazu, and Barva. The paramo-like conditions are maintained by repeated fire regimes. However, when left undisturbed these areas would regenerate into cloud forest instead of retaining the paramo life zone characteristics.

Lecture Abstract

LIFE ZONES OF COSTA RICA

Speaker: Carlos Valerio

Abstract by: Norm Bourg

Living organisms are organized into increasing levels of complexity. Life begins at the level of the cell, moving on to the individual, the population, the community, the biome, and ending with the biosphere. All of these levels are intricately related. One organizational unit, the ecosystem, is at the level of the community but includes the non-living factors in the system. The community level is a very complex unit in the tropics and little is known about community interactions in the tropical biome. These interactions can be mutualistic, commensalistic, parasitic or predatory, and competitive.

In an attempt to construct a classification system for biotic communities, L. R. Holdridge developed the Holdridge Life Zone Classification System in 1947. This system gives primary importance to 2 factors: 1) temperature, and 2) precipitation. These two factors, along with their seasonal variation and distribution, determine the world's vegetation. The Holdridge system added a third parameter as a significant factor in life zone determination: potential evapotranspiration, which is evaporation caused by metabolic activity. These three factors are combined in the Holdridge Life Zone diagram to yield 30 world life zones. The diagram also incorporates latitudinal and altitudinal scales. Costa Rica has 12 of the 13 tropical life zones, testifying to the diversity of its biotic communities.

REPRODUCTIVE STRATEGIES OF ARACEAE

Speaker: Carlos Valerio

Abstract by: Christopher Rosin

Carlos Valerio introduced the topic of aroid reproduction by emphasizing the tropical habit of the family (only one species is found in temperate areas). The members of the family occupy all morphological niches from epiphytes to vines and climbers to terrestrial. All of the plants share a similar flower structure. Differences in this structure allow for the division of the family into four groups. First, there is a twofold division determined by the morphology of the spadix which can be either uniform or two-parted. Each of these divisions are subject to further differentiation according to the persistence of the spathe following pollination. Examples of genera falling within these divisions include:

1) uniform spadix, persistent spathe -- *Anthurium*, *Spathiphyllum*, *Urospatha*; 2) uniform spadix, non-persistent spathe -- *Monstera*; 3) two part spadix, persistent spathe -- *Zyngonium*, *Dieffenbachia*; and 4) two part spadix, non-persistent spathe -- *Xanthosoma*, *Colocastia*.

The pollination of the aroids is related to the sexual activities of several insects. The pollinators are very specific as the spathe is separated into male and female sections, the lower area being female. In the aroids with two part spadix, the pollinators are the cyclocephala. The scarab beetles are attracted to the enclosed lower part of the spadix not by attractants, but by the security offered by the enclosure for copulating beetles. They are also prone to visit several flowers allowing for pollination. The *Anthurium*, on the other hand, produces a oil which is utilized by members of *Englossa* as a sex hormone.

Compared to the specificity of aroid pollination, seed dispersal is extremely generalized. The process for dispersal is endozoochony, or dispersal by birds and mammals. Valerio indicated that this dichotomy is a rarity in the plant kingdom.

PASTURE ECOLOGY AND MANAGEMENT

Speaker: Edzard Van Santen

Abstract by: Jeff Zimpfer

Most research and information concerning grasslands comes from New Zealand, Australia, and Wales. Most people in the U.S. believe that grasslands are God given. Natural grasslands occur throughout the world in areas such as: the Pampas of Argentina, the Plains of the U.S., the Steeps of Russia, and the Savannas of Africa. Often fire is the regulating mechanism of the ecosystems. In recent times, humans have also created grasslands.

Net Primary Production (NPP) is dependent on light, rain, nutrients, and temperature. NPP per unit area increases with a decrease in latitude or altitude. At 10° there is a NPP of 17.8 t/ha/yr. At 40-50 °~~lat~~th is a NPP of 7.5 t/ha/yr. Legume pastures are .42% efficient in converting solar radiation to NPP with 1 being able to support 9 sheep per ha. Native pastures are .14 % efficient in converting solar radiation to NPP and can support 2 sheep per ha. When solar radiation is converted to cattle weight gain, of the 100% solar radiation reaching the plant surface .05% is possible with C₃ grasses and .02 is possible with C₄ grasses.

When comparing fossil energy efficiency for pasture and animal management in terms of outputs to inputs for oats, maize, and silage, the conversion is 2.5-1 and for tropical grass the conversion is 8.6-1.

The objective of pasture management is to keep a high level of output from animals grazing the pasture. In order to achieve this end, the pasture manager can choose the appropriate grass species and the appropriate breed of cattle. Various varieties of grass respond differently to defoliation, therefore, a manager should make use of the optimum frequency, intensity, and timing of grazing. The manager should also consider whether grazing or cutting is a better use of the pasture. Grazing involves treading action and selective defoliation. Defoliation changes the physical environment and may lead to soil erosion. In response to defoliation, plants may not be able to complete their life cycles. Plants may be able to avoid complete defoliation by changing their growth habits such as growing lower or higher. A plant's longevity may shorten as a result of stress.

RESEARCH METHODS IN AGRONOMY

Speaker: Edzard Van Santen

Abstract by: Nabiha Megateli

Knowledge can be thought of as three concentric spheres of changing radii. At the center is the known that is development; then the known/unknown sphere whose interface with the great unknown sphere is research.

Cattle are only human

Agronomy, as a branch of agriculture dealing with field crop production and soil management, integrates the disciplines of botany, entomology, microbiology, molecular biology, soil chemistry, physics, and statistics. Agricultural research is applied, goal oriented and becoming more environmentally sensitive. Sites for research are varied and include the laboratory, greenhouse, small plot, on-farm and watershed sites.

The rules and procedures of experimental design are essential for organizing, initiating, conducting and analyzing a valid experiment. Experimental design provides a mechanism for conducting valid experiments for answering unambiguously prestated hypotheses, as well as a mechanism for improving precision with error control.

Experimental units should be the smallest unit to which a treatment can be applied. Experimental error is a measure of the inherent variation which exists among experimental units treated alike. It can be uncontrollable or controllable by reduction of human errors or sloppiness, awareness of characteristics of experimental units and environmental gradients. One has to not make the statistical mistake of confusing sampling error with experimental error.

Experimental error can be reduced by: (a) replication to increase precision and broaden scopes of inference, (b) randomization to make the estimate of experimental error unbiased so each experimental unit has an equal chance of being exposed to possible disturbances or uncontrollable factors, (c) analysis of covariates (ANCOVA) along gradients within replicates and (d) blocking to unbiased variances.

The two simple experimental designs most often used in agronomy are thus the complete randomized design (assign random numbers representing treatments within experimental area plot design) and the randomized complete block design (each treatment occurs randomly in every block, each block representing a level along an environmental gradient like slope). There are also factorial designs where every level of one factor occurs at every level of another factor, allowing for treatment interactions.

Some of the current experiments are: (a) arrowleaf clover cultivation evaluation on random block designs by visual rating to compare for a lot of fertilizer treatments, (b) application of geostatistics and random block designs to develop contour maps and profiles of nitrogen and ammonia in relation to chicken litter disposal, (c) unbiased evaluations of alfalfa cultivars based on yields as a service to farmers and (d) on-farm trials with peanuts using various soil fertilizer treatments.

INTEGRATED PEST MANAGEMENT

Speaker: Mike Williams

Abstract by: Jeff Zimpfer

Integrated pest management incorporates the use of biological control methods with selective insecticides to manage pests. Biological control is the action of parasites, predators, or pathogens on a host or prey population which produces a lower general equilibrium population than would prevail in the absence of the agents. When determining whether control methods are necessary or not, one must first determine the economic injury level, the general equilibrium level, and the economic threshold. The economic-injury level is the lowest population density that will cause economic damage. An economic threshold is the density at which control measures should be determined to prevent an increasing pest population from reaching the economic-injury level. Pests fall into four group types: non-economic, occasional, perennial, and severe. Non-economic pest general equilibrium levels never reach the economic threshold. Occasional pest population density levels occasionally reach the economic threshold. Perennial pest population frequently exceed the economic threshold and a severe pest's general equilibrium position is above the economic-injury level, for which frequent control measures are needed.

There are several reasons for using biological controls: a resistance of the pest to chemical controls and the ability of the remaining pests to reproduce rapidly, secondary pest outbreaks due to the elimination of natural controls of pests by chemicals, and toxic residues of conventional insecticides.

Biological controls incorporate the use of parasites and microbial organisms. Often biological controls can permanently regulate pest population densities, whereas chemical control may be immediate but only a temporary control. Worldwide there have been 150 pest species that have either been partially or completely controlled through the use of biological controls. Additionally, there have been 170 successful transfers of the initial biological control. There are five characteristics of a successful natural enemy: high searching ability, high reproductive ability, high degree of host specificity, good synchronization with host, and a high degree of adaptability.

List of Student Presentations

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Using Geographic Information Systems and Models for Natural Resource Management	Lucy Buchan
An Introduction to the Southern Atlantic Autonomous Region of Nicaragua	Bruce Ferguson
The Origin and Peasant Management of the Native Cotton of Peru	Jill Fischer
Social Forestry in the Central Himalayan District of Almore, India: An Evaluation	Ankila Hiremath
Animal Behavior and Managed Ecosystems	Laura Howard
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Plants and Nodulated Woody Legumes

Jeff Zimpfer

REGENERATION OF A HURRICANE DAMAGED FOREST IN NICARAGUA

Author: Brent Blair

In 1988 Hurricane Joan hit the atlantic coast of Nicaragua with gusts of wind reaching 290 km/hr. The storm damaged the coastal region from the city of Bluefields to Rama and affected areas up to 50 km inland. The hurricane caused severe damage to 500,000 ha of the regions remaining lowland tropical rainforest, leaving a deep carpet of trees and other displaced vegetation on the forest floor.

This forest is the largest remaining area of rainforest in Central America. The pre-hurricane condition of the affected portion was that of a species rich forest. Data obtained shortly after the hurricane struck found that in two sampled areas, out of 374 trees, there were 80 tree species present. Only 20 species were found in both areas. At this time, there were no pioneer species.

An ongoing study, that began four months after the hurricane, has examined the regeneration of this forest. It is traditionally assumed that such regeneration will occur in a predictable manner as has been observed in other disturbances: treefall gaps, abandoned agricultural lands and pastures. This involves initial dominance by fast growing, light loving pioneer species then by a more or less regular sequence of more shade tolerant species. Although this was the expected result of the study, the magnitude and structure of this "gap" was much different than other types of disturbances and thus warranted further examination.

During the first expedition, it was found that there was significant damage to all trees. Only 20% of the trees remained standing; 53% had snapped trunks and 27% had fallen down completely.

Data collected on regeneration was surprising. Within the seedling subplots that were established, almost all incoming trees were primary forest species. Out of 1019 individuals there were 37 species. Out of this sample, 89% of the species and 94% of the individuals were characteristic of a primary forest. Croton was the only pioneer species present. A study carried out immediately after the hurricane found that only 18% of the trees had leaves present. At the time of the first expedition, massive resprouting had occurred and 77% of the trees had leaves.

From this data it appeared that something unusual was happening. Instead of going through the pioneer, secondary and finally primary forest stages, it appeared that this hurricane damaged forest was regenerating directly into primary forest. From this the

direct regeneration hypothesis was created. It suggests that the species pool present before the hurricane was the source of regeneration.

In subsequent expeditions some pioneer species began to appear but in general their numbers were quite small. The initial resprouting that was seen the first year decreased slightly by the second expedition in 1990, but still accounted for more than 50% of ingrowth into the regenerating forest.

The reason for this direct regeneration is ambiguous. However, in studies carried out after hurricanes in Panama and Puerto Rico, similar results were obtained. A paper written by Katherine Yih suggests five possible explanations for the findings in Nicaragua:

- 1.) The disturbance was a single dramatic event rather than a n ongoing perturbation lasting months or years (i.e., weeding of agricultural fields or grazing cattle).
- 2.) The soil remained protected by a thick layer of organic matter, large trunks, and leaf litter.
- 3.) Although the distribution of biomass was dramatically changed, it was not reduced by fire or sever erosion.
- 4.) The root system of most trees remained intact providing energy for resprouting.
- 5.) Colonization of some secondary species may have been prevented by an initial absence of seed dispersal. This could have been caused by the almost complete lack of birds during the first expedition and prevailing trade winds that enter from the Caribbean sea.

The exact cause of direct regeneration is not understood. It seems likely that a combination of these factors are probably at work, and perhaps others that are still unknown. Further investigation is needed before any firm conclusions can be made.

PRE-CIVIL WAR CONSERVATION ACTIVITIES IN LIBERIA

Author: Norm Bourg

Liberia, a small West African country slightly larger than Costa Rica, serves as an interesting case for comparing conservation programs with this country's conservation achievements. My service in the Peace Corps/Liberia as a wildlife conservation volunteer assigned to Sapo National Park was my first experience in a developing country. While Costa Rica is much more developed than Liberia in some ways, it has many of the same problems in terms of tropical forest and biodiversity conservation.

The present-day country of Liberia was colonized by former American black slaves sponsored by American philanthropical societies in 1817. The colony became the first independent black republic in Africa in 1847. Little development or exploitation of the country's resources occurred until the 1900's. Commercial logging did not commence on a large scale until the 1950's - 60's. Hence, Liberia's forests did not undergo long-term exploitation by foreign or colonial interests. Virtually the entire country was covered by tropical lowland rainforest originally. This rainforest is part of the Upper Guinean Rainforest Block, which is separated from the Congolian Block in Central Africa by the dry lands of the Dahomey Gap in Togo and Benin. Recent estimates of forest cover in Liberia have shown as much as 40 - 50% of the country still under high forest.

Conservation activities in Liberia did not start until the 1970's. Planning for a system of national parks and protected areas began at this time. Sapo National Park, the country's first and only national park, was established in 1983. The park contains approximately 150,000 hectares of lowland primary rainforest and a high faunal diversity including forest elephant, pygmy hippopotamus, forest buffalo, bongo, chimpanzee, 11 other primate species, and 10 species of forest duiker. Many of these animals are endemic to the Upper Guinean Rainforest and are highly endangered. The park, under the jurisdiction of the Wildlife and National Parks Division of the Forestry Development Authority (FDA), was one of the main areas being studied as part of a joint World Wildlife Fund (WWF)/FDA nationwide wildlife survey. Sapo had a staff of 30 guards, rangers, wildlife officers, and wardens. Park activities included controlling poaching, conducting river raft tours of the Sinoe River bordering the Park, censuring wildlife populations, assisting visiting researchers, running a traveling environmental education program for villages around the Park, and promoting agroforestry in the buffer zone.

At least 7 other areas were proposed for protection in the country besides existing forest reserves. Remaining forest areas were under heavy logging pressure from foreign companies since most of areas were divided up into timber concessions. However, conservation was gaining popularity in Liberia as evidenced by the founding of at least

two conservation NGO's in recent years: The Society for Nature Conservation in Liberia (SCNL) and Save My Future (SAMFU). Although the outbreak of civil war in Liberia in December 1989 brought conservation activities to a halt, a group of Liberians and foreigners (including Alexander Peal, the former director of the Wildlife and National Parks Division) have formed the Society for the Renewal of Nature Conservation in Liberia (SRCNL) to develop a national conservation strategy and lend support to conservation activities in the country. Dr. Peal is currently working at the African Wildlife Foundation's Washington, D.C. office to spearhead this effort so that a plan is in place when Liberia's political situation stabilizes.

USING GEOGRAPHIC INFORMATION SYSTEMS AND MODELS FOR NATURAL RESOURCE MANAGEMENT

Author: Lucy Buchan

Increasingly Geographic Information Systems (GISs) are being used as analytic and planning tools in natural resource management. The trend for increasing digital storage of data and the ability for GISs to integrate digital data from multiple sources and conduct spatial and statistical analyses for large scale areas is making the use of this technology more attractive to those involved in resource management. The purpose of this talk was to describe one case study in which a GIS was used to assist a county conservation agent to implement mandates of the 1985 and 1990 Farm Bills in Dane County, WI. These pieces of legislation make farmer subsidies contingent upon implementation of agricultural conservation practices to improve environmental quality. In Wisconsin, it is ultimately the job of the county conservation agent to implement these policies.

Research conducted at the Land Information and Computer Graphics Facility at UW-Madison worked with the Dane County conservation agent to predict soil erosion and sediment delivery (just one measure of environmental quality) from farm fields to surface waters in the Garfoot Creek watershed. The goal was to identify which farmers' fields exhibited the greatest potential for sediment delivery, and therefore needed to be targeted for improved agricultural conservation practices. In order to make the research most useful for the county conservation agent, the Wisconsin nonpoint pollution model (WIN), developed by the Wisconsin Department of Natural Resources, was employed. This model was used because the Wisconsin DNR was the state agency responsible for implementing the national policy, and the WIN model was the approved model for county conservation agents to use. Research was conducted on one watershed to demonstrate how the agent could apply it in other watersheds. The model itself was not critically examined for this research because the intent was to assist the county agent to do his work within the given institutional framework.

The WIN model was written in a software program (RBase) that did not directly interface with the GIS software (ARC/INFO). Therefore, the information required by the WIN model was gathered from the GIS and exported as an ASCII file. Once the model was run, the results were imported into the GIS and spatial analyses were conducted. The model input file was compiled from both existing digital information sources - soils, hydrologic networks, rainfall and evapotranspiration - as well as newly created sources - field and tract delineations, crop rotations, landcover, and topography (used to predict the direction and rate of surface runoff).

One of the major objectives of the research was to compare the effects of different land-uses (primarily agriculture and forestry) and agricultural practices on sediment delivery to surface waters. Several scenarios were created to represent different types and intensities of land-uses, as well as spatial extents of such land-uses at a landscape level. Scenarios compared those agricultural practices incorporating conservation measures such as contour ploughing, leaving crop residual as mulch, particular cropping rotations, etc. with non-conservation practices such as ploughing slopes vertically, removing crop residual from fields, and intensive cropping rotations. Each scenario was built in the GIS, exported as a file, and run through the WIN model.

Results indicated that fields under conservation management schemes experienced sediment delivery rates (100X) lower than fields where conservation measures were removed. Areas planted in forest also resulted in lower sediment delivery rates than areas under agricultural use - both with and without agricultural conservation practices.

The results, though not particularly surprising, were important from a policy perspective because they provided policy makers with quantitative measures of the effects of different land-uses. Without such analysis, only qualitative assertions on the influences of land-use impacts on environmental quality could be used to justify investment of public funds for protection of environmental resources. Of course, the model, like any other, entails a number of assumptions, and the importance of the quantitative results is their relative, not absolute, measure.

Implementing the WIN model with a GIS at the county level enabled the county conservation agent to prioritize his conservation efforts at the farm field level, which had previously been difficult due to the large scale of analysis involved. After viewing the results of the GIS analysis, farmers appreciated the process by which they were selected by the agent for improving agricultural practices because they felt that using the natural resource information in conjunction with on-site farming practices resulted in a more equitable selection process. Regardless of whether or not similar considerations had been taken into account previous to the GIS analysis, the ability for farmers to see their position on the landscape and understand how they were being treated in relation to their neighbors gave them greater confidence in the fairness of the conservation agent's decisions. This perceptual change can be interpreted as a benefit of the implementation of GIS technology.

Obviously, the conservation agent was able to make decisions on which lands to target prior to the GIS analysis, but this process enabled the agent to quickly utilize a massive amount of information on both natural resources and cultural practices, and consistently apply a methodology at a landscape level to prioritize his efforts. Using this methodology also enables the agent to monitor change on the landscape more frequently by entering any change in the natural resource base or management activities, and running the model again. The agent can also calibrate the model over time by checking the model predictions against field observations.

AN INTRODUCTION TO THE SOUTHERN ATLANTIC AUTONOMOUS REGION OF NICARAGUA

Author: Bruce Ferguson

The Caribbean Coast of Nicaragua is culturally and ecologically diverse. Its people are Black Creoles descended from slaves brought from Jamaica and Miskito, Sumo and Rama Indians. These groups generally consider themselves Costeños or Caribbeans before Nicaraguans. Historically, the area has been isolated from the Pacific side of the country and was largely ignored by the Somoza dictatorship. Transportation to and within the area is largely by river. The road connecting Bluefields and Managua is only passable during parts of the dry season. This is the poorest part of the poorest country in the Americas. Increasingly, however, with the reversal of Sandinista land reforms, mestizo campesinos are immigrating from the Pacific side in search of land.

Politically, the Coast is divided into three regions: the Región Autónoma del Atlántico Norte (RAAN), where most of the Miskitos live; the Región Autónoma del Atlántico Sur (RAAS), centered around the city of Bluefields; and an area along the Río San Juan that is controlled by the central government. The RAAS and the RAAN have their own autonomous regional governments with authority that includes control of natural resources. In practice, however, the central government still gives logging concessions in the RAAS.

Forests are rapidly disappearing along an agricultural frontier spreading north and south from a strip running between Managua and Bluefields. Large scale operations in the RAAS include two or three logging companies, and oil palm and sugar cane plantations, and processing plants. On the small to medium scale, people subsist as workers for the larger operations, cattle ranchers, farmers, or, more often, some combination of the above.

The Chontales mountains, on the western edge of the RAAS, catch the moisture-laden trade winds from the Caribbean, creating orographic rainfall that keeps the coastal plain continuously wet. The plain is drained by the Río Escondido to the north of Bluefields, and the Río Kukra to the South. In addition to the largest expanse of lowland rainforest remaining in Central America, the Coast includes three other important ecosystems: mangrove swamps, pine savannas, and swamp forests. Mangrove communities occur along much of the coast, lagoons, and estuaries. Pine savannas, dominated by *Pinus caribaea* and the palm *Aceloraphe wrightii*, occur north of Bluefields, extending into Honduras. These communities grow on beach sediments, apparently deposited by rising and falling seas during the Pleistocene. These sandy soils permit the

vegetation to dry out rapidly in the dry season, allowing frequent fires that maintain the pine savanna disclimax.

The extensive swamps of the region contain a continuum of plant communities that vary with water level. Vegetation in the wettest parts of the swamp is purely herbaceous, while shallower areas are dominated by the palm *Raphia taedigera*. Where there is still less standing water, hardwood species begin to appear, mixed with the *Raphia*, and hardwoods dominate in the driest parts of the swamp. Many of these hardwoods are commercially valuable and often grow in extensive monospecific patches. The swamp forests were perhaps the ecosystem hardest hit by Hurricane Joan. While the rainforest is regenerating rapidly, regeneration of the swamp forest has been hampered by fires that burned 90,000 ha. in the dry season following the storm. Hardwood regeneration in the swamps appears to be almost non-existent.

A system of low-input rice cultivation has been practiced in the *Raphia*-dominated swamps for hundred of years. Farmers clear small patches of forest by burning palm by palm, then scatter rice in the open swamp. The rice grows with little husbandry and is harvested during the September veranillo. The system is perennial, providing a harvest for two to four years before the land "gets tired" and the farmer moves on to a new patch of swamp. Swamp rice yields quite well, and appears to be a fairly sustainable system as practiced. However, it is likely rice farmers who started the fires that burned through the forests after the hurricane, fed on huge amounts of litter left by the storm.

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THE ORIGIN AND PEASANT MANAGEMENT OF THE NATIVE COTTON OF PERU

Author: Jill Fischer

The objective of this presentation is to present the model used by Jack Harlan in his theory of the origin of agriculture¹ and to illustrate this concept by presenting my application of the model, which I used to determine the origin of a variety of cotton found only in the very northern portions of Peru, the extreme southern areas of Ecuador, and the Galapagos Islands. A brief explanation of how this now rare plant has been cultivated and survived for thousands of years will follow.

The subject of my secondary research is a variety of cotton that is referred to most commonly as País, however, it is also known as Aspero and Pardo; these names are appropriate, as they accurately describe characteristics of the cotton, for example, País means country and it is believed that this cotton originated in Peru. The remaining terms refer to the texture and color of the cotton: coarse and brown.

Harlan proposed that the areas where numerous crops were first domesticated were Centers of the origination of agriculture. There are a total of eight, and Northwestern South America is one of these Centers. The term Non-center was also coined by Harlan. This refers to an area where numerous plants that continue to be unique to that area were domesticated. There are only three Non-centers, and an example of one is Ethiopia.

The model upon which this theory is based has four components: living plants - the present day distributions of the wild relatives of the object of study, past plants - archaeological remains of plants, living humans - their practices and uses of the plant, past humans - archaeological remains indicating their practices and uses of plants.

An application of the model, such as the case of Pais cotton, best illustrates the concept. The present day distributions of wild, brown cotton (which is similar to cultivated, brown cotton (País)) are located in northern Peru, southern Ecuador, and the Galapagos Islands.

The archaeological remains of four cotton bolls unearthed at the archaeological site, known as Ancón, play a major role in determining the origin of País cotton. There is a progressive increase in the number and size of seeds, as well as in the fiber diameter (which translates into an increase in the amount of fiber produced by each boll) in four distinct samples: *Gossypium barbadense* var. *darwinii* (found in the Galapagos Islands), the four bolls from Ancón, wild *G. barbadense* (collected by the FAO near Tumbes and Aguas Verdes), and cultivated brown cotton (País) near Piura. It is interesting to note that

an increase in such traits is generally indicative of domestication (or different degrees of domestication).

Currently, there are approximately 10,000 peasant farmers cultivating this brown cotton in home gardens in northern coastal Peru. These agriculturists implement the same agricultural techniques that have been used for thousands of years. In addition, they use the cotton in many of the same ways that their ancestors did.

The traditional methods of cultivating cotton along the arid Peruvian Coast are still utilized. There are three of these mainland management practices: hoyadas (sunken fields), maceteros (stone-lined pits), and huertas (small rectangular plots with raised borders), that share the same objective of capturing condensed fog moisture. Huertas appear to be the most commonly utilized of the three. The huerta has an extra drainage field above the plot that utilizes the slope to direct water directly to the root systems of the plants below.

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SOCIAL FORESTRY IN THE CENTRAL HIMALAYAN DISTRICT OF ALMORA, INDIA: AN EVALUATION

Author: Ankila Hiremath

The Social Forestry program in India was started in 1976 to meet the fuelwood and fodder needs of rural communities. The objectives of the program were to establish mixed species plantations on village common lands or on forest lands that would subsequently be handed over to villages. These plantations were to be created in consultation with villagers and were to be managed by the villagers themselves. In the summer of 1991, I participated in a study to try and evaluate the success of the program in the Almora region in the Central Himalayas. For the purpose of this study, I chose six villages within a 13 km radius of the town of Almora.

The Almora region is in the lower Himalayas. The town has an altitude of about 1600 m. The natural vegetation in the area is evergreen montane forest dominated by the banjh and kharsu oaks (*Quercus leucotrichophora* and *Q. semicarpifolia*) and the chir pine (*Pinus roxburghii*). Much of this vegetation has since been converted to extensive monospecific stands of chir pine.

The history of organized forestry in India goes back to the late 19th century when the Imperial Forest Service was created to meet the growing demand for timber, both for ship-building and for the expanding railway network. By 1878 two Forest Acts had been passed to bring all forest lands under government control. In the process, the customary rights that villagers had formerly enjoyed, in terms of their access to fuelwood, fodder and small timber, were transformed into privileges to be granted by the forest department. In addition, access to resources, which earlier had been governed by community sanctions, was changed to a process that involved agreements between individuals and the forest department.

Social forestry in the Almora region has been in effect since 1980. Each year the state government sets planting targets which are then passed on to the district forest offices to implement. The choice of villages to be included in this study was based on records obtained from the forest department. The villages selected for this study were those where plantations had been established for five consecutive years since 1985. In each of the villages, I surveyed the plantations to try and assess tree survival and growth. I also conducted informal interviews in two of the villages to try and understand how the program was perceived by the people for whom it was intended.

I found that on the whole the plantations showed a very low tree survival, ranging from 2 to 50%. It was not possible to assess the relative suitability of the different

species to being planted under those conditions. This was because of the 12 or 13 species planted, only 3 showed any measurable survival at all. The high mortality of the other species cannot be attributed to environmental factors alone, as the plantations also appeared to be poorly managed. Stealing of firewood and cattle grazing, which is not permitted, were problems that were mentioned repeatedly.

In the interviews I found that not very many people were aware of the plantations in their villages, even though the decisions regarding plantation establishment were supposed to be taken by the village as a whole. While the village head-man (the Sabhapati) and the members of the council (the Panchayat) reported good attendance at the village meetings (the Gram Sabha), other villagers indicated that the Gram Sabha was not a priority amongst their activities. It led me to wonder whether this was out of a general sense of apathy, or whether it was because their views were not given due consideration. Women play a very important role in the home, more so since many of the men from the region go down to the plains to work and households are run almost entirely by women. Yet women appeared to have little say in the affairs of the village.

The study was valuable to me in that it made me think about the complexities of implementing programs such as the social forestry program. It also cautioned me against the somewhat prevalent tendency to think of rural communities as possessing a natural wisdom in regards to the management of community resources.

ANIMAL BEHAVIOR AND MANAGED ECOSYSTEMS

Author: Laura Howard

Today many parks and reserves consider the conservation of biodiversity a primary objective. Understanding the natural history of a target species is essential for planning and for implementing management regimes. Unfortunately, many detailed behavioral studies have focused on captive populations. As a result, little is known about how wild populations interact with biotic and abiotic influences. Behavioral studies of wild populations can offer information imperative to developing tailored conservation programs. Three examples describe the importance of using behavioral data in the formation of management policy.

CASE I: Beaver (*Castor canadensis*) were trapped out of the Minnesota Lake Itasca State Park area by the early 1900's. In 1930 the Canadian government donated 3 beavers for reintroduction to the Lake Itasca region. By 1989 the beaver had become a pest species, building dams that resulted in the flooding of farmers fields, roads, and private lands. DNR censuring methods assumed that beavers failed to reuse old lodges and that the average number of beavers per lodge was 5.2. A radio-tracking study determined that beavers do indeed reuse abandoned lodges, and that lodge size was between 7 and 9. Recommendations resulting from this research were given to the DNR. As a result, censuring techniques were updated resulting in more accurate estimations of the Lake Itasca beaver population.

CASE II: The Carizzo Plains Natural Area, CA established in 1988 targeted the enhancement of endangered San Joaquin kit fox (*Vulpes macrotis mutica*) population as a major management goal. Of major concern was the potential for coyote (*Canis latrans*) predation of kit fox. One proposed management practice involved the reinstatement of compound 1080 laced baits in order to control coyote populations. A radio tracking study showed that coyote predation accounted for a very small percentage of kit fox deaths, however, the disturbance of denning activity, along with a depleted prey base, were considered major factors influencing kit fox mortality. Recommendations resulting from the study included: a continued ban of the use of Compound 1080, a focus on the rejuvenation of native grasses, and a restriction of access to kit fox denning sites.

CASE III: In 1986 the Bahama National Trust of New Providence became concerned by the decline of the White-cheeked Pintail (*Anas bahamensis bahamensis*). Little information existed to help the conservation group plan for the management of this duck species. A five year behavioral study focusing of mating behavior and population dynamics determined that pintail populations on New Providence had declined by eighty percent. The natural habitat of the pintail had been reduced to golf course ponds and a

sewage treatment plant. Recommendations for management involved habitat restoration, restricting boat activity near nesting areas, maintaining captive breeding and fencing the local sewage treatment facility.

Without these studies, poor management practices might have been implemented. In Minnesota, the DNR would have continued to underestimate beaver populations. In California, misguided attempts to control coyote populations might have had disastrous effects. The Bahamas National Trust would lack specific aims for pintail conservation. All three cases show that ecological and biological input into management programs can result in more informed conservation strategies.

CONSERVATION IN INDIA - ISSUES AND TRENDS

Author: Jagdish Krishnaswamy

India is perhaps the only country that has three bio-geographical regions represented within its borders. It is uniquely situated having the Palearctic, Afro-Tropical and Indo-Malayan flora, fauna and ecosystems. This has made it one of the dozen mega-diversity countries that account for 60 - 70% or more of the world's bio-diversity. Despite having only 2.5% of the world's land, India harbors 15% of the human population, 15% of the cattle and goats, and 50% of the world's buffalos, giving some indication of the pressures on land. Fire-wood collection and grazing are therefore serious problems, besides the hunger for land, which is currently stable. Communities both within and around forest areas have traditionally depended on forest resources, including what is erroneously referred to as minor forest products, as a significant source of income.

Conservation in India has been based in the past principally on religious sentiment, royal decrees and hunting needs and more recently, the British colonial administration and modern influences, international in origin. As an example, the world's first official edict on the protection of animals, fish and forest was issued by Emperor Asoka in 252 B.C. and sacred groves probably existed even earlier. Currently, 4.4% of the land and coastal habitats are under some form of legal protection, mostly as Sanctuaries and National Parks. Given the needs of the vast human population, the Green revolution, and over-exploitation by the state, both princely or British, it is indeed remarkable that very few species of mammals, birds and reptiles have been lost, although it is not known how many plant species, insects and varieties of food-crops have disappeared.

Official state based conservation of protected areas was and still is a "guns and fences" approach involving restrictions on the activities and land uses of traditional forest and forest fringe dwellers, and in many cases, translocation and rehabilitation of human and cattle populations from within protected areas. This process can be seen as an extension of the alienation from forest access and use that characterized British colonial administration of forests. Often, this has created hostilities and justifiable resentment against enforcement of protected area regulations and restrictions. It is only as recent as 1983, that official policy at the national level has recognized the need for special attention to the needs of such communities, wherever they affect protected areas or vice-versa.

Two conservation initiatives, perhaps the most ambitious ever undertaken, Project Tiger (1973) and the Crocodile Conservation Program (1974) were successful in their immediate objectives and were remarkable in their impacts on protected area management policies and strategies. Project Tiger set aside over 8000 km² of prime tiger habitat as inviolate, protected core areas and brought under its umbrella a total of over 25,000 km²

of forest and grassland habitat representing a wide variety of forest types, ecosystems and bio-geographic zones. The concept of core and buffer zones was put into practice in India on a scale unparalleled anywhere in the world at that time. As an example, Kanha Tiger reserve has a core area of 940 km² and a buffer of 1005 km², and 22 villages with a population of 33,000 were translocated and rehabilitated to secure the core zone. In some cases the shifting of settlements, ban on grazing and firewood collection, as well as the incidences of human-wildlife conflicts, including cattle lifting and man-eating by tigers moving out of the core areas, have led to serious hostilities and clashes between protected areas and staff on one hand and human communities who have to eke out a living in spite of the restrictions on their access to forest resources. This is a continuing battle with winners and losers on both sides, and a tragedy when poor, marginalized communities have to make most of the sacrifices for protecting and preserving India's wonderful and precious bio-diversity. The challenge is to make the buffer zones a source of income, employment and possibly subsistence food for dependant people without degrading the land or reducing the habitat for most, if not all, of the wild biota.

The crocodile Conservation Program, on the other hand, has succeeded in its first objective to secure viable wild and captive populations of India's three species of crocodilians, and failed in its second one to provide a source of income, protein and employment to local communities. Changes in the wild life act are required to make game ranching and harvesting a legal possibility under closely monitored conditions, at least of captive bred animals. This must be done without endangering the wild populations and encouraging illegal trade in poached crocodile products.

There are some areas in India that are model examples of integrating compatible land uses with conservation, such as protection of catchment areas for irrigation and hydel dam reservoirs, or restricted harvesting of forest products and rotational timber extraction. The two highest priorities in the next twenty years will be to secure, for all time, large enough areas of all fragile and under represented ecosystems, since most of the best protected areas have a large mammal bias at present, and secondly, to gradually replace the "guns and fences" approach with a more humane, sensitive and progressive policy. The basic needs of local communities must figure in all conservation initiatives and must be incorporated in forest and wildlife management, at the cost of some losses and risks. Otherwise we might lose everything. The highly degraded forest areas and watersheds must form the basis for fulfilling these needs. Restoration ecology and watershed science have to be put into practice, otherwise there won't be any tigers to radio-collar. This is not to belittle the importance of wildlife studies, but a plea for reversing the order of priorities. There is very little time left and India, with its rich cultural, bio-diversity and ancient roots in conservation, will hopefully succeed where so many have failed.

Student Presentation

DEPENDENCY THEORY AND INTERNATIONAL TOURISM

Author: Liz Marshall

Many countries rely on protected areas as their fundamental direct method of natural resource protection. The benefits derived from protected areas fall into several categories, including existence value, future value, consumptive value and nonconsumptive value. Tourism is an example of an activity that generates nonconsumptive value.

International tourism is big business. It represents the world's third largest trade item and accounts for more than 7% of all world exports. The Stanford Research Institute forecasts an 8% annual growth rate in general worldwide tourism. Many developing countries (LDCs) are incorporating tourism into their development strategies, for tourism is expected to create jobs, generate foreign exchange, generate additional tax revenue, expand development into non-industrial rural areas, and stimulate domestic production.

The use of tourism as a development tool has been analyzed and criticized in the context of an international development theory called the dependency theory. Dependency theory states that the perpetuation of underdevelopment in LDCs is the result of a dependency/dominance relationship formed when developing nations establish trade relations with developed nations. This theory is based on the resource flows predicted by the core/periphery model.

The core/periphery model divides nations into core economies (represented by capitalist developed countries) and peripheral economies (developing nations). Core countries penetrate the economies of peripheral countries through foreign investment and establish a developmental presence that furthers the interest of developed countries regardless of the goals of LDCs. Dependency theory criticizes tourism, in particular, for its vulnerability to three detrimental conditions predicted by the core/periphery model: high degree of foreign ownership, high import dependence, and the formation of foreign/national elite partnerships.

Ecotourism has been suggested as a way of decreasing vulnerability to these three conditions. Ecotourism facilities are not expected to require the same levels of capital, imports, etc., as conventional tourist facilities do. In the absence of those three conditions, more of the financial benefits should remain in the country, and more of the expected benefits to the national economy should materialize. Policies that could help maximize ecotourism's potential for national development include: efficient taxation policies, policies encouraging small-scale development, available credit for local enterprise, more extensive programs for human resource development and education, and import substitution policies.

Tourism is very important to Costa Rica's economy. It represents the country's second largest source of foreign exchange. Much of Costa Rica's tourism development is related to ecotourism. I would like to pursue research on protected areas in Costa Rica and how they fit into the context of the dependency theory.

GLADIOLA PRODUCTION IN THE BLUE MOUNTAINS OF JAMAICA

Author: Donald Mee

From early 1990 through 1992, a project sponsored by the Jamaica Agricultural Development Foundation (JADF), and coadministered by JADF and the Research and Development Division of the Jamaica Ministry of Agriculture (MINAG), was conducted in a remote mountainous region of East Rural St. Andrew, Jamaica. The purpose of the study was to investigate the feasibility of commercial gladiola culture by small farmers in the area. Prior to this project, variety trials had been carried out at MINAG's Top Mountain Research Station located in the area.

The region has a long tradition of floriculture dating back to the establishment of Cinchonia Botanical Garden in the mid-1850's, and the extension activities emanating from there. Other crops important to the area are european vegetables, subsistence food crops, and world renowned Blue Mountain coffee.

Problems dominating the area are bad roads with little or no public transportation available, undependable water supplies, and a small surplus labor pool because of the extensive coffee plantations:

In September 1990, five farmers were selected to participate in the project. Through the course of two years, four additional farmers were added, and three others were associated with the project to a lesser degree. These farmers were organized in an informal group that meet regularly to discuss their enterprises. They also marketed the flowers collectively.

Local commercial florists were happy to buy any gladiola spikes produced. There appeared to be a potential export market, especially during the winter months in Europe and North America. However, this avenue was not pursued because the local market was paying a premium price.

The major cultural problem was thrips, which were very difficult to detect, and even harder to control. Treating the corms with insecticide prior to planting and crop rotation were the best measures. Some incidents of fungal infections appeared, but removal of infected plants was an effective control. Fungicides were also used to some extent.

By the end of the project, seven of the nine farmers had paid off their loans and were interested in buying more corms to increase their production. However, shortly after that time, problems developed among the farmers and the marketing agent (also one of the farmers). The association soon dissolved and farmers went back to selling to retail florists at a lower price.

CONSERVATION ISSUES IN NGEZI AND JOZANI FOREST RESERVES OF ZANZIBAR

Author: Nabiha Megateli

We are now at a time when the rate of park acquisition in the world is probably reaching a peak. While parks and protected areas are the preferred solution to species conservation, protected areas are and will become fragments, islands in a sea of rapid human activity. Does this then imply a need to not only continue to designate protected areas but also "to project conservation into the lands beyond parks, if for no other reason than to protect the values of the parks themselves"? During my independent project with the School for International Training in Tanzania, I researched the conservation status of Zanzibar's red colobus monkey, the Ngezi and Jozani Forest Reserves, as well as the human dimensions from a "beyond park" perspective (Map 1).

Conservation in Zanzibar is receiving much more political interest than has been the case in the past due to enthusiasm and ground breaking work (since 1989) of its new Department of Environment. In light of newly promulgated environmental policy calls for nature conservation, the promotion of people's participation and environmental education, Zanzibar is at the point of creating protected areas. However, a conservation or national parks authority does not yet exist and the participation of local residents is simply an idea not actively or definitely pursued. Alienation and exclusion of people as stakeholders in conservation has been and could be a potential and serious mistake, particularly considering the lack of awareness, ambivalence and even conflict between Zanzibarians and endemic wildlife. I shall first describe the ecological and social context of the Jozani and Ngezi Forest Reserves, as well as the particular situation of the Zanzibar red colobus monkey. Secondly, I shall summarize some of the recommendations I proposed for future policies and activities to the Forestry and Environment Departments.

The Ngezi Forest Reserve is situated in northwestern Pemba, lined by mangroves to the south and north east, covering 1450 ha of 1/3 moist forest, 1/6 coastal evergreen thicket, and 1/6 giant phillipia heaths (Map 2). Ngezi is a refuge to 200 endemic Pemba flying foxes, blue duikers, 15 translocated red colobus monkeys, the rare *Phillipia mafiensis* and canopy tree *Odyndea zimmermanii* reaching 45 meters, the endemic and endangered wild banana and palm, *Ensete proboscideum* and *Chysalido carpus pembeanus* both in IUCN Red Databook. The reserve is surrounded by coconut, cassava, rice and cloves to the east, rubber to the north and scattered villages relying on the area for fuelwood, construction materials, climbers for thatching and basket weaving. Evidence of illegal wood collection in the reserve is common due to the lack of local alternatives and reduced forest cover in Pemba. A proposed hotel on Verani beach for sport fishing has

been halted by the Department of Environment for destroying thirty endemic palms during foundation preparation.

The Jozani Forest Reserve lies some 25 km southeast of Zanzibar Town in a narrow silted up basin between the northern Chwaka Bay and southern Uzi Bay mangroves (Map 3). Jozani covers 1512 ha, half a dense evergreen coral rag thicket, a quarter tall forest, and a quarter swamp forest. The reserve has 120 plant species, several of conservation interest, such as *Clematis viridiflora* and *Pandanus rabaiensis*. The reserve is core habitat and radiating center of endemic fauna: the endangered Zanzibar Red colobus monkey, the Zanzibar leopard, Jozani suni and red duiker, tree hyraxes, giant and small elephant shrews and bushpigs. A considerable and unknown number of tourists come to Jozani to visit with monkeys, however, often they bypass the reserve and just see them on the road heading to Bwejuu and Paje beaches. Paths in the reserve are heavily eroded. No natural history information or overnight visitor facilities exist to encourage an income generating ecotourism.

The Jozani reserve is surrounded by considerable human activity: coconut plantations and a busy road to nearby Zanzibar Town in the south, banana in the northeast and corn/cassava/papaya/mango to the east. Uncontrolled hunting is endangering the suni and duiker population. Commercial charcoal burning of evergreen and mangrove trees is done to satisfy the voracious Zanzibar Town market, often by Tanzanians from the mainland with permits to Zanzibar land claiming to be vegetable farmers, but really intending to log or make charcoal. Other illegal selective tree felling for boat construction and firewood occurring within the reserve, as well as activities out of the reserve, seem to be seriously degrading, fragmenting and preventing fallow regeneration of vital forest and mangrove habitat in the region.

The Zanzibar red colobus monkey, *Colobus badius kirkii* or kima punji in Kiswahili, is indeed one of the most endangered and distinctive red colobus of the 14 species known across tropical Africa from Senegal to Ethiopia. They are found in 15 locations on Unguja Island and were translocated in 1974 to Ngezi on Pemba Island. In appearance, the most striking features are a fine band of long white hairs radiating in a wide arch from the brows and cheeks, as well as a reddish brown/orange back and tail tipped with blond. The social structure tends to be that of groups of up to 20 or 30, usually led by one or two males and with a home range of 30 to 40 hectares. Being crepuscular primates, kima punjis have two active feeding periods, early morning 7 - 9 a.m. and just before sunset 5 - 6 p.m. Their diet consists mainly of herbaceous material: young leaves, mature leaf petioles of mango and cashew trees, mature leaves of *Terminalia cattapa* and *Sorindeia madagascarensis*, stems, leaf apices of mangrove *Bruguiera* and *Rhizophora*, flowers, bark and dead wood.

Several population estimates have been made ranging from 675 to 1700. The most recent population survey, of which I assisted in, suggests a population of 800 to 1000 red colobus monkey, with half in the Jozani region. With the incomplete information on age

structure and sex ratios, this makes the Zanzibar red colobus monkey endangered, if not in critical status, and suggests a need for concerted conservation action. The major threat to the red colobus monkey continues to be habitat degradation and destruction of unprotected coral rag forests on half of Unguja Island, as well as selective tree felling within forest reserves. Mostly the threat comes from commercialized charcoal production, as well as boat and construction timber. Agricultural clearing and shorter fallow periods have also contributed to rapid vegetation loss and lack of regeneration.

Recommendations

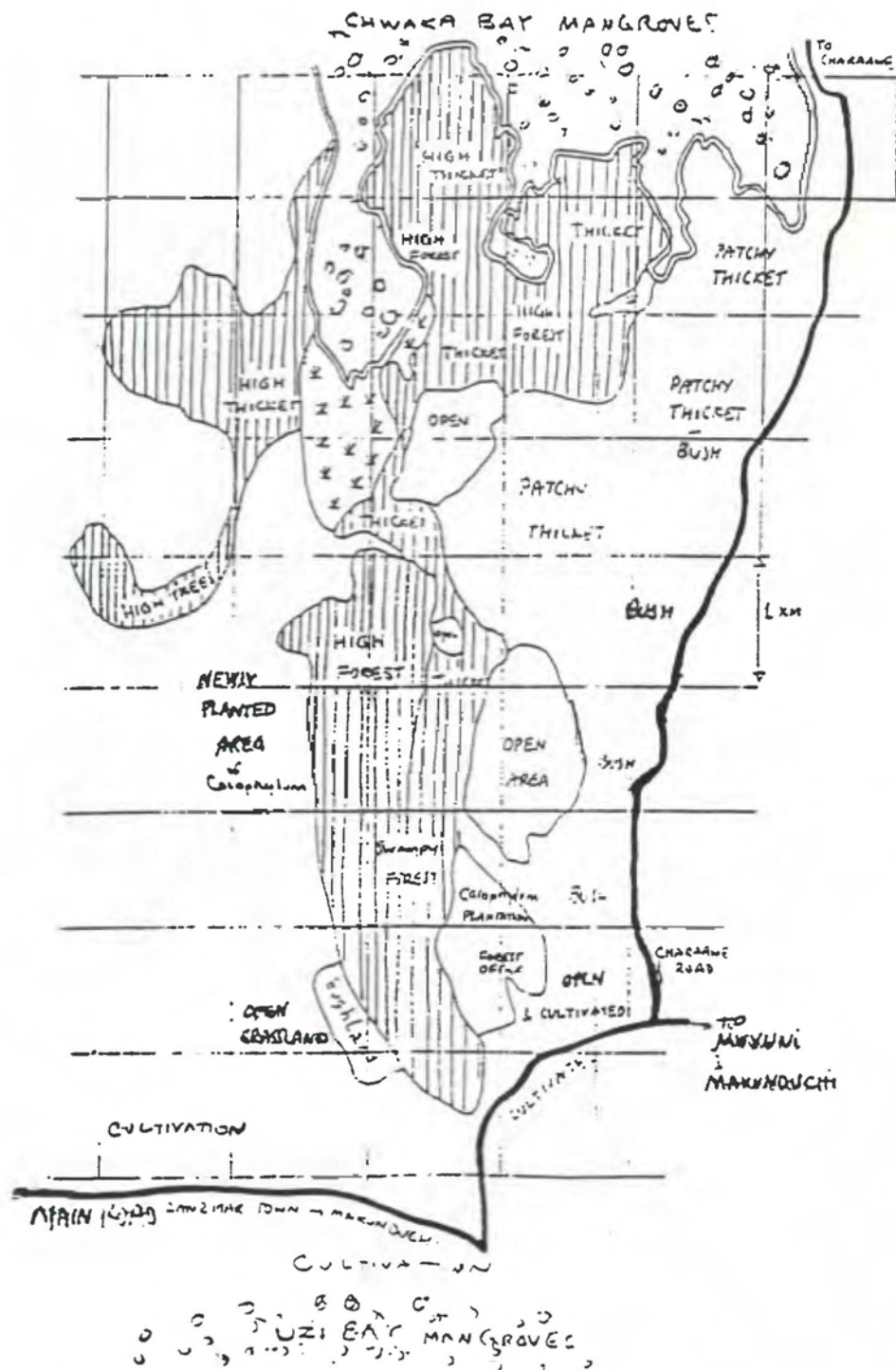
- (a) continue and expand environmental education campaign with radio, tv, mosque and school blitzes on endemism and endangered species like the Pemba flying fox and Zanzibar colobus monkey, as well as on the soil/water improvements of natural regeneration
- (b) ecological research of flora and fauna, especially of target flora and faunal species, in addition to methods for restoration of evergreen thickets and high forests
- (c) regazetting and upgrading Jozani and Ngezi Reserves to national park status including Chwaka mangroves, but only if conditional legitimate agreements made with local residents ensure their land security, access and development of alternative resources, as well as a role in park management
- (d) the additional protection of valuable forests, thickets, mangroves and coral reefs on Uzi Island, Masingini and Kichwele
- (e) initiation of resident participation pilot projects at Pete, Unguja and Kipangani, and Pemba to deal with park creation, benefit sharing, land tenure and agroforestry alternatives for food and fuelwood; the possibility of honey production in Chwaka mangroves and the establishment of a conservation and red colobus viewing (fee to be shared by park and villages - to be paid by tourists passing Jozani on their way to well visited east coast beaches from Zanzibar Town)
- (f) ecotourism promotion of Jozani Reserve with hiking and educational paths linked to local naturalist guides, a center disseminating interpretive materials for local environmental education and ecotourists, selling local crafts such as muslim caps and palm leaflet baskets, as well as organic fruits, nuts, spices (clove, cinnamon, nutmeg, cardamon) and mangrove honey with a Kima Pungi logo
- (g) the continued practice of moratoriums or conditionality to control tourist development potentially damaging to biodiversity and local customs

- (h) the founding of a conservation authority staffed for above projects with sociologist, environmental educator, ecologist, geographer, environmental lawyer, and resource economist
- (i) the use of international environmental NGO's, such as the World Wildlife Fund, the Frankfurt Zoological Society and Conservation International, as well as Tanzanian foreign universities for both financial and research assistance

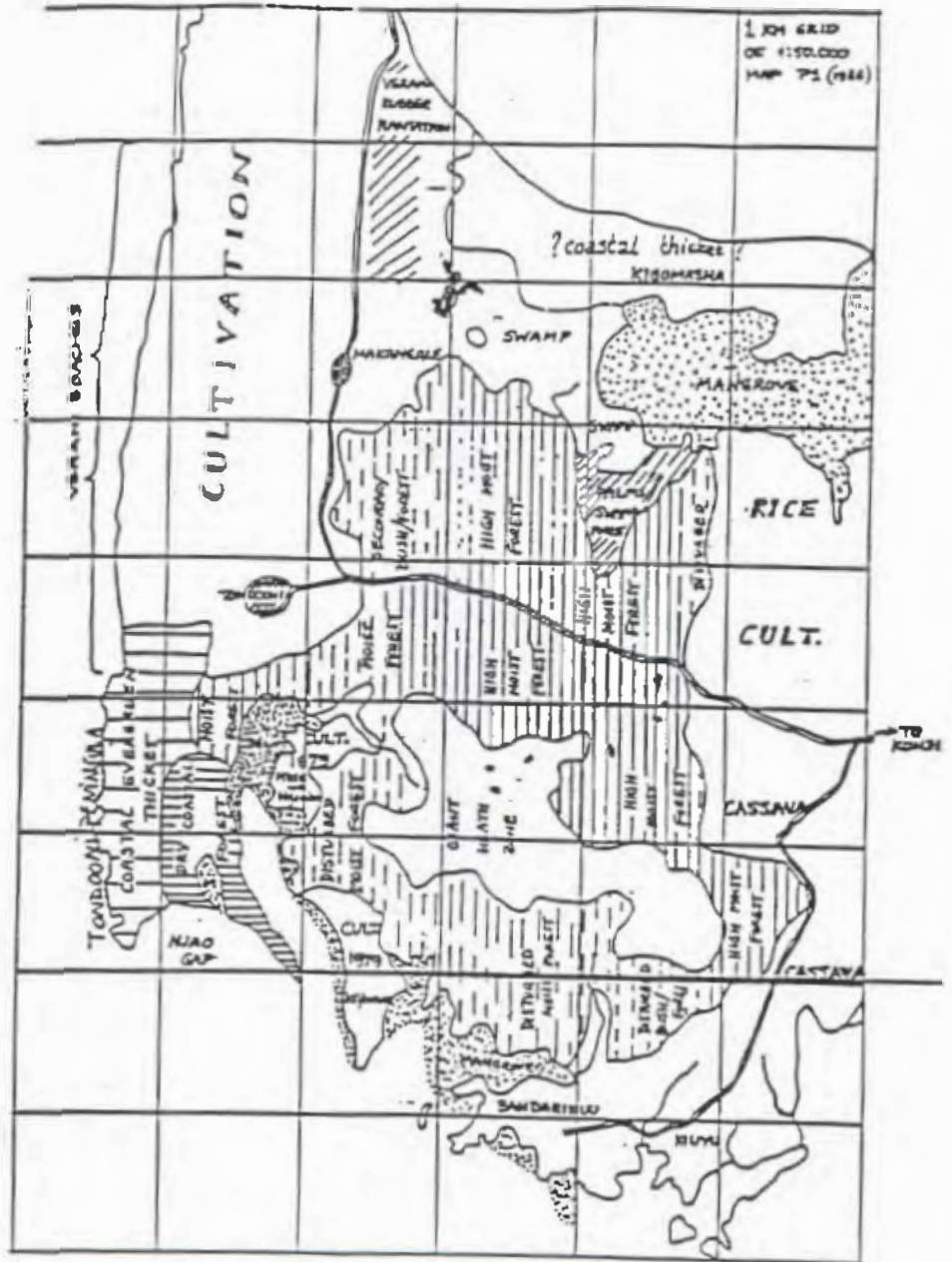
Map 1: Zanzibar Archipelago Mangrove and Forest Habitats
from Shanula 1991 and Beentje 1991



Map 2: Jozani Forest Reserve and Vegetation Types
from Issa and Beentje 1989



Map 3: Ngazl Forest Reserve and Vegetation Types
from Beentje 1991



**LEUCAENA FODDER YIELD UNDER DIFFERENT HEDGEROW
SPACING AND MANAGEMENT REGIMES IN ALLEY CROPPING
SYSTEMS AT MAFIGA, MOROGORO TANZANIA**

Author: Pantaleo K. T. Munishi

Abstract

In 1990 and 1991, an assessment of the effects of hedgerow spacing and management regimes on *Luecaena* fodder yield was done at Mafiga, Morogoro Tanzania. Fodder harvests and assessment were done at an age of 10 years (1990) and 11 years (1991). The harvest consisted of leaves twigs (flowers and pods inclusive), and portions of shoots carrying the youngest leaves. The biomass (dry weight) of the fodder harvests were determined for four different hedgerow spacings (3 m, 4 m, 5 m, and 6 m) and three different management regimes (intercropping with maize, beans and no intercropping clean weeding). The fodder yields by *Leucaena* varied between spacing in both years and between the two years (seasons). The average fodder yield was 5.64 t/ha/annum (4.0 t and 1.64 t in 1990 and 1991, respectively). The annual per - ha fodder production (yield) was not significantly influenced by intercropping (management regime) or interaction between the components of the experiment. However, the annual per - ha fodder yields were significantly influenced by hedgerow spacing.

BIOSPHERE RESERVES: PROMOTING SUSTAINABILITY BY ADDRESSING LOCAL INCENTIVES

Author: Amelia Oliver

There is a powerful need for biosphere reserves to increase the economic benefits gained by the local communities which depend on the reserve resources. Too many of the costs are paid locally whereas the benefits are not localized. New emphasis must be given to strategies that stabilize the precarious economic and ecological situation of farmers. The main challenge to the biosphere reserves is how to integrate sustainable income-generating activities into the production strategies of existing rural peasants. The strategies to be targeted should:

- 1.) Utilize the unique organizational framework and geographic arrangement of the biosphere reserves to develop and monitor programs.
- 2.) Use a grassroots approach, emphasizing local participation at all levels.
- 3.) Promote better socioeconomic institutions.
- 4.) Diversify the production systems within the reserve to alleviate uncertainty.
- 5.) Improve marketing techniques of forest products.
- 6.) Continue research and extension to improve production techniques.
- 7.) Incorporate local knowledge into new systems.

The prevailing obstacles of market imperfection present problems, but by using the above strategies the biosphere reserve approach may have the capacity to accommodate and overcome these obstacles. There are other pressures as well. Would a system such as this withstand the pressures of migration? Will incentives to over-harvest present problems? Will improvement in the reserve infrastructure introduce new problems as access to the reserve would increase? Only time can answer these questions. What is important now is to increase incentives to conserve locally and improve the outlook for sustainability. If market prices were efficient and reflected their true value and if property right were more secure, then resources would be used more carefully as they became scarcer. Improvements in the research base for agriculture, forestry, and other sectors of the rural economy would allow crops, livestock, timber, and other commodities to be produced with less pressure on the environment. Research is a key to opening the doors to sustainability. Although there exist many constraints to sustainable agriculture, through the management network of the biosphere reserve and good exchanges of information, suitable techniques and strategies are possible.

IMPACT OF THE RED IMPORTED FIRE ANT ON GROUND NESTING BIRDS

Author: Ellen Pedersen

Abstract

I present 3 approaches to study the impact of the red imported fire ant (*Solenopsis invicta*) on ground nesting birds and the major limitations.

I first intended to use wild Bobwhite quail (*Colinus virginianus*) as a surrogate species equipped with radio collars to assess the impact on Attwater's prairie chicken (*Cupido attwaterii*). The idea was to study nesting success and mortality of the chicks caused by fire ants. I proposed to locate 40 Bobwhite females, equip them with a collar, and locate their nests. The realization of this project was not possible due to lack of funding and the great amount of time necessary to collect data. Also, the eradication of ants and the close observations of the nests would have caused disturbance.

I proposed a second experiment using a pair of adult Bobwhite as parents of newborn chicks and observe activity in the presence and absence of fire ants. The limitations of this project, among others, was the difficulty of data collection due to presence of non-tame adults that would be disturbed by human presence.

The experiment that I carried out consisted of the comparison of activities performed by newborn Bobwhite in two adjacent areas, one with, and the other without fire ants. This experiment was designed to compare time-energy budgets during the first week of age. I collected data in College Station, TX. The data has not yet been analyzed, but my observations suggest that fire ants do not have an effect during early spring, but as the summer advances, they become a serious problem for the chicks. This experiment was not designed to study mortality, then, I did not have direct mortality due to fire ants.

THE ROLE OF TROPICAL ARBUSCULAR MYCORRHIZAE IN PLANT SUCCESSION AND EFFECTS OF SEVERE DISTURBANCE

Author: Chris Picone

DEFINITIONS: Mycorrhizae ("fungus-root") are mutualistic associations between plants and fungi. A plant supports fungi in the roots with photosynthetic sugars, and in return, the fungi improve nutrient absorption. Two major types of mycorrhizae exist: 1.) Endomycorrhizae, which form sheathes around the roots of pines, oaks, birches, *Casuarina*, *Eucalyptus*, Dipterocarps, and other trees; and 2.) Endomycorrhizae, or arbuscular mycorrhizal fungi (AMF), which do not form sheathes. The latter associate with over 75 - 90% of tropical plants and forest tree species (Janos, 1987; Sylvia, 1992). Such dominance in tropical plants may be related to the high affinity of AMF for phosphorus, an element lacking in many tropical soils.

ROLE IN SUCCESSION (Janos, 1980a,b): The 10 - 20% of plants that do not associate with AMF are almost exclusively pioneers, such as *Phytolacca*, *Cyperus*, and members of the Polygonaceae, Brassicaceae, etc. Secondary forest plants and grasses are generally facultatively mycorrhizal, while shade-tolerant, primary forest plants are often obligately dependent on mycorrhizal associations.

In a small-scale forest disturbance, soil nutrient availability increases for a period of time that allows pioneers and secondary forest plants to invade. They have a competitive advantage since they do not need to support a fungal symbiont at times of high nutrient availability. With nutrient leaching, the diverse secondary forest vegetation increasingly relies on an array of fungal species for nutrition. Theoretically, the greater the plant diversity present, the greater will be the diversity of fungal species supported on a site. Eventually, primary forest plants, which are more shade-tolerant and dependent on mycorrhizal inoculum, can take over.

In contrast to small-scale disturbance, I propose that humans have created environments where plant diversity has remained extremely low for long periods of time, such as in degraded pastures or banana plantations. In such cases, fungal inoculum may disappear from the soil since few host plant species are present. Inoculum may even become sufficiently degraded to prevent successful establishment of primary forest plant species.

RESEARCH: First, I will compare spore numbers and diversity in soils of degraded pasture and adjacent forest in Eastern Nicaragua. I will take samples according to a geostatistical plot design to compare spore variability both within and between sites. Secondly, I will evaluate success of hardwood tree species planted in sterilized soils from

pasture and forest, with each soil receiving pasture and forest fungi, making four treatments.

APPLICATIONS: If spore counts, or more importantly, inoculum, of pasture soils are significantly decreased, then farmers and restoration ecologists that plant trees in pasture may need to add mycorrhizal inoculum to seedlings. Furthermore, this area provides another approach when contrasting ecological changes of small-scale, mixed cropping systems to large, monocultural systems.

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REFORM OF ARTICLE 27: CONCEPTIONS OF PRODUCTION

Author: Christopher Rosin

Interpretations of agricultural reforms in Mexico reflect a history of agriculture policy beginning with the 1917 Constitution. The intent of Article 27 of the Constitution was to form ejidos, communally owned lands. Except during the Cardenas administration in the 1930's, the Mexican elite have generally recognized the ejidos as regressive members of the agricultural sector due to their small size and subsistence crop orientation. When the Rockefeller Foundation sought to improve agricultural production in Mexico, the result was a Green Revolution of techniques accessible to large land owners with irrigation. Mexican agricultural policy continues to follow an industrial model of agriculture. High market production, extensive land use, and technical inputs are given preeminence.

The reform of Article 27 of the Mexican Constitution, its defenders and critics, all respond to an emerging conception of production in agriculture. Initially interpreted as an activity within nature's realm (humans merely benefitted from nature's production in the harvest), agriculture is now redefined as human production. Thus, the actions of the farmer become those of the manager and producer rather than facilitator and reaper. Accompanying the evolving definition of agriculture is that of the harvest from produce to commodity. In this manner, agricultural production has become a controlled manipulation of ecosystems responding to the commodity values of its inputs and outputs.

The reform of Article 27 provides the means for the privatization of the ejido system. As such, the reform is expected to invigorate a stagnating agricultural sector in Mexico. Its authors suggest that privatization will allow farmers to more actively participate in the market system, thereby increasing the production of agricultural commodities. The reform is also expected to reduce government influence on agricultural production. The intention is that Mexican farmers entering the world market will be able to turn competitive advantages in climate and labor into export capital in order to compensate escalating basic grain imports.

Several critiques of the reform have also arisen based on social and ecological arguments. The social impacts of the reform are related to the dissolution of the ejido as a social entity. Many have suggested that loss of identity within the ejido will result in deteriorating cultural and political ties and the imposition of class based social differentiation among the rural population. The modernization of agricultural production envisioned in the reform raises ecological concerns as well. Private land, as a commodity, enables greater access to credit. This, in turn, encourages greater inputs of agrochemicals and mechanization. Exasperating the trend toward mechanization and agrochemical use is the concentration on export crops which are more susceptible to pests and require consolidation of small holdings for profitability.

TIKUNA OF THE UPPER SOLIMORES

Author: Nick Shorr

Abstract

Preliminary research among the Tikuna of the Upper Solimoes, Amazonia, Brazil reveals several large communities with some of the highest local population densities on record for swidden cultivators anywhere in Amazonia. These densities are reflected in very short fallows (2 - 3 years) close to residences. Research is proposed to examine changes in agro-ecology, ethno-agronomic perceptions and agricultural practice over the past generation, a time of rapid density increase and intensification.

Introduction

'Sustainable development' involves both agronomic and ecological criteria. On the one hand, food (and other goods) production (per area, per labor-hour, per purchased input) must remain at adequate levels over the long term; on the other hand, biodiversity (in the soil, of the cultivars, in the field and surrounding habitat) must also not diminish over time. Though shifting cultivation may easily meet both criteria in a context of low population density and long fallows, they present a real challenge when density increases and fallows diminish. Shortened fallows have been shown to cause: a) increased cultivar pests and diseases; b) increased competition from hard-to-eradicate weeds (especially grassy sps.); and c) reduced soil fertility. 'Intensification' is the name given to the process of increasing production per area and time (increasing 'cropping intensity'). 'Sustainable intensification' signifies this process with the additional criteria of adequate returns to labor and minimal biological impoverishment over time.

The Tikuna

Two and a half centuries ago, European explorers found the Tikuna in small dispersed settlements in the unflooded upland rainforest ('terra firme') north and west of the Upper Solimoes, dominated by large and powerful chiefdoms who controlled the fertile floodplains. Between the mid-19th and mid-20th centuries, Euro-Brazilian rubber traders controlled their labor and movements through a system of violent coercion, intimidation, debt-peonage and rum. Since the 1950's, they have achieved a set of important gains: political and economic liberty as well as legal security to extensive areas of the floodplain (the largest indigenous floodplain reserves in Brazil). Over these decades, two trends have combined to cause rapid increase in local population density:

1.) migration down tributaries into larger communities; and 2.) overall demographic growth.

Their agriculture currently centers around bananas (*Musa* sps) and manioc (*Manihota esculenta*), with perhaps more than two dozen named varieties of each group. They also cultivate some maize and watermelon (especially in the floodplain), pineapples, several other tuber species, and grow peppers, onions and a number of herbs in dooryard gardens. Dozens of fruit tree species are utilized, some common in mini-plantations near the house, others in the fallows. Though beans were grown traditionally, these have fallen into disuse. They gain the vast bulk of their protein from the abundant fish.

There are a number of signs that the fallows nearest the residences have diminished to problematic lengths. Only bitter varieties of manioc and some bananas are grown in the nearest gardens. Tikuna told me that the soil was too tired there to grow anything else.

Though a range of diseases and pests were mentioned as being more widespread in near sites, the most obvious was the leaf-cutter ant's (*Atta* sps) presence and its damage, especially to manioc plants. Some five years ago, almost all orange trees grown around homes to support a small 'boom' were defoliated to death by these pests.

Proposed Research

My research includes three areas: agro-ecological measures; ethno-agronomic interviews; and observations of agricultural practices. Agro-ecological measures will focus on the sampling of soil, insects and 'volunteer' vegetation in sites of various fallow-lengths, at various distances from residences. Production estimates will be derived from household diaries, interviews, random scheduled observations of harvests and meals and weighing of harvests from sampled sub-plots. These measures will show how fallow-shortening affects the critical ecological challenges to production and production itself.

Ethno-agronomic interviews will focus on: a) the classification and perceived attributes of relevant biota (both cultivars, volunteers and 'pests') and land-types (fallow, floodplains, soils, etc.); and b) the perceptions of agricultural and ecological trends (changes in productivity, work-effort, crop choices, land-uses, 'pests' and landscapes).

Finally, I will use 'time-allocation' techniques to measure work-effort in agriculture. These involve the random selection of both cultivators and time-intervals and the direct observation and timing of the various tasks, which are coded and tabulated. Over the course of these observations, I will also note any special techniques (i.e., pest control, selective weeding, selective mulching or burning). These observations will allow a calculation (with production estimates) of returns-to-labor.

**PHENOLOGY AND POLLINATOR ABUNDANCES OF
THREE NEOTROPICAL FIGS: IMPLICATIONS FOR CONSERVATION**

Author: Cecelia (Ceal) Smith

Over 700 species of figs (*Ficus*; Moraceae) and their mutualistic pollinator wasps (Hymenoptera; *Agaonid*) are found in the tropics throughout the world. The mutualism requires that fig trees have a continuous, synchronous flowering phenology which has two important consequences for conservation. First, because figs flower continuously throughout the year, their fruit provides a reliable food source during times of the year when other food resources are low. The diet of many groups of frugivores birds, primates, and bats can be comprised of up to 90% figs during these times of the year. Because of their unusual phenology, figs are considered "keystone" resources in tropical ecosystems where they occur. Secondly, because of the intricate timing of fig pollination and wasp dispersal, the cycle is vulnerable to collapse when subject to a reduction in fig or fig wasp populations. Simulation studies suggest that the minimum critical population for the system is 100. Some figs are known to have a synchronous phenology at the individual tree level. *Ficus insipida*, *F. pertusa*, and *F. petiolaris* were studied for 18 months in two climatically different sites in Sonora, Mexico. All three figs were found to vary in the level of within tree flowering synchrony between the two sites. Pollinator abundances also varied in *F. insipida* and *F. petiolaris* in the two sites. Lower pollinator abundances may be correlated with a decrease in within tree flowering synchrony. A breakdown in flowering synchrony at the individual tree level may be an adaptation (or response) to lower fig, fig-wasp populations allowing the species to persist in small populations.

ILLEGAL GOLD-MINING IN THE BRAZILIAN AMAZON

Author: Pamela Stedman

Illegal gold-mining in the Brazilian Amazon, known as *garimpagem*, has begun to attract international attention because of its detrimental environmental impacts in the region. While the environmental problems caused by gold-mining are clear, the economic, social and political factors involved make simple solutions unlikely.

Illegal *garimpagem* produces over one half the gold exported from Brazil each year. The number of miners and mine sites in Amazonia increased dramatically in the 1980's because of the depressed economic situation in Brazil, high international gold prices, and the discovery of several rich sites. All of the gold mined in the Amazon is alluvial gold. Because this alluvial gold is generally found in very fine particles, almost all mining techniques employed in the region use mercury. Mercury forms an amalgam with gold and greatly facilitates its extraction. However, this mercury is released directly into the river system during the extraction process, and into the air when the amalgam is separated at a later stage. The potential for extensive mercury contamination in the region is very serious. Extraction methods range from simple panning to extensive dredging, all of which cause some degree of erosion, in addition to mercury problems.

Although the attraction of gold-mining is often thought to be the freedom it allows, and the chance to strike it rich, the economic and social structures in the Brazilian Amazon are, in fact, very hierarchical. Most miners are also small farmers or farm laborers who come to the *garimpos* during the agricultural off-season. Miners generally work in teams of five to ten, either at on-shore sites or on river boats or rafts. The *dono*, who finances the mining operation (transport, equipment, etc.), pays the workers between ten and twenty percent of the take. Gold is then sold in the towns to small merchants, who form the next rung in the commercialization ladder. It appears that a few individuals at the top of the system control these merchants and receive most of the profits.

Environmental problems, in addition to the mercury contamination and erosion, include encroachment on parks and indian reserves and increased deforestation and immigration in some areas. The gold-mining regions also suffer high levels of disease, particularly malaria, and violence. Nevertheless, the government has been reluctant to tackle these pressing problems. This reluctance probably stems from the important contribution gold sales make to foreign exchange earnings; the political power of those at the top of the gold-mining business; and the complicated nature of the social and economic factors driving gold-mining in Amazonia.

**A PROPOSAL FOR THE USE OF THE IDEAL FREE
DISTRIBUTION MODEL OF HABITAT SELECTION TO
DESCRIBE MIGRATION TO THE ECUADOREAN AMAZON**

Author: Keith Taulbee

Resumen

Following the discovery of oil in the Amazon basin of Ecuador in 1967, the region has experienced a period of ever-increasing migration. The opening of new roads has created an agricultural frontier that the Ecuadorean government is utilizing to decrease the growing urban populations of un- and under-employed. Inexperience with farming in a different environment, and a series of inefficient government policies, have only exacerbated the problem. It is estimated that 36% of the Ecuadorean Amazon has already been deforested, and the rate of deforestation is projected to continue to increase.

Abstract

Migration to the Ecuadorean Amazon has been increasing rapidly since the late 1960's. Consequently, the rate of deforestation in the region has also been rapidly increasing. One model which may be used to describe this migration pattern is the ideal free distribution model. This model predicts that the suitability of all habitats settled by a given population will remain relatively equal, as population density will show a strong correlation with resource abundance.

The ideal free distribution theory is a model of habitat selection that states that a population, given the choice of two habitats, will first settle the most suitable habitat, until population pressure lowers its suitability to that of the next most suitable habitat. At that point, additional individuals will settle within each habitat in such a way that the suitability of each habitat remains equal. This model has several limitations, in that it assumes homogeneity of a given habitat, as well as equal competitive ability of all individuals within a population. However, this model has been applied to several human populations with mixed results.

This study will compare the suitability of the Andean, the Amazonian habitats, through the creation of a suitability index. The index will be based on a combination of socioeconomic, medical, and ecological factors, and will attempt to determine whether or not these two habitats conform to the ideal free distribution model.

**DETERMINING THE NODULATION CAPACITY OF JAMAICAN SOILS
EXPERIENCING DIFFERENT LAND USE HISTORIES FOR
ACTINORHIZAL PLANTS AND NODULATED WOODY LEGUMES**

Author: Jeff Zimpfer

Abstract

As the pressures from ever increasing populations continue to take their toll on our natural resources throughout the world, more and more lands become degraded as a result of over-exploitation. One way to halt the continued degradation of these lands and restore their productivity is through reforestation. Some prior land uses that would benefit from reforestation include: eroded lands or other nutrient depleted sites, mine spoils, soils made saline by irrigation, and areas polluted by hazardous waste. Because many of these soils may be low in available nitrogen, actinorhizal plants and nodulated woody legumes, with their ability to fix atmospheric nitrogen, may play an important role in the recovery process by increasing the amount of available nitrogen in the soil.

Actinorhizal plants form root nodules in the presence of *Frankia*, a genus of actinomycete. From this symbiotic relationship, the plant receives nitrogen and the *Frankia* receive carbohydrates. There are 25 genera of actinorhizal plants in eight diverse dicotyledonous plant families. *Frankia* is normally found in the soil under nodulated host plants. In their native habitats, most actinorhizal plants are found to be nodulated. A site's nodulation capacity generally decreases proportionally with the amount of time an actinorhizal plant has been absent from a site. However, there have been reports of *Frankia* on sites lacking actinorhizal plants. Soil moisture and pH are thought to be the most important factors effecting *Frankia* in soil.

Nodulated woody legumes form symbiotic root nodules in the presence of the appropriate strain of *Rhizobium*. This symbiotic relationship is similar to that of *Frankia* and its' host plant. *Rhizobium*, which have the ability to live saprophytically in the soil, invade the root hairs of the host plant. There are several factors that have been shown to effect the formation of root nodules in legumes: temperature, water relations, pH, and the presence of suitable rhizobia.

Soil samples were collected from seven sites in Jamaica: a bauxite mine that had been reclaimed for one year, a bauxite mine that had been reclaimed for 25 years, a primary montaine forest, an area that had been planted in coffee and vegetables for the last 200 years, an area that had experienced slash and burn agriculture for 30 years, a field that had been under sugar cane production for 300 years and abandoned for 25, and an

adjacent field that had experienced the same land use and abandoned for one year. Three samples were collected at each site.

A bioassay of diluted soil samples was used to determine the effect of *Frankia* and *Rhizobium* units in the soil. Test plants for the study were *Myrica cerifera*, an actinorhizal plant indigenous to the island and an upper elevation species, *Casuarina cunninghamiana* an exotic lower elevation actinorhizal plant commonly planted in Jamaica, and *Leuceana leucocephala*, a lower elevation nodulated woody legume commonly found in Jamaica. The test were grown in 4 x 14 cm plastic tubes filled with 1:1:1 of fine vermiculite, mixed sand, and fine gravel which had been autoclaved. The seedlings were grown in a glass house isolation room at 23°C. The plants were watered every day with a complete one eighth strength nutrient solution. Ten days before inoculation with soil, nitrogen was removed from the nutrient solution. Three month old seedlings were inoculated with soil solutions, the most concentrated solution being 30 cm³ to 300 ml of sterile deionized water (sdw). From this solution 3, 10 fold dilutions were made for inoculating the test plants. Three test plants per species were inoculated with one dilution level for each of the 21 soil samples. Control plants were inoculated with sdw. Eleven weeks after inoculation, the test plants were harvested and the nodules per tube were counted to determine the number of infective units of *Frankia* and *Rhizobium* in an individual soil sample.

Initial results indicated that the *Myrica cerifera* nodulated with the soil from the bauxite mine that had been reclaimed for 25 years, the primary forest soil, and the site immediately below it, and the area of slash-and-burn agriculture, all upper elevation soils. The *Leuceana leucocephala* nodulated only with the 25 year old abandoned sugar cane soil - a lower elevation soil, and the *Casuarina cunninghamiana* with none of the soils. One of the control plants appeared to be nodulated. This basically supports my original hypothesis that the soils from the area of the Island where the plant is found, and was the least disturbed, would have the most infective units of *Frankia* and *Rhizobium*. Possibly, the *Casuarina* did not nodulate because it is exotic and the appropriate strain of *Frankia* was not present.

List of Post Course Research Papers

Title of Paper	Student
A Preliminary Survey of Forest Birds and Their Relative Abundances in the Proposed Coto Brus Biological Corridor	Norm Bourg
Survey of Physical Soil Heterogeneity at Finca Fea, San Vito, Costa Rica	Lucy Buchan
Water Quality Analysis of the Rio Sucio	Laura Howard
Use of Corridors by Fruit Eating Butterflies	Ellen Pedersen

A PRELIMINARY SURVEY OF FOREST BIRDS AND THEIR RELATIVE ABUNDANCES IN THE PROPOSED COTO BRUS BIOLOGICAL CORRIDOR

Author: Norm Bourg

Abstract

A survey of forest birds was conducted over a 12-day period to provide baseline information to the Las Cruces Biological Station (LCBS) for use in the planning and evaluation of the proposed Coto Brus Biological Corridor. Birds were surveyed using fixed- and unlimited-radius point counts in the LCBS and three forest fragments in the vicinity of the Gamboa Marsh. Three-way contingency table analysis found no significant difference in the overall species composition of the forest bird communities in these areas; however, single-species analyses yielded six species that differed significantly in their relative abundances between forest patches. Sample sizes and area surveyed were both probably too small to make reliable conclusions from the data. Recommendations for future studies are noted.

Introduction

The proposed Coto Brus Biological Corridor in southern Puntarenas Province, Costa Rica would connect the Organization for Tropical Studies' (OTS) 300 hectare Las Cruces Biological Station (LCBS) with the nearly 30,000 ha Guaymí Indigenous Reserve. The natural vegetation in this area is mid-elevation (1,000 m - 1,700 m) tropical premontane evergreen forest (Hartshorn, 1983). Both the LCBS and the Reserve consist of primary forest. The nearly 12 kilometer corridor consists of a mixture of degraded pasture and small forest fragments from 1 ha to 50 ha in size. Most of the deforestation has occurred within the last 30 years (Carroll, 1993).

The Corridor Project intends to examine questions of ecologically optimal corridor design and acceptable compromises to this design given that small farmers in the corridor would still need to make a living from their land. As a first step in this process, Carroll (1993) has advocated the inventory of well-known taxonomic groups (e.g., birds, mammals, butterflies, and parasitic Hymenoptera) in the remnant forest patches to assess biodiversity within the corridor and the larger core forest blocks. Staff of the LCBS have also expressed their support and desire to obtain baseline data on these groups in relation to the corridor (Gomez, 1993, pers. comm.; Rosemeyer, 1993, pers. comm.). This study was designed to provide an initial survey of forest bird diversity in the proposed corridor and to test the following hypothesis:

H1: Forest bird community composition and relative abundances of species will differ significantly between forest patches.

Study Sites

Three forest fragments within the potential corridor and the LCBS forest were surveyed. The large patch (L1) was approximately 10 hectares in size and the other two small patches (S1 and S2) were each 1 hectare. A freshwater marsh and cattle pasture separated the large patch from the two small patches by a distance of about 0.5 km. The two small patches were separated from each other by almost 100 meters of cattle pasture and a dirt farm track. All of the fragments were around 2 km from the western boundary of the LCBS' 200 hectare primary forest (LCBS). Elevation ranged from 1,000 - 1,200 m at the LCBS forest to 1,450 m at the forest fragments. Insufficient time prevented the survey of any of the Guaymi Indigenous Reserve as originally intended.

Methods

Birds were surveyed using the fixed-radius point count technique (Hutto et al., 1986). Sampling points were placed at 100 m intervals along a compass bearing in each patch. Where this was not possible, as was the case in the two small patches, points were located as far apart as feasible without coming too close to the edge of the patch. This was done to minimize or eliminate the chance of overlapping individual sampling areas. Two types of data were recorded at each point based on visual and/or aural identifications: 1) the number of individuals of each species detected within a 20 m fixed-radius around the observer; and 2) the presence of each species detected beyond the fixed-radius (unlimited-radius).

Count duration at each point was 10 minutes. Two points were surveyed in each small patch and four points were surveyed in the large patch and in the LCBS forest. Counts were conducted from 0630 - 1130 hours on four mornings in the LCBS forest and patch L1, five mornings in patch S1, and three mornings in patch S2 for a total of 48 point counts over a 12-day period.

Results

A total of 48 bird species were recorded at the count points during the survey period (Appendix A). I chose to perform statistical analyses only on the unlimited-radius (presence/absence) data for two reasons: 1) repeated counts at the survey points may have inflated the number of individuals of a species recorded within the 20 m radius and, therefore, made the validity of this data questionable; and 2) Hutto et al. (1986) have shown that analytical results based on presence/absence information are virtually identical to those using actual numbers detected. Two species, least grebe (*Tachybaptus dominicus*) and purple gallinule (*Porphyryla martinica*) were not included in the analysis because they only occurred in the freshwater marsh adjacent to the forest patches.

The unlimited radius presence/absence data was examined using the log-linear model for analyzing three-way contingency tables (site by species by presence/absence)

(Sokal and Rohlf, 1981). This method involves the iterative calculation of expected frequencies from the observed frequencies and use of the G-statistic to test for an effect of site on the association between species and their abundances. This test showed that there was no significant difference in the degree of association between abundance and species for the different sites (e.g., a three-way interaction was not present, $G = 112.25$ ns, $df = 141$, $P > 0.05$).

Tests for conditional independence (two-factor interactions) yielded the following results:

Independence of species and abundance category (presence/absence) for a given forest patch: $G = 189.16$ ns, $df = 188$, $P > 0.05$.

Independence of species and forest patch for a given abundance category: $G = 6,737.69^{****}$, $df = 282$, $P < 0.0005$.

Independence of abundance category and forest patch for a given species: $G = 6,751.92^{****}$, $df = 144$, $P < 0.0005$.

Therefore, within a given forest patch, species and their relative abundances were independent. Both species and their relative abundances, however, were highly dependent on forest patch for a given abundance category or species (e.g., certain species were present in, or absent from, certain patches).

To determine which species' frequencies of occurrence differed significantly among the forest patches, single-species analyses were performed using Model II R x C contingency tests (Sokal and Rohlf, 1981). Six cases of significance resulted from these tests (Table 1).

Table 1. Single-species Model II R x C Contingency Tests for Differences in Bird Abundances Between Forest Patches Using Unlimited-radius Frequency Data.

Species	Common Name	G Value (with Williams' correction), $df = 3$	Probability Level
<i>Amazona autumnalis</i>	Red-lored Parrot	12.704	$P < 0.01$
<i>Formicarius analis</i>	Black-faced Antthrush	11.569	$P < 0.01$
<i>Corapipo leucorrhoa</i>	White-ruffed Manakin	8.112	$P < 0.05$
<i>Myadestes melanops</i>	Black-faced Solitaire	9.289	$P < 0.05$
<i>Chlorospingus ophthalmicus</i>	Common Bush-Tanager	7.828	$P < 0.05$
<i>Tangara icterocephala</i>	Silver-throated Tanager	11.002	$P < 0.025$

Discussion

The statistical results showed that while no significant difference in overall species composition of the bird communities in the study patches was detected, certain species and their relative abundances were patch-dependent. Only two of the above species were recorded in the LCBS forest (*Formicarius analis* and *Amazona autumnalis*), and *F. analis* was found solely at this site. Additionally, *Myadestes melanops* was recorded only in the larger 10-hectare forest fragment. *F. analis* may be approaching its upper altitudinal range limit (Stiles et al., 1989) at the corridor forest patches, although some species of antbirds may be vulnerable to fragmentation (Harper, pers. comm., cited in Simberloff and Cox, 1987). The fact that *A. autumnalis* was tallied only once from the LCBS, yet recorded frequently from the corridor fragments, supports the statement by Stiles et al. (1989) that this species is common in partially deforested areas. *M. melanops*, commonly called the jilguero and declining in Costa Rica because of its beautiful song and value as a cage bird (Stiles et al., 1989), is listed by Stiles (1991) as being largely or entirely eliminated from the LCBS in recent years.

Although this survey did detect some significant differences in bird communities between the sampled patches, the drawing of conclusions regarding the occurrences or abundances of any of the species should be done with caution due to insufficient sample sizes and incomplete coverage of the forest habitats. A 25 - 30 point count minimum has been recommended in several other studies for obtaining a reasonable estimate (72 - 86%) of the total species eventually recorded at a site (Reynolds et al., 1980; Blondel et al., 1981; Hutto et al., 1986). This sample size was not achieved in any of the forest patches (Table 1). Also, a comparison with a large tract of undisturbed forest was unable to be made since the Guaymi Indigenous Reserve was not surveyed. The results provide the first information on the forest bird community in the corridor, however, and a baseline for comparison with future studies.

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Appendix A

Bird Species Recorded at Count Points During the Survey Period and Their
Frequencies of Occurrence Using Unlimited-radius Data.

Species	LCBS (n=16)	L1 (n=16)	S1 (n=10)	S2 (n=6)
<i>Tachybaptus dominicus</i>	0.00	0.00	0.00	0.50
<i>Micrastur semitorquatus</i>	0.00	0.0625	0.00	0.00
<i>Penelope purpurascens</i>	0.00	0.0625	0.00	0.00
<i>Porphyryla martinica</i>	0.00	0.00	0.00	0.1667
<i>Columba speciosa</i>	0.00	0.1875	0.01	0.00
<i>Leptotila cassinii</i>	0.125	0.00	0.00	0.00
<i>Pionus menstruus</i>	0.00	0.0625	0.00	0.00
<i>Amazona autumnalis</i>	0.0625	0.625	0.200	0.667
<i>Phaethornis guy</i>	0.125	0.00	0.200	0.00
<i>Phaethornis longuemareus</i>	0.0625	0.00	0.00	0.00
<i>Eupherusa eximia</i>	0.00	0.0625	0.00	0.00
<i>Elvira chionura</i>	0.125	0.00	0.00	0.00
<i>Lampornis (castaneoventris) cinereicauda</i>	0.00	0.1875	0.00	0.00
<i>Trogon collaris</i>	0.00	0.1875	0.00	0.00
<i>Momotus momota</i>	0.0625	0.00	0.00	0.1667
<i>Aulacorhynchus prasinus</i>	0.00	0.00	0.100	0.00
<i>Pteroglossus frantzii</i>	0.00	0.0625	0.00	0.00
<i>Piculus rubiginosus</i>	0.0625	0.00	0.00	0.00
<i>Dendrocincla anabatina</i>	0.125	0.00	0.00	0.00
<i>Dendrocincla homochroa</i>	0.0625	0.00	0.00	0.00
<i>Sittasomus griseicapillus</i>	0.00	0.00	0.100	0.00
<i>Xiphocolaptes promeropirhynchus</i>	0.00	0.00	0.00	0.1667
<i>Synallaxis albescens</i>	0.00	0.0625	0.00	0.1667
<i>Synallaxis brachyura</i>	0.00	0.00	0.100	0.00

Appendix A continued

Bird Species Recorded at Count Points During the Survey Period and Their
Frequencies of Occurrence Using Unlimited-radius Data.

Species	LCBS (n=16)	L1 (n=16)	S1 (n=10)	S2 (n=6)
<i>Cranioleuca erythropis</i>	0.00	0.00	0.00	0.1667
<i>Premnoplex brunescens</i>	0.00	0.0625	0.00	0.00
<i>Automolus ochrolaemus</i>	0.00	0.00	0.200	0.00
<i>Automolus rubiginosus</i>	0.0625	0.00	0.00	0.00
<i>Dysithamnus mentalis</i>	0.0625	0.00	0.00	0.00
<i>Myrmotherula schisticolor</i>	0.0625	0.00	0.00	0.00
<i>Gymnopithys leucaspis</i>	0.0625	0.00	0.00	0.00
<i>Formicarius analis</i>	0.500	0.00	0.00	0.00
<i>Tityra semifasciata</i>	0.0625	0.00	0.00	0.00
<i>Corapipo leucorrhoa</i>	0.00	0.0625	0.300	0.500
<i>Henicorhina leucosticta</i>	0.0625	0.250	0.00	0.00
<i>Turdus plebejus</i>	0.125	0.00	0.100	0.00
<i>Myadestes melanops</i>	0.00	0.500	0.00	0.00
<i>Catharus aurantirostris</i>	0.125	0.00	0.00	0.00
<i>Geothlypis aequinoctialis</i>	0.00	0.0625	0.00	0.1667
<i>Myioborus miniatus</i>	0.0625	0.125	0.500	0.00
<i>Psarocolius wagleri</i>	0.0625	0.00	0.00	0.00
<i>Chlorophonia callophrys</i>	0.00	0.00	0.100	0.00
<i>Tangara icterocephala</i>	0.00	0.375	0.400	0.667
<i>Tangara gyrola</i>	0.0625	0.0625	0.00	0.00
<i>Thraupis episcopus</i>	0.00	0.0625	0.00	0.00
<i>Piranga flava</i>	0.00	0.00	0.00	0.1667
<i>Eucometis penicillata</i>	0.1875	0.00	0.00	0.00
<i>Chlorospingus ophthalmicus</i>	0.00	0.375	0.400	0.333
<i>Saltator maximus</i>	0.00	0.0625	0.100	0.00
<i>Atlapetes brunneinucha</i>	0.00	0.0625	0.00	0.00

SURVEY OF PHYSICAL SOIL HETEROGENEITY AT FINCA FEA, SAN VITO, COSTA RICA

Author: Lucy Buchan

Introduction

The objectives of this post course project were severalfold: to explore the potential of several sites for dissertation fieldwork; to discuss potential dissertation research questions with key resource people located in the San Vito region; and to collect data on the land-use history, weed diversity, and heterogeneity of soil structure at Finca Fea, the site owned and managed by Dr. Lynn Carpenter. The project particularly focused on this site due to confluence between personal research goals and those of Dr. Carpenter. Prior to her acquisition of the site, the land was used to graze cattle. In the broadest sense, her research is to rehabilitate the degraded land using native plant species. Treatments include planting individual species, combinations of species combinations and natural succession.

Due to unanticipated impediments, the full scope of this project was not attained. Heavy and frequent precipitation, and difficulty in attaining timely transportation, limited the number of hours in the field. Furthermore, the former manager of the site, who was to divulge the land-use history, was not available during my site visit. Therefore, the quantitative scope of the project was narrowed to acquiring data on heterogeneity of soil structure.

Since the first and second objectives involved informal data gathering of a relatively personal nature, they do not lend themselves to in-depth discussion in this report. The focus of this paper is to report my findings from Finca Fea in a format that will be most useful to Dr. Carpenter. Based on discussions between she and I prior to my departure from Costa Rica, I am including the primary data as attachments, and refraining from discussing them in the terminology used for documentation. The data are recorded according to the United States Department of Agriculture (USDA) soil taxonomy system, which is widely used by the soil science community. In order to facilitate communication in this setting, the terminology will be generalized and the data will be discussed in summary format. To facilitate interpretation of the primary data, copies of documents describing the terminology used are attached. A copy of the site plan is also included for reference purposes.

Physical, chemical, and biological aspects of soils are important determinants of vegetation associations and ecological processes. They are also key factors influencing profit of income earning activities that utilize a natural resource base. Often, however, soil characteristics are not included in land-use decisions, either due to lack of site-

specific knowledge, or more generally, lack of knowledge about their influences on other biological processes. The latter is most often an artifact of poor communication because a rich body of knowledge about soil characteristics exists due to experimentation and observation by both agriculturalists and institutional scientists.

While modes of experimentation and communication are terribly important and compelling topics, they were not the immediate focus of this project. Rather, the goal was to address the former issue - lack of site specific data - by gathering data on soil structure at Finca Fea. Developing an understanding of the spatial patterns of soil heterogeneity is the key to the main research goal at Finca Fea because, in large part, vegetation growth depends on soil fertility and structure. It will be important for researchers there to pay attention to the effects of vegetation treatments on soils because correlation between vegetation treatments and improvement in soil fertility and structure may be a selling point for application of the research in the local agricultural community. Hopefully, the scientific mode of experimentation undertaken at Finca Fea will both contribute to the published wealth of knowledge about soils and their role in ecological processes, and enrich the perspectives of local agriculturalists.

Introduction to Soils

According to the Costa Rican Soil Survey (that also uses the USDA classification system), the soils at Finca Fea are characterized as Ultisols. Ultisols are generally characterized as having a relatively low percentage of base saturation (<35%) and a relatively high percentage of clay content that increases with depth in the soil profile. Ultisols are typically formed in udic moisture regimes - conditions under which mean annual soil temperature is 8°C or warmer and soils are not dry for as long as 90 cumulative days. Temperatures of this magnitude, accompanied by relatively high levels of precipitation for prolonged periods of time, result in extensive leaching of materials from the soils. The outcome is fairly rapid and complete alteration of weatherable minerals into a stable suite of secondary clays (kaolinites and hydroxy interlayered vermiculites (HIV)) and iron oxides that accumulate in the subsoil horizons.

The surficial horizons (A and E) usually exhibit relatively light colors (ochric epipedon) reflecting the tendency for mineralization to occur rapidly. In less stable landscapes, some organic matter may be incorporated into the surficial horizons (through the process of melanization), creating a darker epipedon (umbric). Typically, aluminum, iron and organic matter are leached through the profile and result in a marked zone of depletion designated as the E horizon. However, in Ultisols, the ratio of free iron oxides to clay minerals is similar between the E and B horizons, making this distinction between horizons difficult.

The subsoil B horizons are characterized by argillic horizons - zones where clay typically accumulates in thin skins on the outside of organic and silica particles. Two mechanisms may explain the characteristic appearance of clay accumulation in the subsoil

horizons. In one scenario, clay particles migrate downward (eluviate) through the profile. There is also significant evidence for in-situ formation of clays through weathering. Also characteristic of Ultisols are reticulate patterns of bright red mottles, sometimes forming indurated layers of highly oxidized clays (plinthites). Induration typically occurs at or near the water table, and is driven by the seasonal fluctuations in the water level. Upon repeated wetting and drying, some of the mottles harden irreversibly. Once formed, plinthites act to restrict water movement through the profile. A third characteristic common to Ultisols is the formation of another water-restricting complex, fragipan. Fragipans are reduced mineral associations, characteristically occurring as gray mottles within a reticulate plinthite zone. They typically create a perched water table. Their presence is frequently noted in Ultisols, but their genesis remains undefined.

Methods

Soils were characterized to depths of approximately 50 cm at the center-points of parcels in blocks 2 and 3. The pits had been previously established by other researchers for the purpose of collecting samples for chemical analysis. The pits are meant to serve as sites for long-term monitoring of soil pedogenesis. A total of 17 parcels were described. Field conditions were relatively similar each day: sunny to cloudy, intermittent light rain in the morning, followed by relatively heavy rainfall in the afternoon and evening. The net impact was to create soil moisture conditions slightly more saturated than field capacity. Soils were never sampled during heavy rainfall or immediately afterwards to avoid problems associated with describing saturated soils. Soil pits were cleared of contamination resulting from erosion prior to classification. All pits were sampled on the side facing the slope, except for 3S, because the wall of the pit was too thin. In this case, sampling occurred on the East side of the pit.

For each sample point, metadata about the position of the point itself was collected: aspect, slope percent and position (both at the site level and the micro-position of each point on the slope). Soils were characterized by depth, horizon, boundary distinction and topography, color (including mottles), texture, moisture and consistence, physical ped structure (size, abundance and shape), and some additional descriptive notes as well.

Results

The attached sheets contain descriptions of soil structure. The following table describes the slope, aspect, and landscape position of each pit sampled.

Parcel #	Aspect (Degrees)	Slope (%) Micro	Macro	Landscape Position
9S	340NW	60	85	Backslope of noseslope
8S	348NW	75	75	Backslope of interfluve
7S	36NE	3	50	Backslope of interfluve
6S	356NW	85	85	Backslope of noseslope
5S	346NW	75	15	Backslope of headslope
4S	341NW	35	7	Backslope of interfluve
3S	344NW	755	10	Backslope of headslope
2S	280NW	37	9	Backslope of headslope
1S	240NW	50	7	Backslope of headslope
F1	318NW	2	2	Toeslope of noseslope
F2	350NW	22	22	Shoulderslope of noseslope
F3	54NE	25	25	Backslope of headslope
F4	250NW	20	20	Footslope of alluvial
F5	No Data			
F6	342NW	18	18	Toeslope of alluvial
F7	330NW	10	10	Toeslope of one
F8	62NE	17	17	Footslope of alluvial
F9	64NE	50	10	Backslope of alluvial

Discussion

Limitations to Analysis

Soil profiles were only examined to a depth of approximately 50 cm for two reasons. First, sampling equipment required to reach depths much beyond 50 cm was not available. Second, the procedure for soil profile descriptions followed the sampling design established for collection of samples for chemical analysis, which was to sample soils in pits at a depth of 10 cm and thereafter 20 cm to a depth of 50 cm.

At this point in time, it is difficult to confidently analyze the data for the following reasons. Four weeks prior to data collection, cattle were grazing on the site, thus it was in a highly disturbed state. Since the USDA soil taxonomy system is geared toward analyzing soils subject to natural processes, analyzing the baseline data collected on the

soil profile is difficult because the effects of grazing and trampling greatly alter what one expects from natural processes. For example, one expects topography at both a macro (landscape) and micro scale (within a square meter) to effect the depth of the horizons, the amount of organic matter present, and the extent of mineral and particle movement due to infiltration of moisture. Typically, soil profiles on summits or shoulders of ridges will exhibit less-developed surficial horizons and correspondingly less incorporation of organic matter due to the impact of erosive processes. Moving downslope, particularly from interfluvies into alluvial valleys, one expects to find deeper surficial horizons with higher amounts of organic matter due to accumulation of materials from erosive processes. At the landscape level this set of processes is still relatively visible, however, the impact of cattle-related activities on a micro-scale is so strong that it makes comparison of data between pits located in comparable spatial positions difficult. Despite similar location on a landscape, the effect of grazing and trampling at a particular site may create a relatively deep A horizon. In this case, the data recorded reflects a disturbance effect rather than a landscape process. Therefore, at this initial stage, data must be compared with a relatively broad paintbrush approach. The baseline data established by this project will become more valuable with time. Once data has been collected at the same location for several years, it will be possible to compare changes in soil properties with the various vegetation treatments applied to the parcels.

General Trends Interpreted from the Data

Comparing depth of A horizons to position on landscape reveals a general trend that one would expect: the A horizons tend to be deeper at the lower positions of the landscape, most noticeably in the alluvial valleys. As is typically the case in Ultisols, detection of an E horizon was difficult due to similar ratios of iron oxides between the E and B horizons. In addition to change in color, change in texture is usually another key factor distinguishing E horizons from A and B horizons. However, presence of HIVclays interfered with the ability to texture soils using manual methods. The likely result was an overestimation of clay and underestimation of sand content, masking the presence of an E horizon. In some cases, this zone of eluviation was noted as a gradual transition between an A and B horizon (denoted as AB), in other cases this zone was noted as a proper E horizon, and in yet other cases where no clear evidence arose to demarcate a separate zone between A and B, no such delineation was made. Despite the difficulty in detecting texture, there was a general trend for clay content to increase with depth in the profile. With this caveat in mind, the relative proportional changes in texture appeared to trend from silty clay loams in the A horizon to silty clays in the upper portions of the B horizons, to clays in the lower B horizons.

The surficial horizons tended to exhibit colors characteristic of umbric rather than ochric epipedons, meaning that color was darker due to higher content of organic matter than typically expected in Ultisols. As a result, one may similarly expect a higher percent base saturation. As also expected, virtually every profile sampled exhibited clay and alluvial accumulation of sesquioxides in the B horizons. Many profiles contained

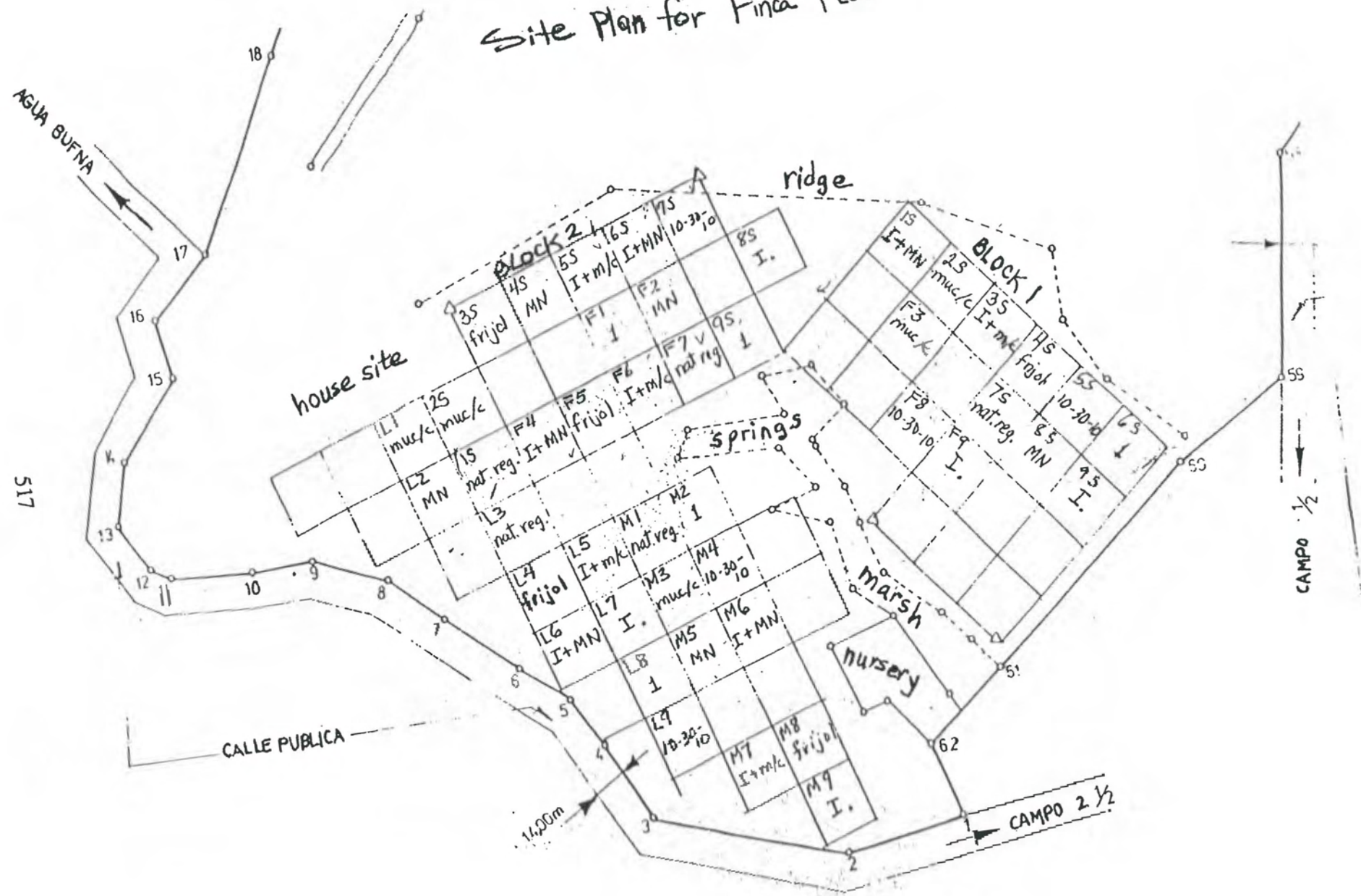
evidence of extensive mottling, an indication of oxidation and reduction of particles containing iron. Virtually every profile sampled contained evidence of either gravelly/clay B horizons near the 50 cm depth, either to the point where the consistency of the soil was almost as hard as stone, or as clearly indurated masses of plinthite and fragipans. The latter were often interwoven as solid masses present throughout the width of the sampling pit. The size of the pits did not allow for assessment of their full areal extent. However, observations in other areas of the site where erosive processes had created bare escarpments revealed several examples of plinthite/fragipan masses, at least a meter in length.

Observation of ped size, shape, and strength, as well as well-distributed presence of roots and pores throughout the depth of the solum sampled left an impression that soils were relatively uncompacted. Since each pit has been sampled by other researchers for compaction, it may be instructive to compare their results with the visual observations of ped size and grade from this research. Once these other soil samples have been chemically analyzed, the data collected for this project will be useful for comparative purposes.

Conclusions

The data collected as part of this project establishes a modest baseline which can be greatly expanded upon. Seventeen parcels were sampled at their centerpoints, however, in the future, the four additional pits located at the corner of each parcel could be examined, as well as the remainder of the parcels. Given more time for observation of change in physical and chemical soil properties, comparison of this baseline data will become increasingly useful. By examining physical and chemical properties of soil, the relationship between soil and vegetation treatments should become more apparent, and provide useful information to those attempting to rehabilitate cattle-degraded lands in the region - agriculturalists, consultants, and institutional scientists alike.

Site Plan for Finca Fea



DEPTH

Measure from:

- 1a) the top of the mineral soil if the O horizon is <40 cm thick or
- 1b) the top of the O horizon if it is >40 cm thick.

Measure to:

the center of boundaries separating horizons.

Measure to the nearest cm.

BOUNDARY

Distinctness - the thickness of the transition between two horizons.

- A - Abrupt: <2 cm
- C - Clear: 2-5 cm
- G - Gradual: 5-15 cm
- D - Diffuse: >15 cm

Topography

S - Smooth

W - Wavy
(Depressions are wider than deep)

I - Irregular
(longues are deeper than wide)

B - Broken
(horizon is discontinuous)

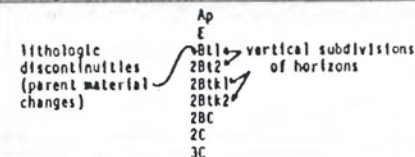


THE NEW SYSTEM OF DESIGNATIONS FOR SOIL HORIZONS AND LAYERS*

Master Horizons	Subordinate Distinctions of Master Horizons	
	Used with only one master horizon	Used with two or more master horizons
O - organic material	a - highly decomposed (sapric) e - intermediate decomposition (hemic) l - slightly decomposed (fibric)	b - buried genetic horizon (buried) c - hard concentrations or nodules (concentrations) f - frozen soil containing ice (frozen) g - strong gleying (gray colors) k - CaCO ₃ , MgCO ₃ accumulation (Ger. kalk, lime) m - cementation or induration (massive) n - exchangeable sodium accumulation (Na ⁺) o - residual sesquioxide accumulation (oxic) q - silica accumulation (quartz) v - plinthite x - fregipan character y - CaSO ₄ accumulation (gypsum) z - accumulation of salts more soluble than gypsum (Ger. Salz, salt)
A - darkened by organic matter	p - disturbed surface (plowing)	
E - eluvial horizon, loss of clay		
B - illuvial clay color structure	h - illuvial organic matter (humus) s - illuvial sesquioxides and organic matter (sesquioxides) t - illuvial clay accumulation (texture; Ger. Ton, clay) w - development of color or structure (weak B)	
C - below major biologic activity	r - weathered or soft bedrock (rock), dense till, can be dug with spade	
R - hard bedrock	(R is always used without a small letter suffix)	

Transition Horizons		Use of the Prime
AB, BA, AC, EB, etc.	gradual, homogeneous transition horizons (more like letter listed first)	A - The prime is used to designate the lower of two Bt horizons with the same letter designations if the two horizons are separated by a different horizon. It follows the capital letter. Example: E', B't.
E/B, B/E, B/C, etc.	transition horizons with distinct, recognizable properties of 2 master horizons.	

Lithologic Discontinuities and Vertical Subdivisions



DEPTH	HORIZON	BOUNDARY
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Sample should be moist but not have a film of water on the surface.

Record dominant matrix color or crushed color and up to two mottle colors.

Record crushed colors for surface horizons which are dark enough to be Mottled epipedons.

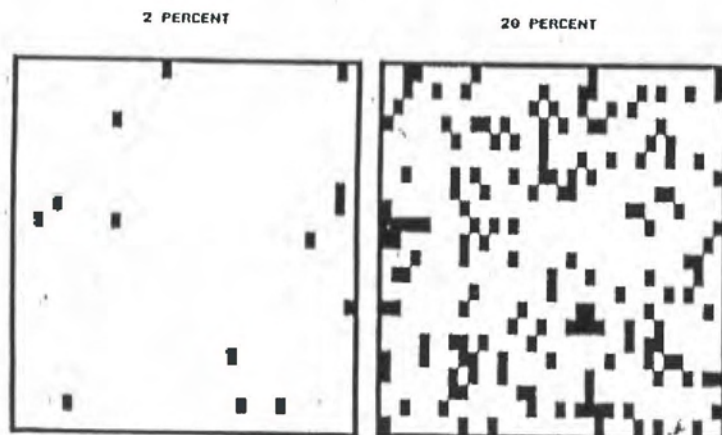
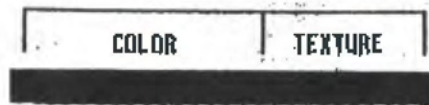
Abundance - percentage of the observed surface occupied.

Crushed color
 F - few: <2%
 C - Common: 2-20%
 M - Many: 20-40%
 V - Very Many: >40%

Size
 1 - Fine: <5 mm across
 2 - Medium: 5-15 mm across
 3 - Coarse: >15 mm across

Contrast - degree of visual distinction.

F - Faint: -hardly noticeable
 -colors differ by only one chip or less
D - Distinct: -readily seen
 -colors differ by 2 to 4 chips
P - Prominent: -most obvious color feature
 -colors differ by >4 chips, hues often contrast strongly.



<15% Rock Fragments by volume.

(none used)

15-35% Rock Fragments by volume.

G - Gravelly: 0.2-7.6 cm approx. equidimensional (up to about the size of an apple)

H - Channery: 0.2-15 cm long, flat (chanter) (up to about the size of your hand)

C - Cobbly: 7.6-25 cm approx. equidimensional (up to about the size of a large cantaloupe)

F - Flaggy: 15-30 cm long, flat (flagstone) (up to about the length of your forearm)

S - Stony: 25-60 cm approx. equidimensional or 30-60 cm long if long and flat (up to big enough to sit on)

B - Bouldery: >60 cm approx. equidimensional or long and flat (BFR)

35-60% Rock Fragments by Volume:

Use very (V) as modifier.
 Example: VG = very gravelly.

>60% Rock Fragments by Volume.

Use "extremely" (E) as modifier.
 Example: EG = extremely gravelly.

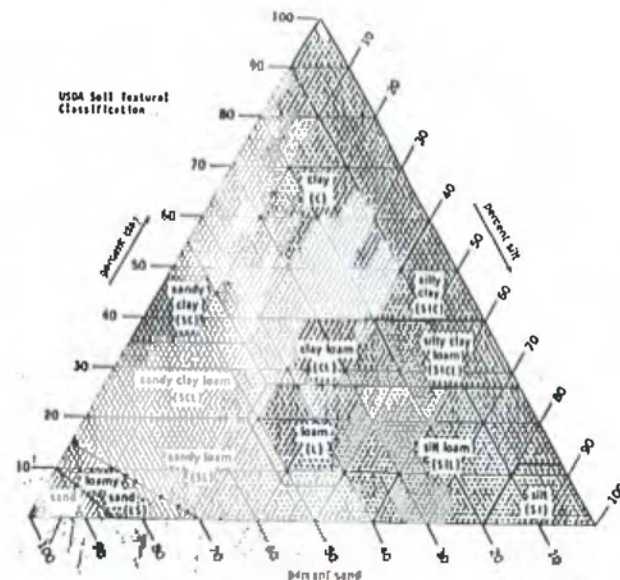
See textural triangle.

For sandy textural classes, include modifiers to indicate dominant sand size:

VCS - Very coarse sand 2.0-1.0 mm
 CS - Coarse sand 1.0-1.5 mm
 (none) - Medium sand 0.5-0.25 mm
 FS - Fine sand 0.25-0.10 mm
 VFS - Very fine sand 0.10-0.05 mm

Example: LVFS = loamy very fine sand,
 FSL = fine sandy loam.

Clay - your estimation



CONSISTENCE

Moisture - moisture content of the sample.

AD - Air-dry
FC - Field capacity
CD - cemented material, air-dry
CM - cemented material, wet or saturated (moist)

Consistence - soil strength.

	Consistence		Field method and condition of failure of specimen
Air-dry	Field capacity	Cemented material	
L-Loose	L-Loose		No specimen can be obtained.
S-Soft	YFR-Very friable		Specimen crushes or breaks when very slight force is applied by thumb and forefinger.
SH-Slightly hard	FR-Friable		Specimen crushes or breaks when slight force applied by thumb and forefinger.
SH-Slightly hard	FI-Firm	MC-Weakly cemented 1/	Specimen crushes or breaks when moderate force applied by thumb and forefinger.
H-Hard	VFI-Very firm	MC-Weakly cemented 1/	Specimen crushes or breaks when strong force applied by thumb and forefinger.
VH-Very hard	EFI-Extremely firm	MC-Weakly cemented 1/	Specimen cannot be crushed or broken by thumb and forefinger but can be by squeezing slowly between hands.
EH-Extremely hard	EH-Extremely hard	MC-Weakly cemented 1/	Specimen cannot be crushed or broken in hands but can be broken or crushed underfoot by person weighing 80 kg applying weight slowly.
		SC-Strongly cemented	Specimen cannot be crushed underfoot but can be crushed or broken by blow of 3 J. 2/
		I-Indurated	Specimen cannot be broken or crushed by blow of 3 J. 2/
	BR-Brittle		Moist specimen shatters instead of deforming when force is applied by thumb and forefinger.

1/ If applicable.

2/ A weight of 1 kg dropped a distance of 10 cm = 1 joule. A geologist's hammer weighing 1.36 kg dropped a distance of 0.22 m exerts an impact energy of 3 J.

STRUCTURE

Grade - distinctness of peds.

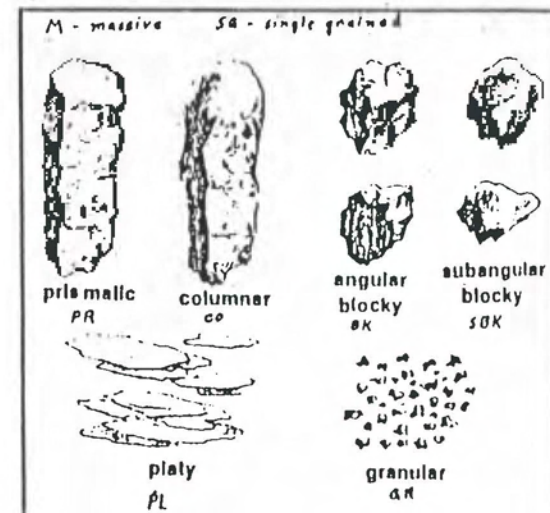
- 0 - Structureless: no observable structure.
- 1 - Weak: peds are barely observable in place. When gently disturbed, the material parts into a mixture of entire and broken peds and much material that has no ped faces.
- 2 - Moderate: peds are well-formed and evident in undisturbed soil. Disturbed material parts to a mixture of many entire peds, some broken peds and little material that is not in peds.
- 3 - Strong: peds are distinct in undisturbed soil. Disturbed material separates mainly into entire peds.

Size - size of peds.

Size classes vary according to the ped shape.

Ped Shape	Size Classes				
	VF-Very fine (VTN-Very thin)	F-Fine (TN-Thin)	M-Medium	C-Coarse (TH-Thick)	VC-Very Coarse (VTH-Very Thick)
	mm	mm	mm	mm	mm
Platy	<1	1-2	2-5	5-10	>10
Prismatic & Columnar	<10	10-20	20-50	50-100	>100
Blocky	<5	5-10	10-20	20-50	>50
Granular	<1	1-2	2-5	5-10	>10

Shape - shape of the peds.



PORES

Description of pores within peds.

Abundance

F - Few: <1 per unit area
C - Common: 1-5 per unit area
M - Many: >5 per unit area

Size

VF - Very fine: <0.5 mm in diameter (unit area = 1 cm²)
F - Fine: 0.5-2 mm in diameter (unit area = 1 cm²)
M - Medium: 2-5 mm in diameter (unit area = 100 cm²)
C - Coarse: >5 mm in diameter (unit area = 100 cm²)

Shape

V - Vesicular: approx. spherical or elliptical
T - Tubular: approx. cylindrical and elongated
I - Irregular: Irregularly shaped

ROOTS

Abundance

F - few: <1 per unit area
C - Common: 1-5 per unit area
M - Many: >5 per unit area

Size

VF - Very fine: <1 mm in diameter (unit area = 1 cm²)
F - Fine: 1-2 mm in diameter (unit area = 1 cm²)
M - Medium: 2-5 mm in diameter (unit area = 100 cm²)
C - Coarse: 5 mm in diameter (unit area = 100 cm²)

Location

I - Interior of peds
E - Exterior of peds
W - Will distributed throughout soil matrix

ADDITIONAL FEATURES

Abundance

F - Few <25
C - Common 2-200
M - Many 20-400
V - Very Many >400

Size

1 - Fine: <5 mm across
2 - Medium: 5-15 mm across
3 - Coarse: >15 mm across

Kind

Surface elements

CL - Clay skins
OM - Organic matter coats
SI - Silt coats
CA - Carbonate coats
MM - Manganese coats
SA - Sand Coats
SL - Silicified
ST - Stress surface
EB - clay bridges and grains

Interior features

CO - Concentrations
CR - Crystals
MO - Modules
SO - Soft accumulations
PS - Pseudo-rock fragments
PN - Plinthite
SK - Streaks
OC - Dry color
MO - Mottles

~~ME - Mn concentrations~~

Location

PI - Ped Interiors
PX - Ped exteriors

CH - Channels
GR - Grains
IH - Internal planes of peds
PE - Pores
PP - Peds and Pores
RO - Rock fragments

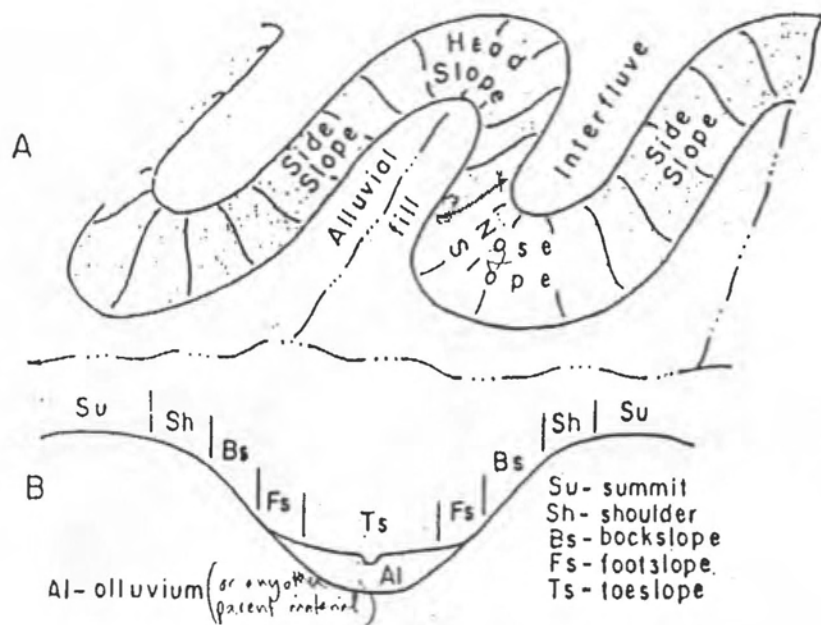
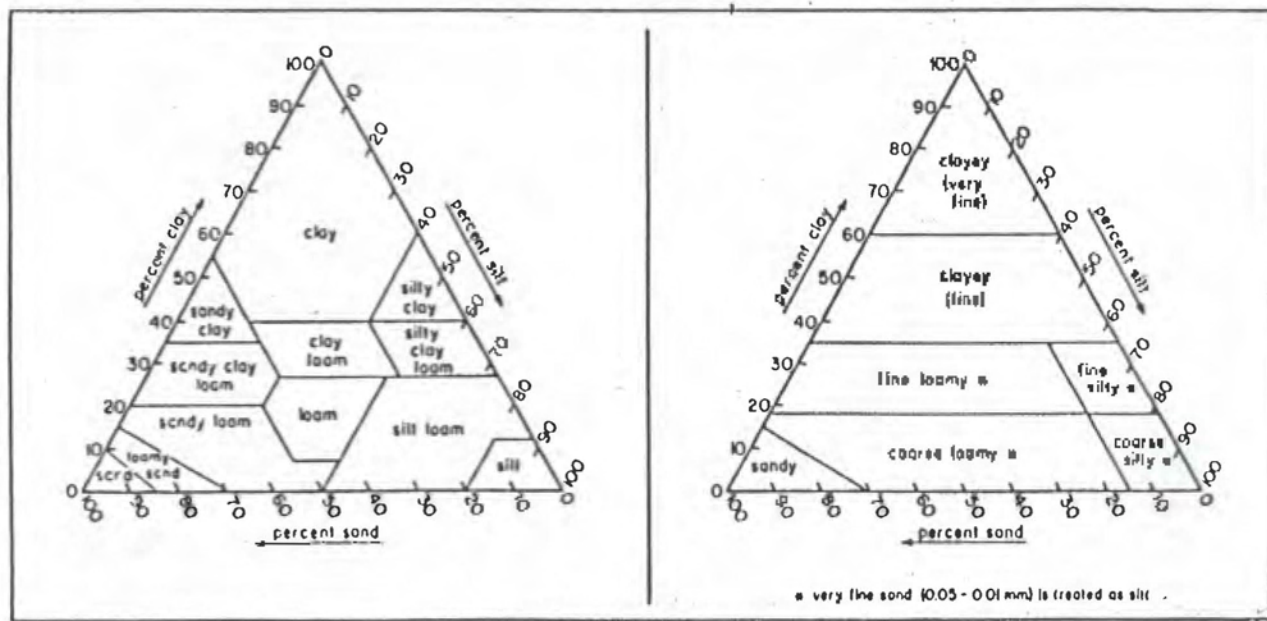
REACTION

pH - record pH in distilled H₂O.

Effervescence - reaction to 10% HCl

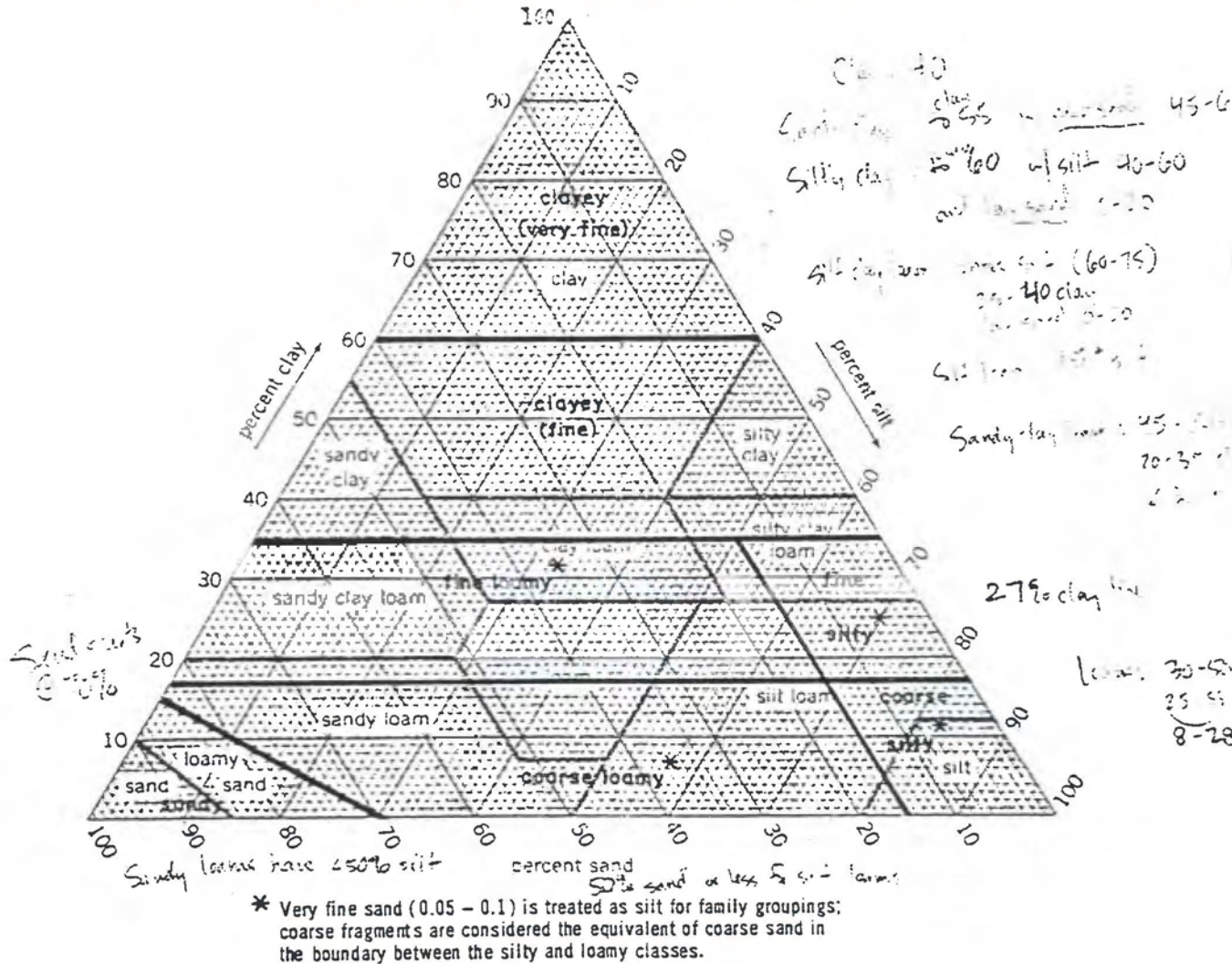
N - No effervescence
YS - Very slightly effervescent: few bubbles seen
SL - Slightly effervescent: bubbles readily seen
ST - Strongly effervescent: bubbles form low foam
VI - Violently effervescent: thick foam forms quickly

PORES	ROOTS	ADDITIONAL FEATURES	REACTION
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Chapter 6

GUIDE FOR TEXTURAL CLASSIFICATION IN SOIL FAMILIES



COMPARISON OF PARTICLE-SIZE SCALES

Sieve Openings in Inches						U. S. Standard Sieve Numbers							
3	2 1/2	1 3/4	1 1/2	3/4	3/8	4	10	20	40	60	200		
USDA	GRAVEL					SAND					SILT	CLAY	
						Very Coarse	Coarse	Medium	Fine	Very fine			
UNIFIED	GRAVEL		SAND					SILT OR CLAY					
	Coarse	Fine	Coarse	Medium	Fine								
AASHO	GRAVEL OR STONE					SAND					SILT - CLAY		
	Coarse	Medium	Fine	Coarse	Fine	Coarse	Fine	Silt	Clay				
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ANGULAR AND SUBANGULAR BLOCKY STRUCTURES

Very Fine
(less than 5 mm. diameter)



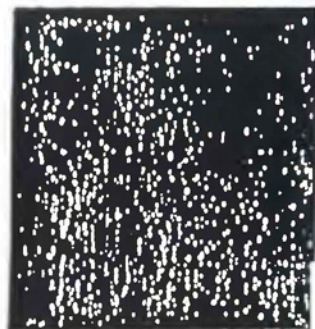
Fine
(5-10 mm. diameter)



Medium
(10-20 mm. diameter)



Coarse
(20-50 mm. diameter)



GRANULAR AND CRUMB STRUCTURES

Very Fine
(less than 1 mm. diameter)



Fine
(1-2 mm. diameter)



Medium
(2-5 mm. diameter)



Coarse
(5-10 mm. diameter)



Very Coarse
(more than 10 mm. diameter)



WATER QUALITY ANALYSIS OF THE RIO SUCIO

Author: Laura Howard

Abstract

The use of agrochemicals on Costa Rican banana plantations has been blamed for the environmental degradation of nearby ecosystems. The goal of this study was to determine whether the banana plantations along the Rio Sucio were influencing the water chemistry of the river. The river was sampled every kilometer for 26 kilometers and samples were collected from the plantation canals and factories. Water quality analysis was performed using the LaMotte kit. All water quality parameters increased from above to below the plantations. Dramatic increases in Rio Sucio samples occurred at the zone of influence of the banana plantations. Increasing water temperature, turbidity, and conductivity are likely the result of severe bank erosion. In addition, increasing non-carbonate hardness and pH may be the result of the cation exchange between agrochemicals, soil particles, and rainwater leaching.

Introduction

The rapid banana expansion in Costa Rica has been accompanied by allegations of environmental degradation. Since 1978, over 40,000 hectares of land have been converted to banana production (Carlson, 1991). To increase the output of these lands, banana producers often apply copious amounts of agrochemicals. Unfortunately, these agrochemicals often wind up causing environmental damage to nearby nontarget areas. For example, aerial pesticide applications and canal drainage have been linked to massive fish kills in the Matina and Suerte Rivers (Fuentes, 1993), and the Madre de Dios Lagoon in Tortuguero (Sheaff, 1992).

Flora and fauna of natural areas located near banana plantations may be particularly vulnerable to the deleterious effects of agrochemical contamination. For instance, the director of Tortuguero National Park, Eduardo Chamorro, has expressed concern over a visible decline in the number of fish in local river systems which has been attributed to agrochemical contamination of local waters (Sheaff, 1992). In addition, the plastic bags used to cover banana bunches during ripening are currently causing the deaths of both leatherback and green sea turtles who ingest the bags. Furthermore, Cortez and Risk (1984) found that the decline of the coral reef in Cahuita National Park could be attributed to increased sedimentation and agrochemical pollutants caused by nearby banana production. Other studies have shown an increase in heavy metals in local water systems (Sandi, 1990) and in aquatic organisms (Holothuria: Rojos, 1990), whereas high levels of DDT have been detected in tilapia and carp in Guapiles (Rodriguez, 1990).

Recently, in the canton of Sarapiquí, agrochemical use on banana plantations has been linked to local human health problems. Human health problems range from chronic health issues to irreparable damage. For example, in Puerto Viejo, Sarapiquí, local health officials treat at least 5 cases of chemical intoxicification (exposure to cholinesterase inhibiting chemicals) per week. Similarly, numerous reports of dermatitis, burns and intoxication have been linked to exposure to paraquat and other chemicals (EIS, 1991). Serious health effects appeared in the late 1970's when exposure to the nematicide 1,2-Debromo-3-chloropropano (DBCP) caused the sterilization of 1500 workers in Sarapiquí (Ramirez, 1980).

The ecological degradation caused by agrochemicals also has serious consequences in Sarapiquí. Recently, expansion in the Sarapiquí region has brought production-maximizing banana companies close to several protected areas including, the Organization for Tropical Studies La Selva Biological Station. In the past, fish kills in local river systems have been linked to pesticide applications. In 1987, the Rio Sucio, located to the northeast of La Selva, was the site of a fish kill attributed to aerial fumigation (Blanco, 1990). In 1992, analyses of water samples taken from the confluence of the Sarapiquí and Frio rivers showed traces of 13 organochlorine pesticides, including malathion and dieldrin whose concentrations exceeded safe limits (Carlson, 1993). In Rio Frio, the water from a yellowish, foaming effluent drains into nearby streams. (Carlson, 1992).

Few studies have focused on the ecological impacts of the 1,600 hectares of banana plantations near the Organization for Tropical Studies' La Selva Field Station. In the past, water quality research at La Selva Biological Station has focused on the characterization of watersheds within the park proper (Pringle et al., 1990; Pringle, 1991). More recently, a group of scientists conducted a comprehensive study of the impact of the banana expansion, "Evaluación del impacto socioambiental de la expansión bananera en Sarapiquí, Tortuguero y Talamanca" (EIA, 1992). However, the 1991 draft of this study indicated that little empirical research had been conducted in attempt to quantify the impact of agrochemical use.

In the 1991 draft of EIA, researchers noted that the drainage canals running off of the banana plantations probably carried large amounts of sediment and agrochemical residues to the river systems. However, no studies have been conducted to quantify the chemicals present even though the Programa de Plaguicidas (PPUNA) had documented cases of intoxication and dermatitis of workers exposed to these canal waters. Furthermore, researchers stated that waters flowing out of packaging plants likely contain large amounts of chemical residues. The high number of health problems reported in conjunction with exposure to packaging plant waters seems to support this claim. As yet, no analysis of these waters has been conducted.

The current study focuses on the Rio Sucio watershed in Sarapiquí, Costa Rica. The goal of this study was to determine whether banana cultivation along the Rio Sucio influences the water quality parameters of that river. Even though large scale banana

cultivation is generally viewed as nonpoint source contamination, this study attempted to locate sites of potential point source contamination.

Study Site

The La Selva Biological Station is located in northern Costa Rica (10°26'N, 84°01'W). The Rio Sucio flows northward, running northeast of La Selva, approaching the park to within approximately 3.5 km, then flowing into the Sarapiquí River 10 km to the northeast of the park (Figure 1). The alluvial soils of the river are sandy and clayey, primarily entisols and inceptisols. Approximately 25 km of the Rio Sucio was sampled (from 2-68,5-44 to 2-79,5-33, National Survey maps). Banana plantations line both banks of the Rio Sucio in this area. The major banana companies in the study area include Deba, Cobal (Chiquita), and Geest, which have 800, 4,000, and 4,000 hectares, respectively, in banana production in Sarapiquí. Several other smaller plantations also hold land adjacent to the Rio Sucio.

Methods

Sampling the Rio Sucio and inspecting the banks for erosion, canal drainage, and plastic bag dumps were conducted using a boat hired at La Selva Biological Station. Samples collected from drainage ditches, settlements, and packaging plants, within the plantations, were collected by either walking or driving through the plantations. All the water samples were collected during the rainy season. However, rains were infrequent during the localized collecting in August.

To analyze the water quality of the Rio Sucio, 26 samples of river water were collected at approximately 1 km intervals (Figure 1). The 18 plantation samples were collected from random drainage ditches located in the Deba, Orlich, Gavilan, and Rebusca plantations. Site descriptions and approximate latitude and longitude are summarized in Table 1. Analysis of the samples included measurements of temperature, dissolved oxygen, total alkalinity, total hardness, pH, turbidity, and conductivity. Water quality analysis was performed using the LaMotte Kit.

In addition, analysis of biological indicators included a survey of algae and aquatic macro invertebrates. Algal samples were collected with water samples from the Rio Sucio. Samples of the silt and sand of the river bottom were collected for invertebrate analysis.

Some sampling points were not included in data analyses. The sampling points are numbered such that number 1 represents the most upstream sampling point, whereas sample 24 represents the most downstream point, the junction of the Rio Sucio and the Sarapiquí rivers (Table 2). Samples 25 and 26 were samples of the Sarapiquí and were not included in data analysis of Rio Sucio samples. The plantation results included data collected from standing pools in the Deba plantation. These were not included in data

analyses because standing pools may fail to be truly indicative of water quality in the canals. Therefore, only data from flowing canals were included in the analysis.

The data were grouped to facilitate comparisons and to reveal general trends. Rio Sucio data were grouped into three intervals. The upper third (samples 1-8) consist of the most upstream samples. The middle third (samples 9-16) represent the samples located adjacent to large plantations and point source contamination. The lower third (samples 17-24) includes the most downstream samples. In order to make a comparison between Rio Sucio water samples and the samples from the plantations, the plantation samples were matched to sampling points along the Rio Sucio. Thus, the total plantation samples correlated with the middle third of the Rio Sucio samples. Although these samples were not taken from the banks of the Rio Sucio, flooding and runoff from these sites may influence the Rio Sucio at these locations.

Results

Visual Inspection

Little natural vegetation, a few trees and patches of grass, lines the steep banks of the Rio Sucio. The plantations plant banana trees right to the edge of the river such that the shallow roots of the banana trees can be seen poking through the riverbanks. As a result, the banks are severely eroded. Also, apparent along the banks are numerous blue plastic bags used to cover banana stalks during ripening. Near the Deba plantation the remains of an old bag dump are evident on the southern shore. Identified point sources include: a canal located on the Cocobolo plantation which drains directly into the Rio Sucio (sampling point 16) and silt-laden rainwater runoff from the Deba plantation (sampling point 14).

While walking through the plantations proper, there was a consistent chemical smell. Most of the packaging facilities had huge mounds of blue plastic bags nearby. The water running from the packaging plants was greasy, blue or yellow, and sometimes foamy. The banana trees were planted very close to one another, close to the roads, and surrounding worker housing. The soil was a sandy clay, firmly packed into mounds beneath each banana tree. Almost no vegetation was evident in the plantation proper.

Drainage in the banana plantations consists of ditches and culverts cut into the ground for drainage of the bananas. The ditches vary in depth (.5 - 4 m) and width (.5 -2 m). Smaller ditches permeate the banana stands and run into larger ditches, which generally contained water. Apparently, the natural drainage of the plantation has been completely altered by the creation of these channels.

Biological Indicators

No significant results were found in either the algal or the aquatic invertebrate analyses.

Water Quality Analyses

Results of the water quality analysis of individual data points are listed in Table 2. The grouped data are summarized in Table 3.

Water Temperature

Rio Sucio water temperature (degrees celsius) fluctuates, yet increases between sampling points 1 and 15 (Figure 2). A dramatic increase in temperature is evident where the Cocobolo canal empties into the river. However, one kilometer downstream of the canal, the water temperature declines. The grouped data show elevation of water temperature from the upper third (mean=23.8) to the middle third (mean=26.1), and a decline in the lower third (mean=25.1) (Figure 3). The range of temperature values is greatest in the middle third group, where the plantation samples (mean=28.4) would be of greatest influence.

Dissolved Oxygen

The dissolved oxygen levels fluctuate somewhat along the Rio Sucio, with the highest value (9.2) at sampling point 20, and the lowest (6) at sampling point 23 (Figure 4). The mean values increase from the upper and middle thirds (7.5) to the lower third (7.9) (Table 3).

pH

The pH of the Rio Sucio increases gradually from upstream to downstream (Figure 5). The lowest pH (pH=5.5) is found in the runoff from the Deba fields, whereas the highest pH (pH=7.4) is found in the Cocobolo canal runoff. Overall, the mean values increase from 6.5 in the upper third, to 6.7 in the lower third (Table 3). The range of pH values is greatest in the middle and lower third groups, where the plantation samples (mean=6.8) would be of greatest influence.

Total Alkalinity

Total alkalinity (ppm CaCO_3) remains relatively constant (20 ppm CaCO_3) between samples 1 and 13 (Figure 6). However, a wide fluctuation appears between samples 14 and 19, ranging from 7.5 ppm CaCO_3 at the Deba field (sample 14), to 80 ppm CaCO_3 from the Cocobola canals (sample 16). Mean values of alkalinity increase from 19.4 in the upper third, to 24.9 in the middle third, and decrease to 21.3 in the lower third (Table 3). The widest range in alkalinity values are found in the middle third group, where the plantation samples (mean=83.4) would be of greatest influence (Figure 7).

Total Hardness

The total hardness (ppm CaCO_3) increases between sample 1 and 12, with a pronounced fluctuation appearing between samples 13 and 18 (Figure 8). The minimum value (0) in the fluctuation appears in sample 14, the Deba field runoff, whereas the maximum value (90) is found in the Cocobola canal runoff, sample 16. Total hardness increases from the upper third group (mean=40) to the middle third group (mean=35), again increasing to the lower third (mean=48.8) (Figure 9). The middle group shows the highest range of hardness values (0 to 90) which are most similar to the plantation group values (20 to 110) (Table 3).

Conductivity

Conductivity (umhos/cm) fluctuates from sample 1 to 11 where 2 large fluctuations appear (Figure 10). The peak of the first fluctuation is the Cocobolo runoff, sample 16, (250 umhos/cm) whereas the second peak appears at sample 21 (1000 umhos/cm). In general, conductivity increases from the lower third (mean=114) to the middle third (mean=117.4), where a significant increase to the lower third occurs (mean=213.5) (Table 3). The range of values for the middle (28 to 259) and the lower third (80 to 1000) of the Rio Sucio samples are similar to the range of values found in the plantations (20 to 1000) (Figure 11).

Turbidity

Secchi depth (cm) generally fluctuates between 12 and 28 cm with a decrease in secchi depth evident between samples 11 and 15 (Figure 12). This decrease in secchi depth means an increase in turbidity. Rio Sucio samples measured using Jackson Turbidity Units (JTU) showed an increase between samples 13 and 21 (Figure 13). The increase in JTUs indicates an increase in turbidity. Thus turbidity increases from upstream to downstream, particularly after sampling points 12 and 13. The Deba field runoff (sample 14) and sample point 18 were so filled with sediment, that turbidity could not be measured using the two techniques. Therefore, the two samples remain classified "offscale" measurements.

Discussion

Ignoring existing policies, banana producers plant banana trees right to the edge of the banks of the Rio Sucio. Article 89 of the Constitution, article 68 of the Ley Forestal, and articles 1 and 44 of the Ley de Conservacion de la Fauna Silvestre (Ley No 6919) state that a buffer zone must exist between the banana plantations and local rivers and ravines (ABAS, 1990). In particular, along river banks 100 meters should remain forested and along ravines 10 meters should remain forested. The banana producers policy of planting banana trees to the edges of the Rio Sucio is in direct noncompliance with these existing policies. As a result, increased erosion and turbidity can be seen in the Rio

Sucio. In addition, the lack of a buffer zone often leads to aerial spraying of agrochemicals directly over the river.

The lack of treatment facilities for the plantation effluent also represents noncompliance with existing policies. Visual inspection of the banana plantations and drainage systems indicated a lack of water treatment facilities. Many effluent flowed directly from factories into the fields, or from the fields directly into the Rio Sucio. According to articles 1 and 44 of the Ley de Conservacion de Fauna Silvestre (Ley, 6919) (ABAS, 1990), plantation effluent should be treated, especially those thought to have significant amounts of chemical residues. The lack of treatment facilities is in direct noncompliance with existing policies, resulting in nontreated effluent entering the Rio Sucio.

The water quality of the Rio Sucio is influenced by parent geologic material and soils, in addition to anthropogenic influences. Rainwater most likely leaches ions from the soils which contribute to the changing chemistry of the water system. However, dramatic changes in water chemistry are seen after an eight kilometer stretch of river was sampled. Furthermore, no major surface waters empty into the Rio Sucio in the study area. Therefore, most of the changes in water chemistry may be contributed, at least in part, to the influence of the banana plantations.

Overall trends in the Rio Sucio study include increases in water temperature, dissolved oxygen, total alkalinity, pH, total hardness, conductivity and turbidity. In general, these parameters increase in the middle or lower thirds of the study area. The plantation samples measured higher in all water quality parameters than those measured in the Rio Sucio. Since the middle third coincides latitudinally with the plantation samples, effluent from the banana plantations may be elevating the water quality parameters of the middle and lower thirds of the Rio Sucio.

Increasing water temperatures may negatively impact the river ecosystem. Along the 25 km of the Rio Sucio under study, water mean water temperature increased by 1.3° C. Although this increase may not be significant, the local ranges of water temperature may be deleterious. In particular, the highest temperature was found in the Cocobola effluent (34°C) and Rio Sucio samples taken nearby (30). These values exceed the mean value of the Rio Sucio samples by 5°C. An increase of 5 degrees may indeed be intolerable to aquatic organisms. As biological activity increases with water temperature, there is an increasing demand for dissolved oxygen. This situation may be further strained in that the solubility of oxygen in water decreases as water temperature increases.

However, dissolved oxygen concentrations increased from the upper third of the Rio Sucio to the lower third. Thus, although the water temperature increased, the dissolved oxygen failed to decline. Since dissolved oxygen can vary greatly in time and space (Brooks 1990), perhaps the churning and flow of the Rio Sucio compensates for the lowered oxygen solubility. The mean values for the lower (7.5), middle (7.5), and upper

(7.9) thirds each exceed the minimum desirable range quoted for pond water (5) (Deutsch, 1993).

The Rio Sucio samples indicate a mean pH of 6.5, which falls at the low end of the optimal pH range 6.5 - 8.2 (Deutsch, 1993). However, local values of pH drop to between 5.5 and 6.4. Since a pH less than 7 indicates acidic waters and the presence of H⁺ ions, the Rio Sucio may be characterized as a slightly acidic river with local increases in acidity. Since the plantation pH values ranged from 6.6 to 7.9, the most likely causes of the decrease in pH may be rainwater (pH=5.5) and a decline in carbonate or bicarbonate ions. Fish and invertebrates may be negatively affected by the pH fluctuations.

Mean alkalinity of 21.9 ppm CaCO₃ indicates that the Rio Sucio may be susceptible to fluctuations in pH. Total alkalinity measures the buffering capacity of water or the capacity of water to neutralize acid. Brooks (1990) reports that total alkalinity ranging from 100 to 120 will support aquatic life. However, Deutsch (1993) states that total alkalinity between 100 - 200 will stabilize stream pH, although values between 20 - 200 are normally found in fresh water. The mean alkalinity of the Rio Sucio falls far below Brooks criteria and remains at the low end of Deutsch's range. In contrast, the mean alkalinity for the plantation (83.4) and relatively high pH (6.8) indicates the presence of hydroxide ions in these samples. Since some of these samples were taken near packing plants, it is likely that detergents from the packing plant contributed to the alkalinity.

Usually, high alkalinity is associated with high pH and excessive dissolved solids. However, the Rio Sucio is very turbid (excessive dissolved solids), is slightly acidic and has a low alkalinity. This indicates that the particulate matter in the Rio Sucio waters have a reduced carbonate and bicarbonate buffering capacity. In general, the natural buffering capacity of water slows the drop in pH to approximately 6.0, where a rapid decline in pH will occur with acid added to the system. Already the Rio Sucio has a mean pH of 6.5, thus acid added to the river system may result in a rapid drop in pH. As a result, immature organisms and sensitive species will likely be affected.

Total hardness averages 44.5 ppm CaCO₃ in the Rio Sucio, which indicates moderately soft water. The plantation mean for total hardness is 79 ppm CaCO₃ indicating moderately hard water. Total hardness is attributed primarily to the abundance of calcium, magnesium and iron cations (Figure 14). Calcium hardness averages 17.8 ppm Ca for the Rio Sucio and 31.6 for the plantations. The magnesium concentrations average 10.3 ppm Mg for the Rio Sucio and 19 ppm Mg for the plantation. Usually calcium levels of 10 ppm indicate oligotrophic waters, while levels above 25 are considered characteristic of eutrophic waters (Deutsch, 1993). Apparently, calcium hardness would indicate that the Rio Sucio is slightly oligotrophic. Magnesium concentrations usually range from 5 to 50 ppm (Deutsch, 1993), indicating that the Rio Sucio is at the low end of the magnesium range.

When total hardness exceeds total alkalinity, the excess is attributed to non-carbonate hardness, which indicates the presence of chloride and sulfate ions. On average, the total hardness values for the Rio Sucio exceed the total alkalinity values by 22.6 ppm Cl and S (Figure 14). These values may indicate the chlorine and sulfate ions present due to leaching from parent material or agrochemical degradation.

Conductivity increases dramatically from upper third (mean=114) to the lower third (mean=213.5) where conductivity equals that of the mean plantation value (213.3). Conductivity indicates the presence of ions from dissociated electrolytes. These acids, bases or salts may be derived from the decomposition of agrochemicals. The upper and the middle third conductivity values are very similar, whereas the lower third is almost twice as high. Since the zone of influence of the plantations may encompass the lower third, effluent from the plantations may be increasing conductivity of the Rio Sucio.

Turbidity and suspended sediment increases from the upper to the lower third of the Rio Sucio, which may adversely impact the river ecosystem. High levels of turbidity may restrict sunlight from reaching aquatic vegetation, increase water temperature, or smother benthic communities, and cover gravel important for fish spawning. The sediment itself may carry nutrients and metals which can affect water quality. In addition, pesticides may adsorb to soil particles and be transported downstream. High concentrations are often the result of accelerated erosion caused by disturbances in drainage areas, particularly when disturbances are close to the river system (Brooks, 1991).

High conductivity may be seen in conjunction with high turbidity, yet for the Rio Sucio and plantation values, conductivity increases at a much faster rate than turbidity. This implies that the sediment may contribute to some of the conductivity, but not proportionally. However, it would make more sense if the sediment were binding ions which would contribute to conductivity, which may also explain the increased non-carbonate hardness.

Agrochemicals may be contributing to the increasing ion gradient in the Rio Sucio. The following agrochemical have been used or are in current use on the banana plantations: DBCP, chlorothalonil, phorate, malathion, dieldrin, Counter, paraquat, benomyl, dursban, Furadan, NemaCore, 2,4-D, chlordane, neptachlor, lindane, and aldicarb. These chemicals may persist for up to 5 years in the soil (DBCP, chlordane, dieldrin), and be carried by soil particles washed off the plantation fields. Other chemicals may be generally biodegradable (parathion), and some may persist for only 2 - 4 weeks (2,4-D).

The degradation of these chemicals depends on the nature of the chemical itself, however, highly soluble chemicals, particularly herbicides, leach from the soil relatively quickly. Photodecomposition and hydrolysis facilitate microbial degradation of some of these compounds, thereby releasing chemical constituents into the soil. The water quality parameters of the Rio Sucio seem to be influenced by the banana plantations lining its

banks. Increases in water temperature, turbidity and conductivity seem to be due, at least in part, to increased soil erosion in the plantations. Increased conductivity may also be the result of the increase in clay and silt particles carrying ions or agrochemical residues. Increases in non-carbonate hardness may reflect the addition of copper, sulfate and other ions leaching from the plantation soils. The acidic waters of the Rio Sucio indicates the presence of cations which may be derived from the soil cation exchange and rainwater leaching.

The parameters measured in this study indicate a trend in water quality as the Rio Sucio passes through the banana plantations near La Selva. In order to truly understand the dynamics of this system, a regular monitoring program should be established. The following suggestions are made for anyone interested in establishing such a program:

1. Sample many points along the Rio Sucio, perhaps using locations similar to this study. In particular, monitor above and below the Cocobola canal and the Deba fields. Samples collected farther upstream would allow for a better indication of the changing water chemistry.
2. Measure the water quality parameters frequently and note timing of sampling in relation to aerial spraying or manual application of agrochemicals. Also, note rainfall patterns and river levels.
3. If you can perform pesticide analyses, collect samples shortly after the application of pesticides, as many of the chemicals degrade quickly.
4. Set up artificial plates in the river to monitor the presence of macro invertebrates.
5. Perform a bioassessment using fish or shrimp.

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Table 1. Sampling Site Descriptions and Locations.

New Name	Old Name	Site Description	Latitude	Longitude
1	I	SUCIO (#1CN)	43.7	68.8
2	14	SUCIO	43.5	69.8
3	H	SUCIO (GUYACON)	42.6	70.7
4	13	SUCIO	42.8	70.9
5	K	SUCIO (NOGAL)	42.7	71
6	12	SUCIO	42	72.2
7	11	SUCIO	41	72.4
8	7	SUCIO	39.3	72.5
9	6	SUCIO	38.5	72.4
10	15	SUCIO	37.9	72.8
11	8	SUCIO	37.7	71.8
12	5	SUCIO	37.5	71.4
13	J	SUCIO BRIDGE	37.3	71.3
14	C	RUNOFF INTO SUCIO DEBA FIELDS	37.2	71.4
15	16	SUCIO	36.5	73.2
16	17	RUNOFF INTO SUCIO COCOBOLA CANALS?	35.5	73.3
17	19	SUCIO POOL AT BASE OF COCOBOLA CANAL	35.5	73.3
18	20	SUCIO OUTSIDE CANAL	35.5	73.3
19	4	SUCIO	35.1	73.9
20	3	SUCIO	34.7	74.8
21	E	SUCIO (CHIRIPA)	34.7	75.5
22	2	SUCIO	34.6	76.2
23	1	SUCIO	33.7	77.4
24	9	SUCIO PRIOR TO SARAPIQUI JUNCTION	33.9	78.2
25	18	SUCIO POST-SARA	33.8	78.2
26	10	<u>SARAPIQUI</u>	33.5	78.3

Table 1 continued.

New Name	Old Name	Site Description	Latitude	Longitude
27	30	REBUSCA CANAL FLOWING	34	75.5
28	26	REBUSCA FACTORY #1	35-36	72-73
29	27	REBUSCA FACTORY #2	35-36	72-73
30	28	REBUSCA CANAL FLOW	33.5-36	72-75.5
31	29	REBUSCA CANAL FLOW	"	"
32	31	REBUSCA CANAL FLOW	"	"
33	32	REBUSCA CANAL FLOW	"	"
34	21	DEBA STANDING POOLS	37-39	70-71.2
35	22	DEBA STANDING POOLS	"	"
36	23	DEBA STANDING POOLS	"	"
37	24	DEBA STANDING POOLS	"	"
38	25	DEBA STANDING POOLS	"	"
39	34	CANO NEGRO INTO SAR	37.3	70.6
40	F	CANO NEGRO (#2CN)	39.8	70
41	35	DEBA CANAL FLOW	36-38	73.5-71.3
42	36	DEBA CANAL FLOW	"	"
43	37	DEBA CANAL FLOW	"	"
44	38	GAVILAN HOUSING	38.2	74.6
45	B	COYOL FACTORY RUNOFF	38.1	75.6

(Latitude and longitude are approximate locations based on maps from Instituto Geografico Nacional, San Jose, Costa Rica.

The four maps include: Chaparron 3347 I, Rio Cuarto 3347 II, Rio Sucio 3447 III, and Chirripo Atlantico 3447 IV.)

Table 2. Water Quality Test Results.

SAMPLE	AT	WT	DO	ALK	pH	HARD	TURB	COND
1	23	22	8.1	25	6.5	20	30	134
2	32	23.6	7.4	20	6.5	35	16	95
3	29	26	7.3	20	6.3	30	25	142
4	27.6	23.5	7	20	6.6	55	11.5	80
5	30.5	24.5	---	20	6.5	50	90	144
6	29	23.5	6.9	17.5	6.8	45	14	101
7	26	23.5	8	15	6.6	25	27	100
8	28	24	7.7	17.5	6.2	60	27	120
9	34.5	24.5	7.8	22	6.2	60	28	110
10	31	25	7.4	17.5	7	40	13.5	100
11	31	24.5	7.9	17.7	6.3	55	26	110
12	31	23.5	7.7	20	6.1	55	21	110
13	31	26	---	20	6.3	20	25	126
14	---	---	---	7.5	5.5	0	OFFSC	38
15	30	25.2	6.7	15	6.6	40	11	95
16	28	34	---	80	7.4	90	30	250
17	29	30	---	35	7	60	---	120
18	29	30	---	40	6.9	55	OFFSC	80
19	32	23.6	8	12.5	6.6	40	18	100
20	32	23.5	9.2	16	6.6	50	17	100
21	24	23.5	8.2	20	6.5	50	35	1000
22	25	23	8.7	17.5	6.7	50	14	100
23	25	23	6	15	6.4	35	14	98
24	28.5	24.5	7.8	15	6.6	50	19	110
25	29	24.5	7.3	12.5	6.7	40	18	75
26	31.5	23.4	7.7	25	6.6	11.5	150	60

Table 2. continued.

SAMPLE	AT	WT	DO	ALK	pH	HARD	TURB	COND
27	---	---	---	80	6.6	80	10	9.5
28	29	---	---	70	6.6	65	---	115
29	29	---	---	90	7	80	---	125
30	30	---	---	70	6.6	70	---	110
31	30	---	---	88	6.6	85	35	150
32	29	25	5	40	6.7	50	35	100
33	27	26	6.6	22.5	6	20	20	40
34	29	---	---	15	5.5	40	OFFSC	20
35	---	---	---	20	5.2	40	OFFSC	18
36	---	---	---	10	5.6	30	OFFSC	18
37	---	---	---	15	5.7	40	OFFSC	20
38	28	---	---	50	6	40	OFFSC	29
39	27	24.5	6	40	6.7	50	20	100
40	24.5	23	---	20	6.6	15	2	42
41	26	31	---	90	7.9	90	OFFSC	200
42	26.5	31	---	22.5	5.5	30	OFFSC	45
43	27	30	---	90	7	100	30	220
44	29	27.5	7.2	90	7	110	40	200
45	---	---	---	190	7	110	---	1000

Table 3. Comparison of Water Quality Parameters of Total Rio Sucio Samples (1 - 24), Upper Third (1 - 8), Middle Third (9 - 16), Lower Third (17 - 24), and Total Plantation Samples (27 - 33 and 41 - 45).

	Total Rio Sucio	Upper Third	Middle Third	Lower Third	Total Plantation
WATER TEMPERATURE	Celsius				
Maximum	34	26	34	30	31
Minimum	22	22	23.5	23	25
Mean	25	23.8	26.1	25.1	28.4
Std. Dev.	2.7	1	3	3	1.4
DISSOLVED OXYGEN					
Maximum	9.2	8.1	7.9	9.2	
Minimum	6	6.9	6.7	6	
Mean	7.7	7.5	7.5	7.9	
Std. Dev.	1.8	0.4	0.4	0.9	
ALKALINITY	ppmCaCO ₃				
Maximum	80	25	80	40	190
Minimum	7.7	15	7.5	12.5	22.5
Mean	21.9	19.4	24.9	21.3	83.4
Std. Dev.	13.7	13.4	21	9.6	38
pH					
Maximum	7.4	6.8	7.4	7	7.0
Minimum	5.5	6.2	5.5	6.4	6.6
Mean	6.5	6.5	6.4	6.7	6.8
Std. Dev.	1	1	0.9	0.1	0.4
HARDNESS	ppm CaCO ₃				
Maximum	90	60	90	60	110
Minimum	0	20	0	35	20
Mean	44.5	40	45	48.8	79
Std. Dev.	17.5	13.7	25	7.4	24.5

Table 3 continued.

	Total Rio Sucio	Upper Third	Middle Third	Lower Third	Total Plantation
CONDUCTIVITY	umhos/cm				
Maximum	1000	144	259	1000	1000
Minimum	38	80	38	80	40
Mean	148	114	117.4	213.5	213.3
Std. Dev.	180	22.4	55.8	129	242
TURBIDITY*	JTU				
Maximum	offscale				offscale
Minimum	30				10
Mean	39*				28*
Std. Dev.	42				10
TURBIDITY	Secchi				
Maximum	28				
Minimum	11				
Mean	19				
Std. Dev.	4				

*=Turbidity was measured using two methods. The secchi disk was more appropriate for river samples, whereas the shallow canals of the plantations were more adequately quantified using Jackson Turbidity Units.

**=Mean calculated from measurable data. Offscale points represent highly turbid waters beyond the measuring capabilities of the JTU test. Thus, the actual means would be much higher if the offscale measures could be included.

Figure 1. Map of Study Area.

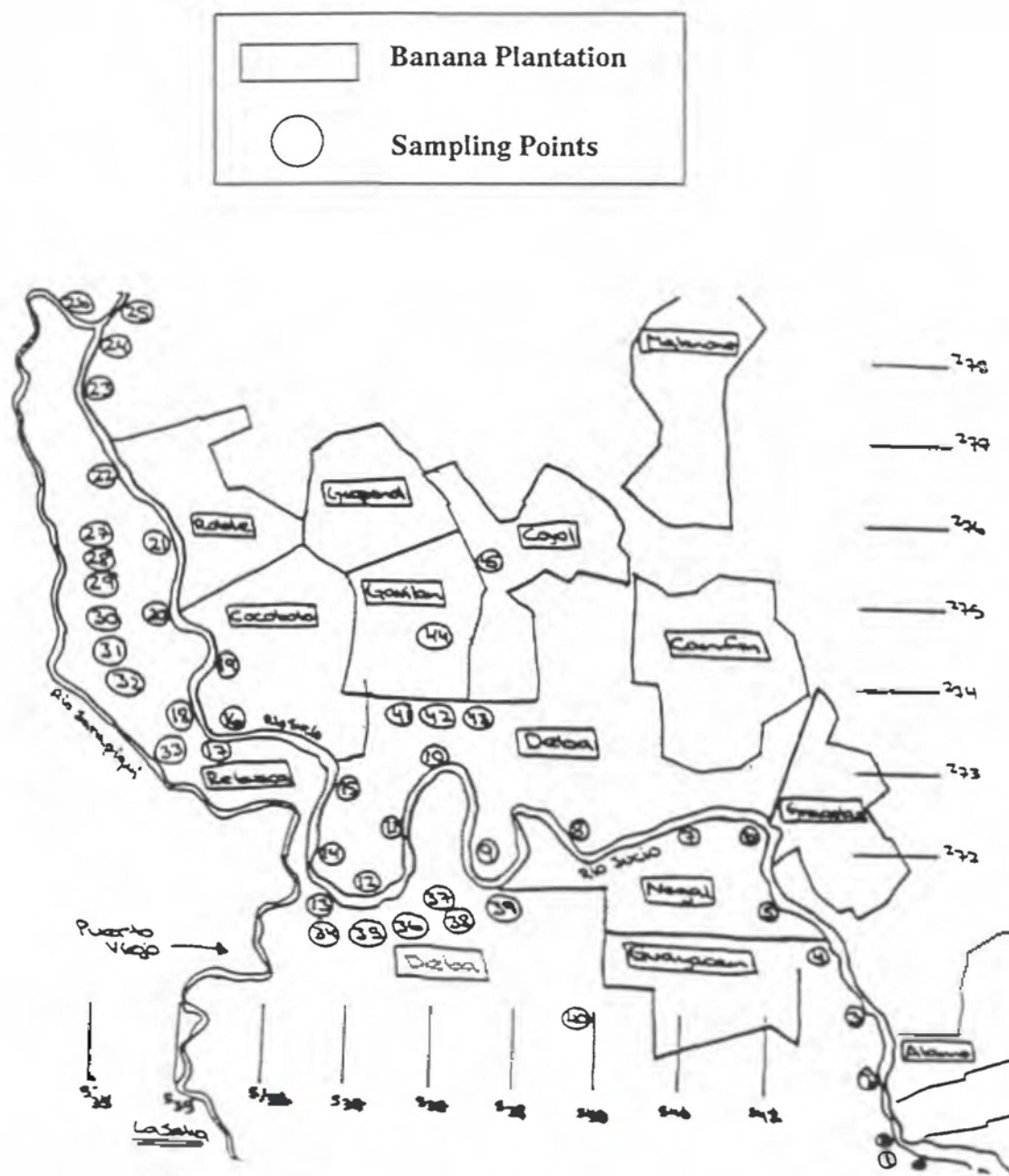


Figure 2. Water Temperature of Rio Sucio Samples.

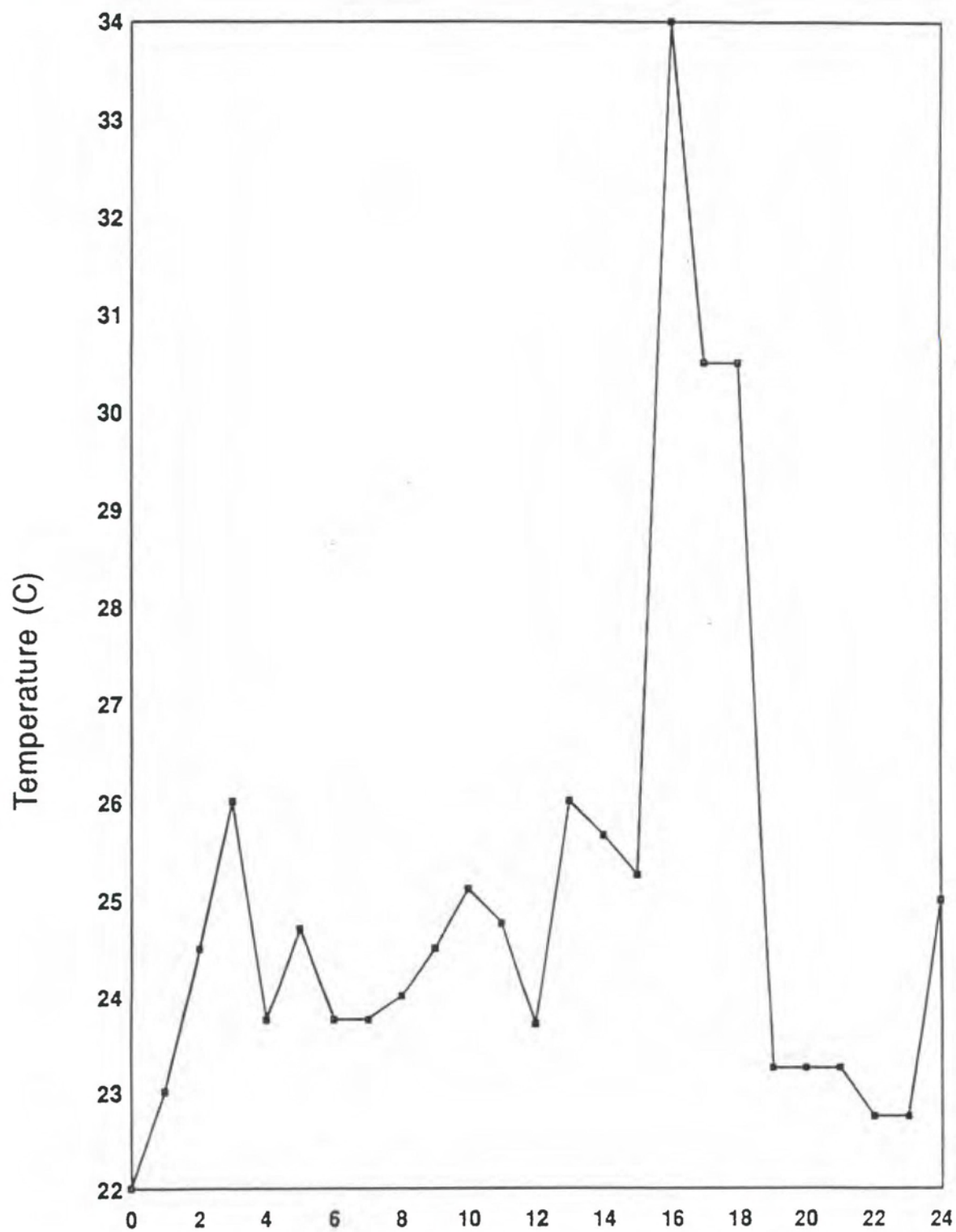


Figure 3. Temperature Means ($\bar{X}$), Ranges (—), and Standard Deviation ($\square$), Total Rio Sucio Includes All River Samples, Upper Third Samples (1 - 8), Middle (9 - 16), and Lower (17 - 24), Total Plantation Includes All Canal Samples.

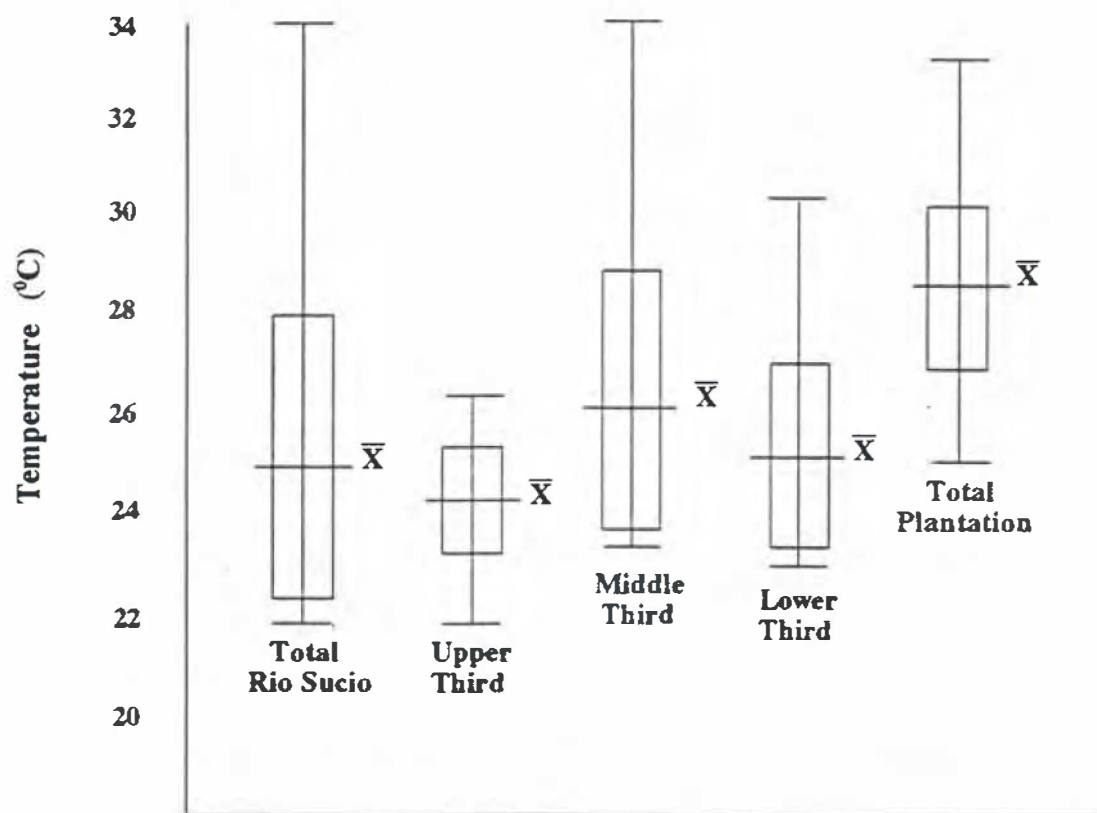


**Figure 4. Dissolved Oxygen (ppm DO)
Concentrations of Rio Sucio Samples.**

(1 = most upstream; 24 = most downstream sample)

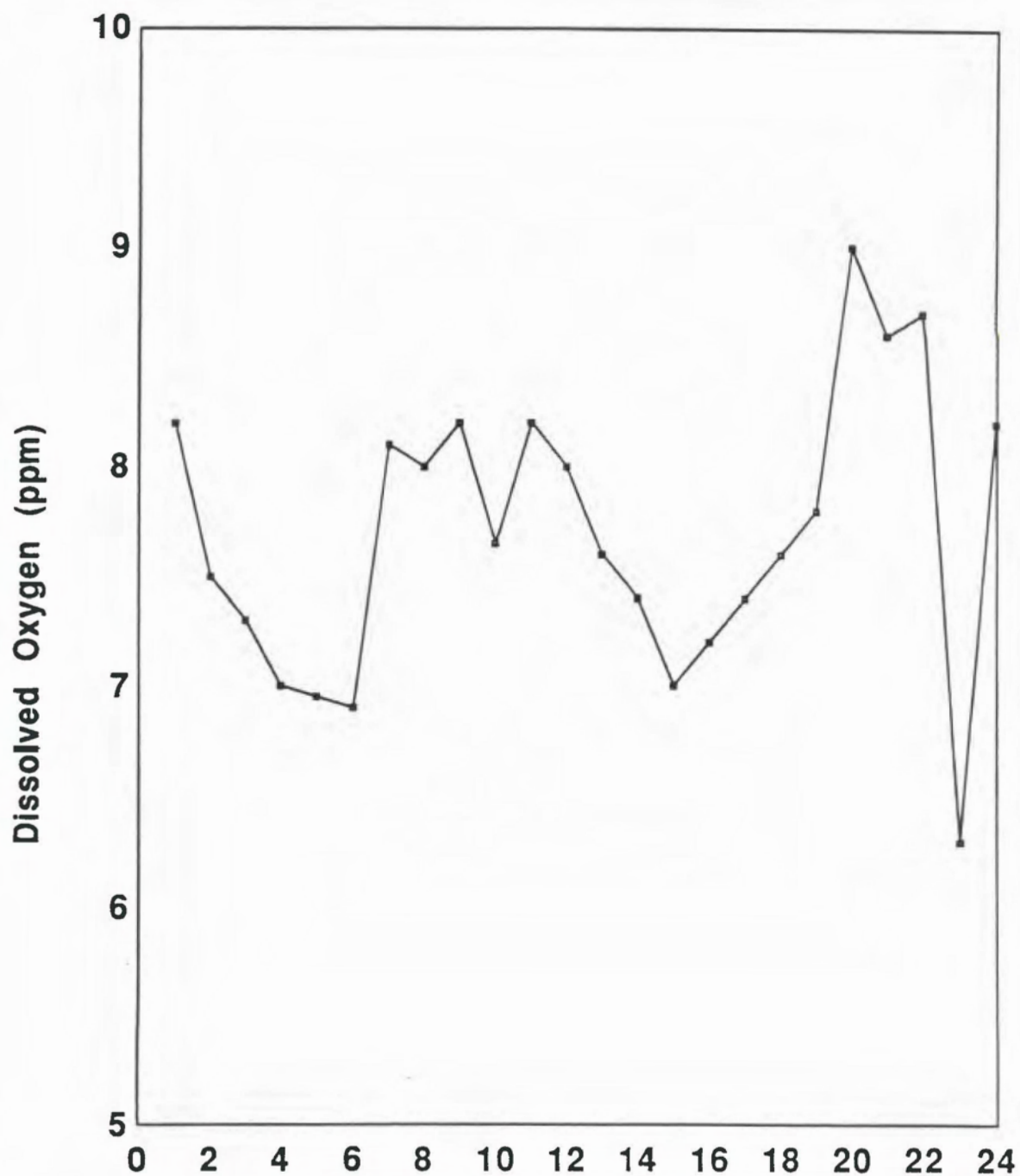


**Figure 5. pH for Rio Sucio (-) and
Plantation Canal (---) Samples.
(1 = most upstream; 24 = most downstream)**

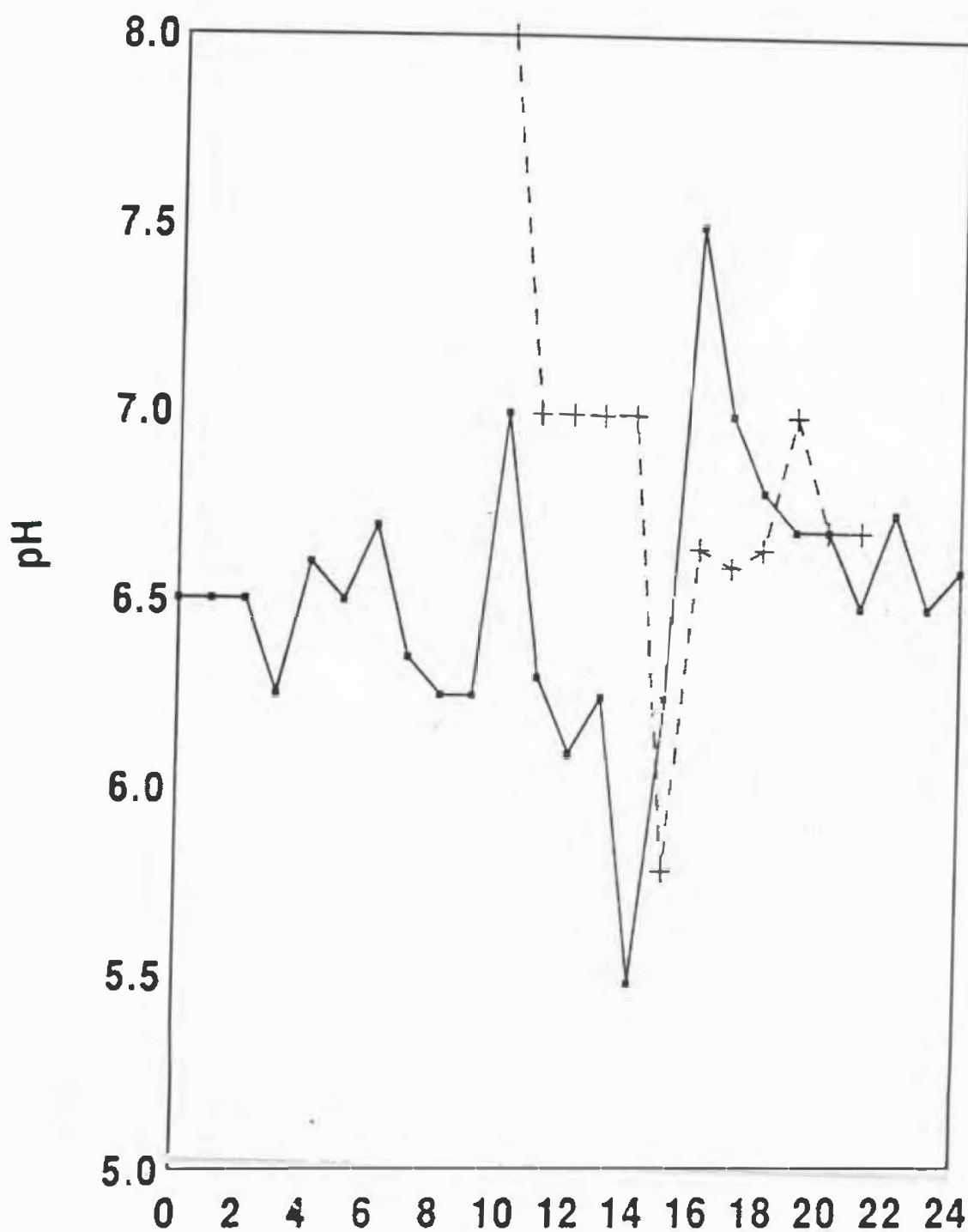


Figure 6. Total Alkalinity (ppm CaCO_3) of Rio Sucio (-) and Plantation Canals (---).

(1 = most upstream; 24 = most downstream)

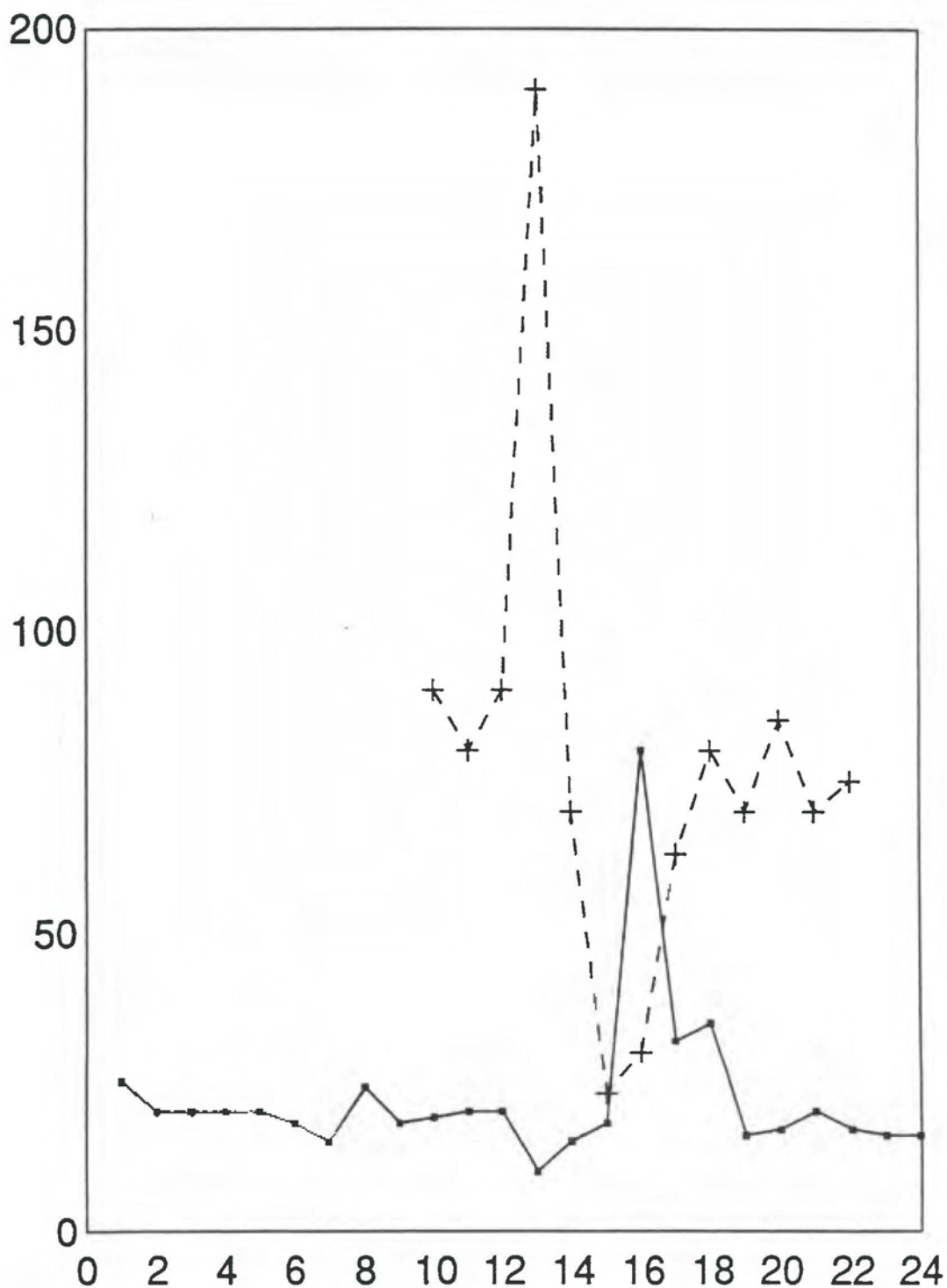


Figure 7. Total alkalinity means ($\bar{X}$), ranges (—), and $\pm$ standard deviation ($\square$), Total Rio Sucio (1 - 24), upper third (1 - 8), middle third (9 - 16), and lower third (17 - 24), total plantation includes all canal samples.

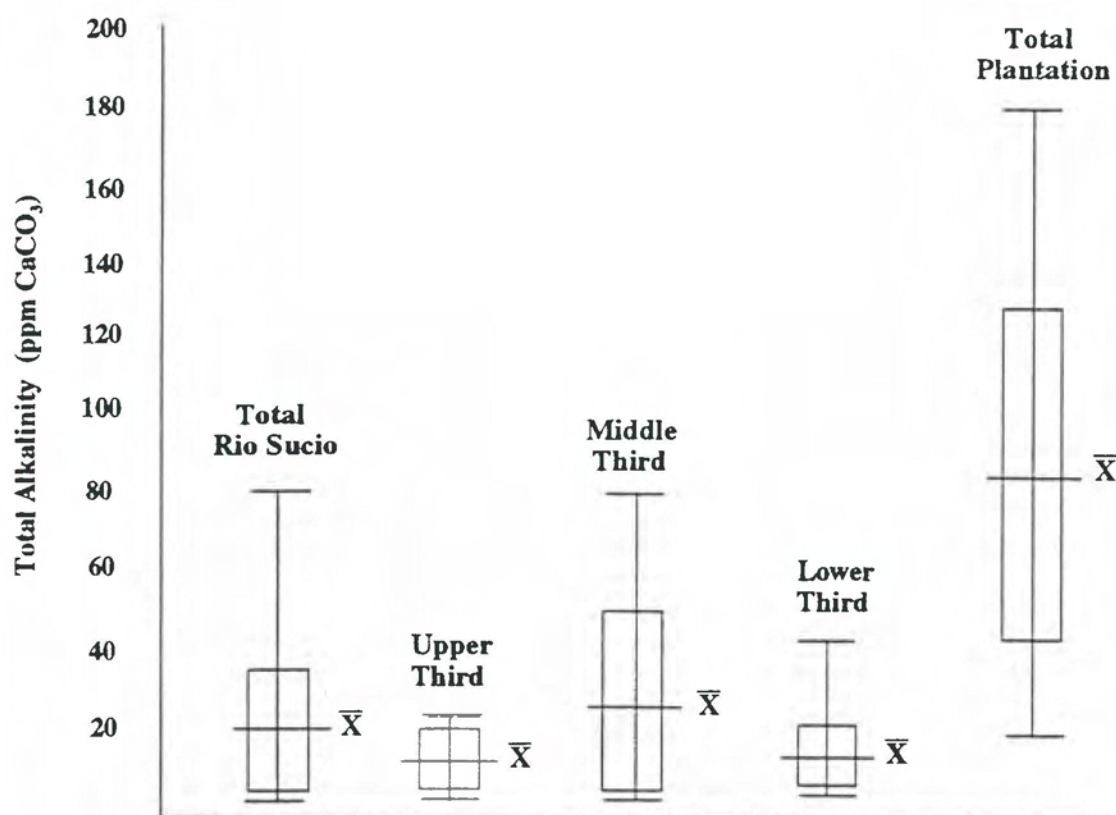


Figure 8. Total hardness (ppm CaCO_3) for Rio Sucio (-) and plantation canal samples.

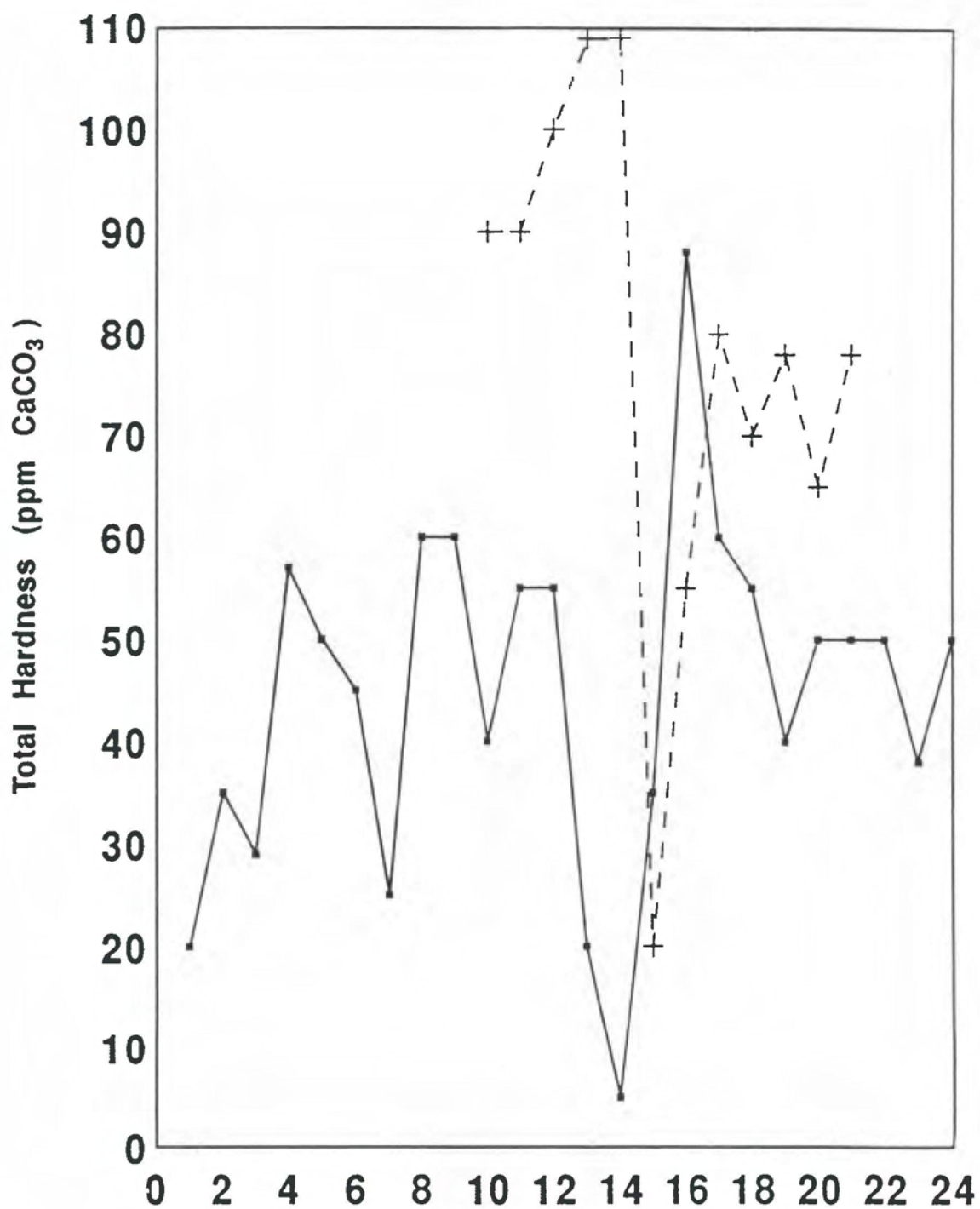


Figure 9. Mean Total Hardness ($\bar{X}$), ranges (—), and $\pm$ standard deviation ($\square$).

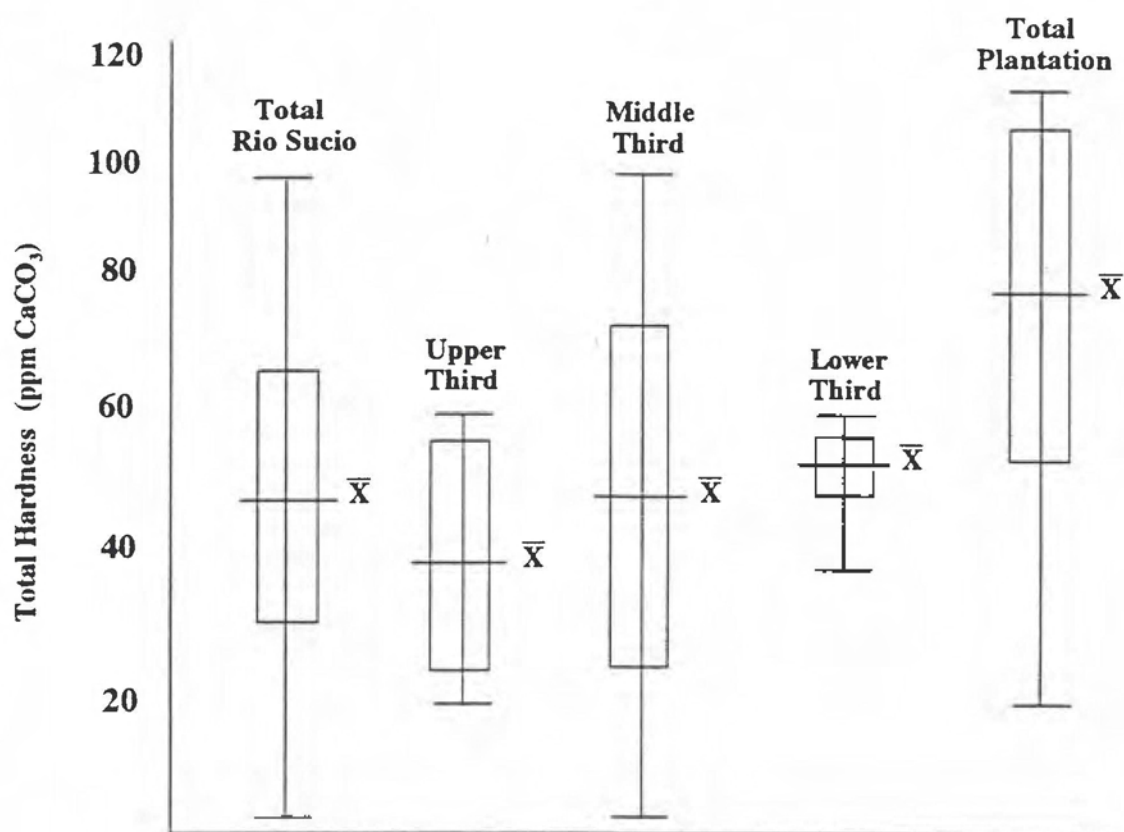


Figure 10. Conductivity (umhos/cm) of Rio Sucio (-) and plantation canal samples.

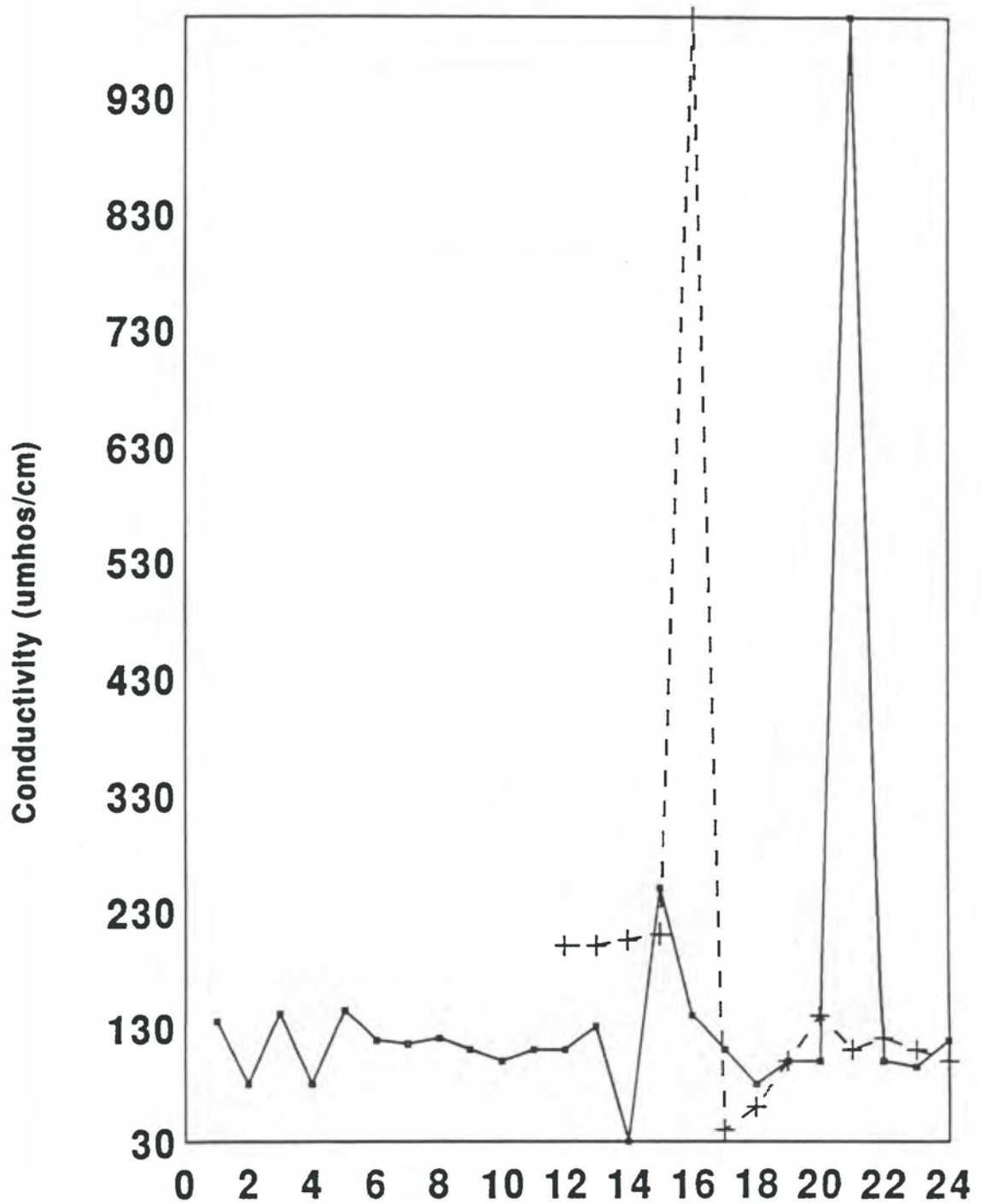


Figure 11. Mean Conductivity ($\bar{X}$), ranges (—), and $\pm$ one standard deviation ($\square$).

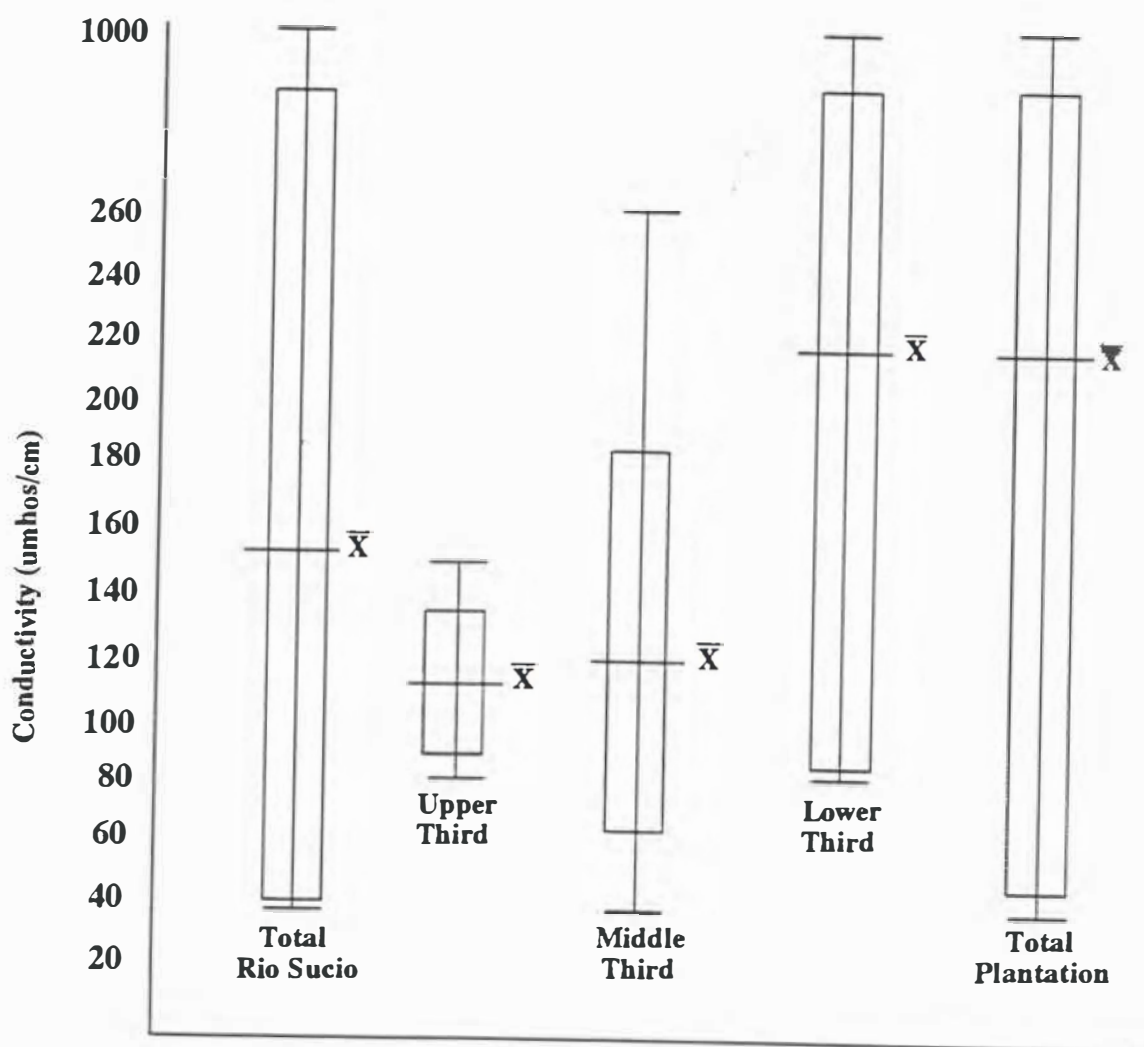


**Figure 12. Secchi Disk Readings
for Rio Sucio Samples.**

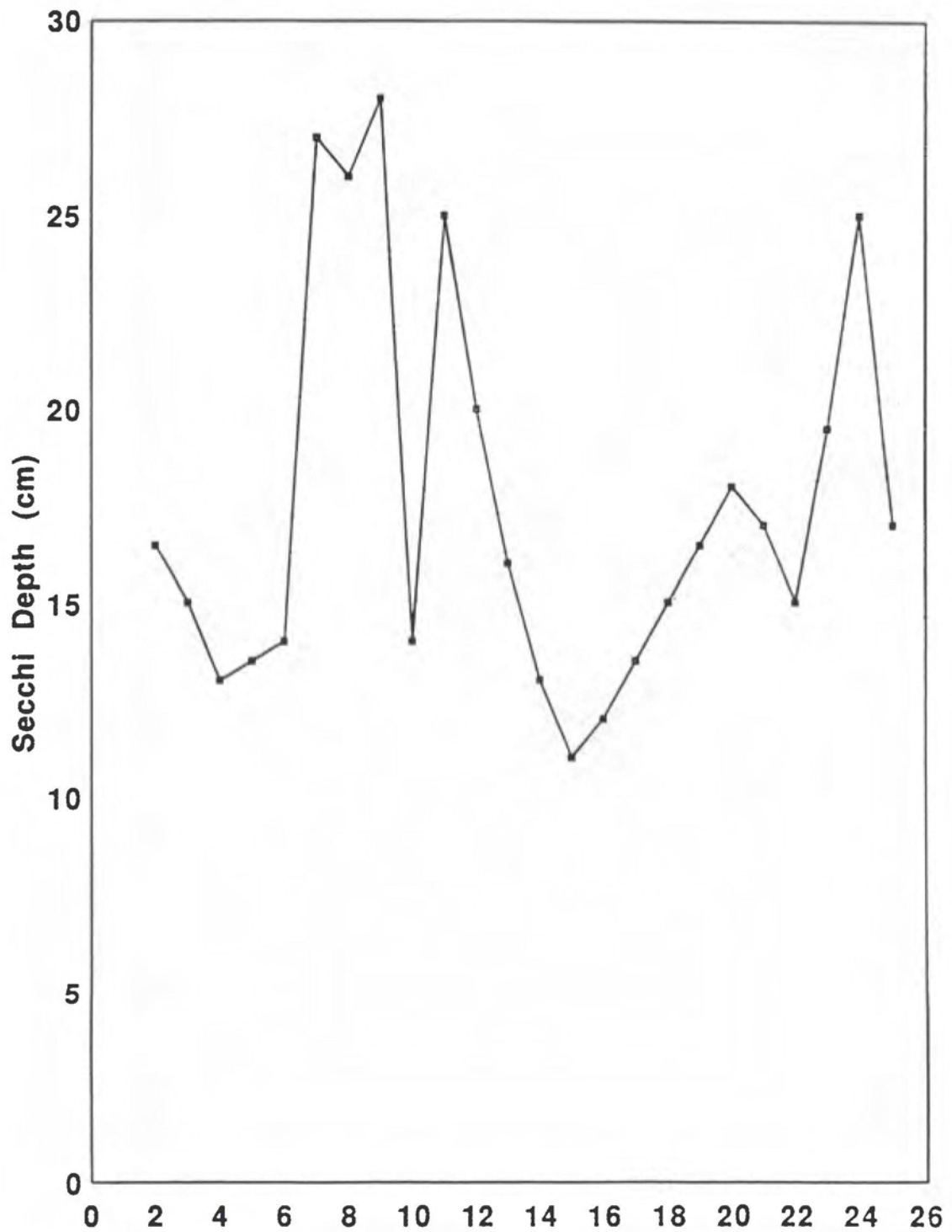


Figure 13. Turbidity (ITU) of Rio Sucio (-) and Plantation Canal (---) Samples.

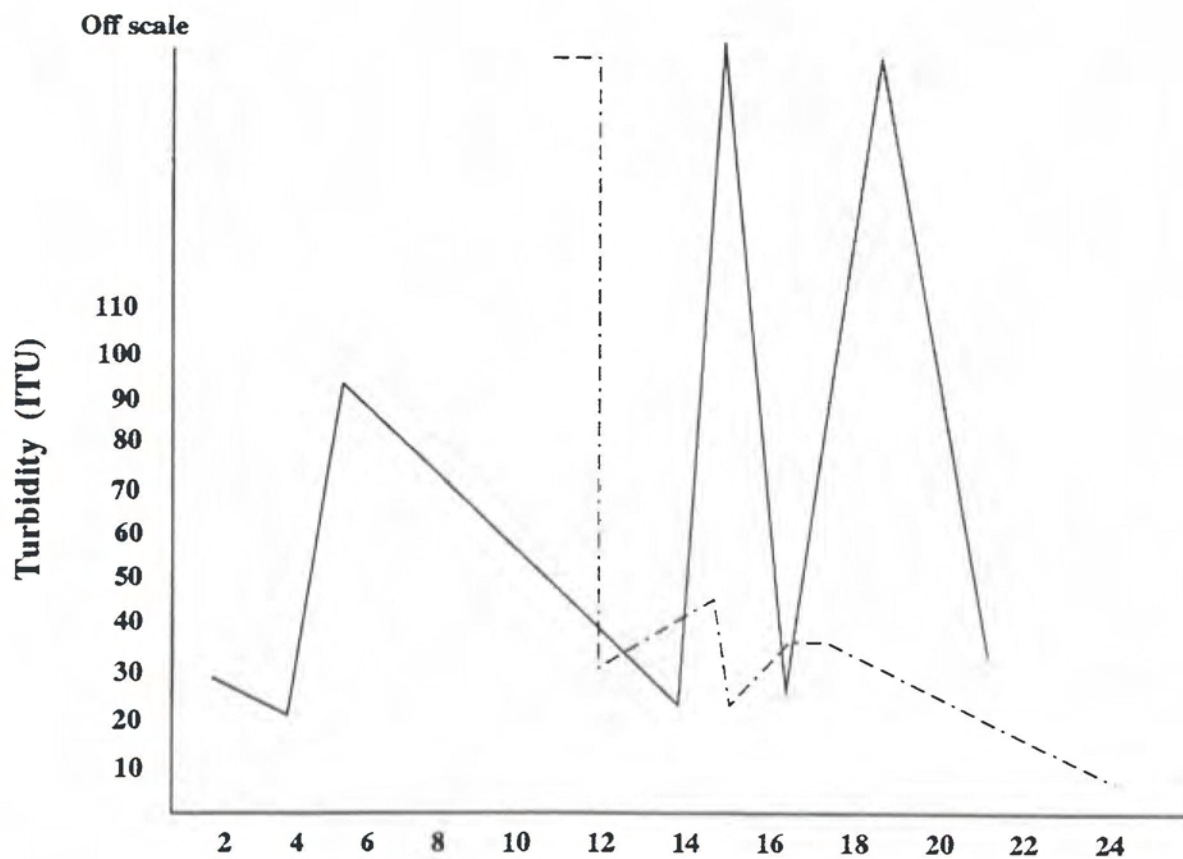
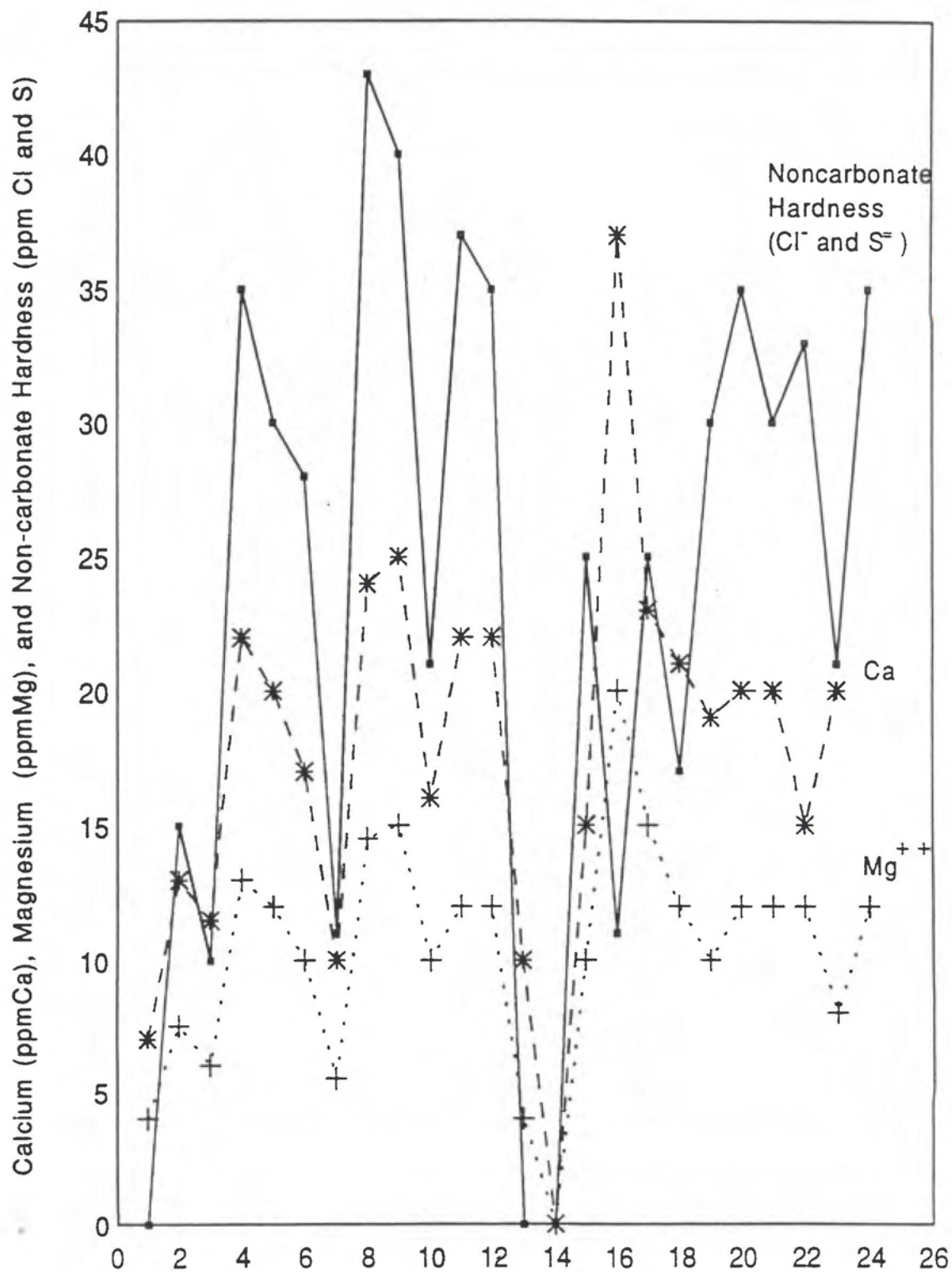


Figure 14. Non-carbonate hardness (ppm Cl and S) (-), Calcium Hardness (---), Magnesium Hardness (. . .), of Rio Sucio Samples.



USE OF CORRIDORS BY FRUIT EATING BUTTERFLIES

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Abstract

Fruit eating butterflies from three forest patches, an open pasture, and a riparian corridor were studied to determine movements between patches. *Cissia satirina* was the most abundant species. Most captures occurred in an open forest patch. The highest diversity was observed in the smallest forest patch. Movements of *Cissia satirina* was determined along the pasture in two occasions. Cloudy and rainy conditions might have jeopardized movements. A short sampling period, along with the weather, may be the reason for low captures.

Resumen

Se estudiaron mariposas frugívoras en 3 fragmentos de bosque para determinar los patrones de movimiento de estas especies. La especie capturada mas frecuentemente fue *Cissia satirina*. El mayor número de capturas correspondió al fragmento de bosque abierto. Se observó movimiento de *Cissia satirina* a lo largo de la pastura. El bajo número de capturas se puede atribuir a las malas condiciones climáticas y a la corta duración del estudio.

Introduction

Tropical rainforests are disappearing at a high speed, thus, affecting native species. This negative effect is difficult to determine in the short period of time left before its total destruction. The needs for corridors is critical for a great array of species. However, the evaluation of the usefulness of corridors for many species is not possible. Therefore, taxa that are geographically informative, relatively well characterized, and easy to measure or observe, should be targeted (Kremen, 1992). Butterflies, birds, small mammals, and parasitic Hymenoptera have been proposed in such cases (Ehrlich, 199-).

The proposed Coto Brus corridor includes pastures intermixed with the present forest patches and areas reforested with native tree species. These pastures may act as barriers for butterflies, and other less mobile species. The objective of this study was to determine the use of a pasture and a riparian corridor by fruit eating butterflies for daily movements.

Methods

This experiment was carried out from the 9th to the 17th of August as a continuation of the independent field project (Pedersen, this book); data from both projects were combined. Three forest patches were selected at the Gamboa property near the marsh (Figure 1). A dense 2.7 ha forest patch ("dense patch"), a more open 2.0 ha forest patch ("open patch") and a bigger, about 5 ha "squared patch", were selected using 1992 aerial photographs. The dense patch was separated from the open patch by a pasture containing 2 Guayaba trees, and the squared patch was connected to the open patch by a stream. This stream was densely vegetated and considered to be a riparian corridor.

From August 9 to 14, eight Van Someren-Rydon butterfly traps were set in the same locations as the independent field project: 3 in the dense patch, 3 in the open patch, and 2 in the pasture hanging from the Guayaba trees. On the 15th of August, twelve additional traps were set: 3 more in the open patch closer to the stream, 5 along the stream, and 4 in the squared patch. All traps were hung close (<10 m) to the forest edge from tree limbs at 1 - 3 m above the ground or above the stream. The traps were baited with rotten banana, rum, sugar, and vanilla, and checked every day, except on August 10 and 12 due to heavy rain caused by a hurricane tail. All traps were collected on the 17th of August. Three of the traps in the open forest, those in the dense patch and in the pasture, were open during 12 days. All the remaining traps were open for 8 days. Butterflies captured were identified (Devries, 1987), marked with a unique number for the species on the wing, and released. Recaptures and trap numbers were noted to determine the existence of movement along and between the forest patches.

Results

Few fruit eating butterflies were attracted to the traps during this study. Only six species were captured: *Caligo eurilochus*, *Memphis arginusa*, *M. beatrix*, *Morpho peleides*, *Cissia satirina*, and *Cissia sp.* Some moths were also marked, but not identified.

There were no captures in the pasture during the entire period. All six species of butterflies (41.3% of the total number) were captured in the dense forest patch, even though it was the smallest of all the patches. The highest number of captures (53.3%) occurred in the open patch where *M. beatrix*, *C. satirina* and *Cissia sp.* were attracted to the traps. *Morpho peleides* and *Caligo eurilochus* were captured along the stream where 2.67% of the captures occurred, and *C. eurilochus*, and *M. peleides* at the squared forest patch (2.67% of the captures). *C. satirina* was the species most often captured (69.9%), followed by *Cissia sp.* (12.3%), *C. eurilochus* (6.8%), *M. beatrix* (5.5%), *M. peleides* (4.1%), and *M. arginusa* (1.4%).

Recapture occurred mostly in the same forest patch, and in the same trap. In two occasions *C. satirina* was recaptured in adjacent forest patches indicating movement along the open pasture. In 4 occasions the traps along the stream were found clean of bait and scrambled.

Table 1. Species Captured During the Entire Study.

Species	%
<i>Cissia satirina</i>	69.9
<i>Cissia sp.</i>	12.3
<i>Caligo eurilochus</i>	6.8
<i>Memphis beatrix</i>	5.5
<i>Morpho peleides</i>	4.1
<i>Memphis arginusa</i>	1.4

Discussion

Prevailing adverse weather conditions might have been the reason for the low number of captures and species attracted to the traps (Ehrlich, 1984). The lack of captures in the pasture could be attributed to the abundance of Guayaba fruits laying on the ground. *Cissia renata* was abundant along the pasture, especially around both trees, however, it was never attracted to the bait in the traps. The greatest diversity was observed in the dense forest, perhaps because it was relatively undisturbed.

The low number of captures along the stream could be attributed to the presence of other animals eating the baits and, as a consequence, reducing the number of trapping days. However, the sampling period was shorter in both the squared patch and the stream.

Although little is known about the dispersal of butterflies (Pollard and Yates, 1993), loss of habitat is the major cause for reduction in diversity. The presence of broad pastures intermingled between forests and exotic trees may act as a barrier for some butterfly species and other arthropods (Wood and Samways, 1991), therefore, only native mixed tree species should be considered for the corridor.

Literature

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Appendix

Table 2. Data of Fruit Eating Butterflies Corresponding to the Entire Sampling Period at Gamboa's Marsh.

Day	Time ²	Loc ¹	Trap #	Species	#	Previous Location ³	Observations
6/8	p	dense	1	<i>Cissia satirina</i>	1		
7/8	a	open	4	moth			
7/8	a	dense	2	<i>Cissia satirina</i>	2		
7/8	a	dense	1	moth			
7/8	p	dense	1	<i>Cissia satirina</i>	23		
7/8	p	dense	1	<i>Cissia satirina</i>	24		
7/8	p	dense	1	<i>Cissia satirina</i>	25		
7/8	p	open	4	<i>Cissia satirina</i>	26		
7/8	p	open	5	<i>Cissia satirina</i>	27		
7/8	p	open	5	<i>Memphis beatrix</i>	1		
8/8	a	dense	2	<i>Cissia satirina</i>	2	2	recapture
8/8	a	dense	1	<i>Caligo eurilochus</i>	1		
8/8	p	dense	2	<i>Cissia satirina</i>	6	3	recapture
8/8	p	dense	2	<i>Cissia satirina</i>	24	1	recapture
8/8	p	dense	2	<i>Cissia satirina</i>	40		
8/8	p	dense	2	<i>Cissia satirina</i>	41		
8/8	p	open	4	<i>Memphis beatrix</i>	2		
8/8	p	open	5	<i>Cissia satirina</i>	43		
8/8	p	open	5	<i>Cissia satirina</i>	44		
8/8	p	open	5	<i>Cissia satirina</i>	45		
8/8	p	open	5	<i>Cissia satirina</i>	46		
8/8	p	open	6	<i>Cissia satirina</i>	47		
8/8	p	open	6	<i>Cissia satirina</i>	48		
9/8	a	open	5	moth			
9/8	a	open	5	<i>Cissia satirina</i>	49		
9/8	a	open	5	<i>Cissia satirina</i>	50		
9/8	a	open	4	<i>Cissia satirina</i>	51		
9/8	a	dense	1	<i>Memphis arginusa</i>	1		
11/8	a	open	5	<i>Cissia satirina</i>	51	4	recapture
11/8	a	open	5	<i>Cissia satirina</i>	26	4	recapture
11/8	a	open	4	<i>Cissia satirina</i>	47	6	recapture
11/8	a	dense	3	<i>Cissia satirina</i>	24	2, 1	recapture
11/8	a	dense	1	<i>Cissia sp.</i>	48	6	
13/8	a	open	6	<i>Cissia sp.</i>	49	5	recapture
13/8	a	open	5	<i>Cissia satirina</i>	51	5, 4	recapture
13/8	a	open	5	<i>Cissia sp.</i>	52		
13/8	a	open	4	<i>Memphis beatrix</i>	1	5	recapture
13/8	a	open	4	<i>Cissia sp.</i>	43	5	recapture
13/8	a	open	4	<i>Cissia satirina</i>	47	6	recapture
13/8	a	dense	2	<i>Cissia satirina</i>	1	1	recapture
14/8	a	open	4	<i>Cissia satirina</i>	53		
14/8	a	open	4	<i>Cissia satirina</i>	54		

Table 2 continued.

Day	Time ²	Loc ¹	Trap #	Species	#	Previous Location ³	Observations
14/8	a	open	4	moth	1		
14/8	a	dense	2	<i>Caligo eurilochus</i>	--		escaped
14/8	a	dense	2	<i>Cissia satirina</i>	2	4	recapture
14/8	a	dense	1	<i>Cissia satirina</i>	48	1, 6	recapture
14/8	a	dense	1	<i>Cissia satirina</i>	55		
14/8	a	dense	--	--	--		bait eaten
15/8	a	open	5	<i>Cissia satirina</i>	--		escaped
15/8	a	open	10	<i>Cissia sp.</i>	56		
15/8	a	open	11	<i>Cissia sp.</i>	57		
15/8	a	open	11	<i>Cissia sp.</i>	58		
15/8	a	stream	14	<i>Morpho peleides</i>	A		
15/8	p	open	7	<i>Cissia sp.</i>	59		
15/8	p	dense	3	<i>Cissia satirina</i>	60		
15/8	p	dense	3	<i>Cissia satirina</i>	61		
15/8	p	dense	3	<i>Cissia satirina</i>	2	2, 4	recapture
15/8	p	dense	2	<i>Cissia satirina</i>	1	1, 2	recapture
15/8	p	dense	2	<i>Cissia satirina</i>	48	1, 6, 1	recapture
15/8	p	dense	1	<i>Cissia satirina</i>	62		
15/8	p	open	9	<i>Cissia satirina</i>	47	6, 4	recapture
16/8	a	open	7	<i>Cissia sp.</i>	63		
16/8	a	open	7	<i>Cissia sp.</i>	59	7	recapture
16/8	a	open	8	<i>Cissia sp.</i>	64		
16/8	a	open	9	--			no bait
16/8	a	open	11	<i>Cissia sp.</i>	58	11	recapture
16/8	a	open	11	<i>Cissia satirina</i>	65		
16/8	a	stream	12	--			no bait
16/8	a	stream	13	--			no bait
16/8	a	stream	14	--			no bait
16/8	a	squared	18	moth	--		
16/8	a	squared	16	<i>Morpho peleides</i>	--		escaped
16/8	a	dense	1	<i>Morpho peleides</i>	B		
16/8	a	open	9	<i>Cissia satirina</i>	47	9, 6, 4	
16/8	a	dense	3	<i>Memphis beatrix</i>	4		
16/8	a	dense	3	<i>Cissia satirina</i>	66		
16/8	a	dense	2	<i>Cissia satirina</i>	1	1, 2, 1	recapture
17/8	a	squared	18	<i>Caligo eurilochus</i>	--		
17/8	a	stream	15	<i>Caligo eurilochus</i>	--		
17/8	a	stream	13				no bait
17/8	a	dense	3	<i>Caligo eurilochus</i>	1	1	recapture
17/8	a	open	7	<i>Cissia satirina</i>	45	5	recapture
17/8	a	open	7	<i>Cissia satirina</i>	67		
17/8	a	open	8	<i>Cissia satirina</i>	47	9, 6, 4, 9	recapture

¹ (dense) dense forest, (open) open forest, (squared) squared forest, (stream) stream.

² (a) morning, (p) afternoon check.

³ trap where previously marked or captured.

Figure 1. Representation of the study area. Forest patches separated by pastures and stream connecting two patches. Trap locations represented by numbers, roads by broken lines.

