



Sustainable Land Use in a Mosaic of Agriculture and Forest

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Bruce Haines, Dept of Plant Biology, University of Georgia, Athens, Ga. 30602, USA
Tel 706-542-1837, Fax 706-542-1805, E-mail haines@plantbio.uga.edu

Ivelisse Ruiz-Bernard, Biology Department, University of Puerto Rico, San Juan, Puerto Rico, 00931
Tel 787-764-0000 ext 2767, e-mail iveruiz@hotmail.com, iveruiz@yahoo.com

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1. Abstract

The human population is rapidly growing, but the size of planet Earth remains the same. Thus, material resources to support each additional person continue to decrease. Local die back of human populations is a repeated theme in our history. How many human civilizations have survived intact to 1000 years? Are we managing the human and life support resources for sustainable quality of life? What alternative spatial arrangements of land uses might facilitate sustainability?

We are developing a conceptual package of field measurements, remote sensing and model simulation that will enable resource managers to explore spatially explicit alternative resource uses that may enhance sustainability. For the Haines and Peterson project, “Research towards sustainable land use and biodiversity in a mosaic of agriculture and tropical forest in Costa Rica,” we are characterizing the process regulating regeneration of forests on abandoned agricultural lands. Consultation by Haines and Ruiz-Bernard in Costa Rica in June-July 2002 with people at EARTH University, at the Coopabuena coffee cooperative, at the Las Cruces Biological Station, at Finca Loma Linda and at VOLCAFE increased our opportunities to collaborate in addressing basic science and policy in the arena of sustainability.

We found that some groups working towards sustainability are not aware of each other’s programs. We see opportunities to increase communication between interested parties within Costa Rica and to expand the experiences of students at EARTH University so that following their graduation and return to their home countries, they can promote more sustainable resource use and human communities. The participation of EARTH University in International Long-Term Ecological Research (ILTER) - Costa Rica will enhance student understanding of the need for global cooperation in management of our planet EARTH’s life support system. Collaborations between Haines and present and past EARTH University students and faculty will continue.

2. EARTH University

2.1 First Visit 6 and 7 June 2002

2.1.1. Getting Acquainted

The purpose of the first visit during 6 and 7 June was to become acquainted with faculty, facilities and vegetation cover at EARTH University (Figure 1). Plans for collaborative research on forest regeneration were developed with **Dr. Ricardo Russo**.

2.1.2. Chronosequence study of forest regeneration

The first project is a chronosequence study in



(Figure 1) Graduate Students Maria Giraldo (University of Georgia) and Ivelisse Ruiz-Bernard (University of Puerto Rico) stretch their legs after bus ride from San Jose to Earth University gateway.

which patches of regenerating forest are identified through interviews with people who worked the land prior to the establishment of EARTH University. Once patches are identified and the land use histories are recorded, structural characteristics of vegetation patches of different ages will be quantified. From chronosequence data we can reconstruct growth rates of the forest. Presently most data on forest regeneration in the Caribbean Lowlands of Costa Rica come from tree plantation trials, mostly at the near by OTS La Selva Biological Station. Little is known about rates of “natural” or “volunteer” forest regeneration.

If land use managers and planners wanted to explore alternative future land uses they would find chronosequence data on forest regeneration to be an important planning tool. Among other benefits, chronosequence data enables managers and planners to estimate how many years will be required to convert land uses such as cattle pasture, cacao plantations, sugar cane field, and banana plantations back to forest.

2.2 Second Visit July 16-18, 2002

2.2.1 Land use histories from interviews of local people

Dr. Russo provided Ruiz-Bernard and Haines with a list of local people who had worked or presently work on what is now the EARTH University property. Dr. Russo introduced us to Sr. **Mario Nunez (Chiquitin)**, resident of Pocora, who then introduced us to additional workers. Chiquitin showed us various field sites suggested by Dr. Russo. Following interviews (Figure 2) and visits to field sites, Ruiz-Bernard provided Dr. Russo with a synopsis, in Spanish, of land use histories for seven sites on EARTH University property.

Now that study sites have been identified, protocols for quantifying vegetation need to be developed in collaboration with Dr. Russo and Dr. Chris Peterson.

2.2.2 Need for Herbarium at EARTH University

Further development of the herbarium of EARTH University will be needed to house working collections of plants from our forest sampling that we are trying to identify. Later the identified voucher specimens can be used by future generations of students to learn to recognize plants on their campus. Access to a computer will be needed with which data from the forest plots can be recorded.

2.2.3 Long-term tree growth studies

Chronosequence studies do not provide data on long-term growth characteristics of individual trees. Chronosequence studies are less likely to have the educational value to students of EARTH University than will long term studies of individual trees that generations of students could measure and re-measure for decades and centuries into the future.



(Figure 2) Land use histories were obtained through interviews with people who had worked the land before and after the establishment of EARTH University. From left to right, **Senora Carrazo, Senor Don Guillermo Carrazo, and Senor Mario Nunez (Chiquitin)** in the Carrazo home at La Mercedes de Guacimo, CR. Don Carrazo has lived and worked for 69 of his 89 years in Guacimo.



(Figure 3) Active coffee finca (left) and 50 year old forest (right) where trees were identified and measured.

In this study the annual growth rates (increments of diameter growth) will be evaluated for permanently marked trees. This study will be valuable both for basic science and for training students about the relevance of basic science and long term studies in developing long-term land use plans in their home countries. As the human population grows, increasing the demands on agricultural and natural resources, there is an increasing need for developing long term resource management plans for sustainability of our life support system.

The relevance of long-term tree growth studies for basic science is illustrated by results of a

long term study at the La Selva Biological Station where Clark, Clark et al found year to year variance in diameter growth in trees. Attempts to explain these variations lead Clark, Clark et al to the realization that the abilities of tropical rain forests to sequester carbon dioxide from the atmosphere into plants and soils varied from year to year. Further, the computer simulation models used to forecast abilities of tropical forests to ameliorate the problem of increasing global atmospheric CO₂ were using inaccurate data for CO₂ uptake by tropical forests. The findings of Clark, Clark et al resulted in a study of carbon dioxide exchange between the forest and the bulk atmosphere in relation to climatic variables. This multi-investigator, long term study of carbon dynamics in the forest at La Selva was funded by the US National Science Foundation, the US Dept. of Agriculture and other agencies. It provides important basic science information for the management for our EARTH life support systems. Long-term studies at EARTH University may also generate unexpected and surprising results.

The results of chronosequence studies and long-term tree growth studies at EARTH University in the Caribbean lowlands (at less than 100 meters elevation) can be compared to parallel studies in San Vito vicinity at greater than 1000 meters elevation. This comparative research between hot and wet lowland forests and cooler and wet high elevation forests will help students learn through hands-on experience about environmental controls to forest production.

3. San Vito, Coto Brus, Costa Rica

3.1. Forest chronosequence study at San Vito vicinity

In the San Vito region, landowners were interviewed during June 2002 to identify regenerating forest patches on abandoned agricultural lands. Identified abandoned lands included those used for growing beans, coffee and cattle pastures. The most useful information was obtained at Finca Loma Linda, Agua Buena, Coto Brus, where owner **Darryl Cole** identified patches of old growth forest that were about 500 years old (Figure 3) and patches of forest regenerating on agricultural lands that he had abandoned to forest succession in 1952, 1962, 1964, 1973, 1990 and 1991. With the assistance of his farm staff, we observed local wild life (Figure 4) and put number tags on more than 327 individual

trees. We measured and recorded the diameters of each of these trees (Figure 5). Sometimes on our breaks from tree measuring, we visited with people on adjacent farms (Figure 6). All trees have been identified to local Spanish common names. Voucher specimens were obtained from the trees and identified by personnel of InBio (Heredia, Costa Rica) and of the Herbario Nacional, Museo Nacional (San Jose, Costa Rica).

These data will be used to test the validity of a forest regeneration model, FOREST INVASION, being developed by Dr. Peterson, Dept. of Plant Biology, UGA. Existing forest regeneration models (Zelig, Sortie, and others) are designed to simulate regeneration of forest where falling trees have created gaps in the forest canopy. They are not designed to simulate growth of forest outward from forest fragments into abandoned agricultural lands such as those commonly found in tropical America. Abandoned banana plantations, cattle pastures, and coffee fincas are examples of abandoned agricultural lands in Costa Rica. The model FOREST INVASION is being developed to simulate the colonization of abandoned cattle pastures by seeds of plants in existing forest fragments in the landscape of San Vito.

Results from Haines, Ruiz-Bernard, Peterson and Cole-Christensen chronosequence study were present at the Ecological Society of America annual meeting 2003 in Savannah, Georgia, in August 2003.

3.2 Sustainable coffee production, San Vito

The long term goals and preliminary findings of the Haines and Peterson project titled “Research towards sustainable land use and biodiversity in a mosaic of agriculture and tropical forest, Costa Rica” were presented to the “Coopabuena” coffee growers cooperative administration in Coopabuena, Coto Brus, Costa Rica on July 1, 2002. This presentation was made with PowerPoint software into color slides and presented in Spanish as “Investigacion hacia el uso sustentable de tierra y biodiversidad en un mosaico de agricultura y bosque tropical” by Ruiz-Bernard. The Coopabuena coffee growers cooperative was established in the 1930’s and presently has 1,300 members. This group is concerned with falling global coffee prices, the economic futures of their members, their ability to sustain themselves in the region, and their ability to conserve their land. Soil erosion and land slumping are clearly recognized long-term environmental problems. Following this presentation, the leaders of the cooperative took us on a tour to show us their erosion problems and their group efforts at forest restoration on one degraded site. One member showed us his “organic” coffee farm.

3.3 Programa Pueblos

This is a community based sustainability project with an office in Coopabuena, Coto Brus. It has a team of scientific advisors-collaborators from several North American universities including



(Figure 4) Wildlife included this Eyelash viper, *Bothrops schlegelii*, on a shrub in the forest understorey.

Evergreen State, Univ. of Calif., Santa Cruz, and UGA.

Their most pressing concern at present is marketing their coffee in such a way as to capture a larger fraction of the retail sale price. They are also concerned with alternative cropping strategies, soil erosion etc. etc.

3.4 *Volcafe*

VOLCAFE is a Swiss owned company, coffee farm near the town of Rio Negro, north of San Vito, Coto Brus, Costa Rica. Noteworthy features of this commercial operation are a) use of shade plants over the coffee. Shade plants favor the presence of wildlife, b) use of organic mulches in place of “inorganic chemical fertilizers”, c) vegetation buffers to minimize soil erosion and nutrient run-off into streams, d) use of a natural organic compound (as opposed to a synthetic chemical) to control nematode infestations, d) wood fired coffee driers (as opposed to fossil fuel fired driers), e) water renovation ponds to remove nutrients and organic matter from coffee bean processing waste water before the waters are returned to the stream, f) health care clinics for seasonal coffee pickers, and g) day care facilities for children of the coffee pickers.



(Figure 5) Tree being measured by Senor Roman (on tree) and Bruce Haines while Ivelisse (partly hidden) records the data.

4. General Impressions

4.1 *Sustainability*

There is an increasing interest in resources management for sustainability. EARTH University is strong promoter and practitioner of sustainability.

Some people interested in sustainability in Costa Rica either have not heard of EARTH University or know little about its programs. One example is the *Programa Pueblos*. Its organizers know very little about the work of EARTH University towards sustainable resource use.

We see opportunities for students at EARTH University to interact with other groups working on sustainability issues. Graduates from EARTH University can take their experiences with sustainability issues back to their home countries. We also realize that there will be problems of transporting EARTH University students to off-campus sites where they could interact with other groups.

4.2 *Long Term Ecological Research (LTER)*.

4.2.1 *The Global Challenge*

As the human population continues to expand on planet EARTH, there is a need to better understand how natural resources and humans can interact in a more sustainable manner. In 1980 the US Na-

tional Science Foundation established a Long-Term Ecological Research program (www.lternet.edu) in the conterminous USA including Antarctica. Subsequently this network has expanded into an International Long Term Ecological Research network (www.ilternet.edu) with 24 additional countries. Each of these countries supports their own research sites. Costa Rica is part of the ILTER network.

4.2.2. International Long Term Ecological Research (ILTER) Sites In Costa Rica.

The ILTER sites in Costa Rica are:

- Marine Biology Station-Universidad Nacional
- Cloud Forest Reserve Monteverde
- Biological Reserve Alberto M. Brenes at San Ramon
- OET / OTS La Selva Biological Station
- OET / OTS Las Cruces Biological Station
- OET / OTS Palo Verde Biological Station

See <http://crlter.ots.ac.cr/sites1.shtm> for details.

4.2.3 Potential roles of EARTH University and University of Georgia, San Luis in ILTER

We believe that EARTH University and the San Luis facility of the University of Georgia Study Abroad Program in Guanacaste, Costa Rica should join the ILTER Costa Rica network. Membership in ILTER Costa Rica facilitates:

- Information exchanges between investigators throughout the world having related interests
- Development of collaborative research across large spatial scales and long time scales
- Data archival to preserve data for use by future generations
- Realization by students at EARTH University and at UGA Study Abroad site that regardless politics, religion, national origin and gender, humans share the oceans, the atmosphere and the lands. For example, dust from Africa comes in the atmosphere to the Americas and air from Asia can bring black carbon and nitrogen to the Americas. El Nino and La Nina phenomena affect people in Africa, America, Australia and Asia.
- Contributions by students to database on global ecology

One example of the need for information exchanges among investigators over large spatial and time scales is research into the biophysical controls of the leaf-cutting ant in the Americas. Leaf-cutting ants (*Atta*) in the Americas are comprised of 15 species which range from Texas and Louisiana, USA, southward through Mexico, Guatemala, Costa Rica, Panama, Colombia, and most of South America down to Argentina. *Atta* are the single most important insect pest in agriculture in the Americas. *Atta* are a problem common to most of Latin America. Collaborative studies of control measures could be facilitated through the ILTER



(Figure 6) Ivelisse Ruiz takes a break from measuring trees to talk with children in adjacent coffee finca.

network within Latin America. We suspect that there are bits and pieces of knowledge in conventional scientific literature and especially in the oral traditions of indigenous peoples that could be used to develop vegetation and land use management strategies to minimize loss of crops to these insect pests. The investigation of *Atta* through ILTER has not started. Haines is trying to facilitate development of an ILTER-Ecuador network and would like to start an *Atta* research program from ILTER-Ecuador. Maybe this could be better started from an ILTER-Costa Rica - EARTH University agricultural ecology site.

Data archival becomes an essential component of large scale and long-term studies. The ILTER - Costa Rica web site has a page dealing with data archival and lists presently available "Meta Data" for Costa Rica.

Many other examples of benefits of ILTER could be sketched out. In Latin America the networks are best developed in Venezuela and in Brazil (www.ilter.edu). Uruguay has a network. Although Colombia is listed as having a network, they do not have an active web site.

5. Collaborations between EARTH University and University of Georgia facilitated by Bruce Haines back in Georgia during fall semester 2002

5.1. Getting Acquainted Athens

On September 14, 2002 Haines organized a lunch session at the State Botanical Garden with:

- **Andre Garcia**, Exchange student from EARTH University during fall of 2002 who is a citizen from Ecuador
- **Adriana Rodriguez**, Exchange student from EARTH University during fall 2002 who is a citizen of Costa Rica
- **Sarah Hemmings**, third year student at UGA who is majoring in Anthropology and Ecology. She was in Costa Rica first for the "MayMester" program at the UGA Ecodge, San Luis facility and later was a volunteer at another field station. She is a citizen of Canada.
- **Oscar Sierra**, UGA student in food science, who works in the CLACS office and is from Mexico.

The goal of this lunch session was to welcome Andre and Adriana and to introduce them to current undergraduate students at UGA.

5.2 Water Resource Management

Maria Ruth Martinez, graduate of EARTH University in December 2001, and Adriana Rodriguez expressed interest in learning more about water resource management. Haines took them on a one day excursion of the U.S. Forest Service, Coweeta Hydrologic Lab, Otto, North Carolina (Figures 7 & 8). The goal was to help them visualize how water resource management studies could be done in their country, Costa Rica.



(Figure 7) Earth University students Adriana Rodriguez (left) and Maria Ruth Martinez (not shown) visit US Forest Service Coweeta Hydrologic Lab, North Carolina with Bruce Haines (right).

5.3 Consultation With EARTH University Faculty

On October 24, Haines and Martinez took EARTH University Faculty members **Dr. Daniel Sherrard** and **Dr. Carlos Hernandez** to the State Botanical Garden for a lunch time consultation on research collaborations between EARTH University and UGA. We also discussed possible research topics that Haines could suggest for EARTH University students to work on for their required senior theses. They suggested that Haines develop some alternative senior thesis plans for current year EARTH University and exchange student Adriana Rodriguez.

After lunch, we showed Drs. Sherrard and Hernandez the UGA “Bioconversion” facility for composting plant and animal wastes. Hernandez works on bioconversion of wastes into organic fertilizers at EARTH University. He was very interested in learning about this related program at UGA.

5.4 Recruitment To Graduate School At University of Georgia

Maria Ruth Martinez came to UGA from October 1-27, 2002 to work on applications for Graduate Study. She used Haines’ laboratory space and computers to study for her Graduate Record Exam (GRE) and to arrange interviews with potential professors in Agricultural Engineering, Anthropology, and Ecology. Haines provided constructive criticisms of various drafts of her Curriculum Vitae (Resume), statement of career goals, and other matters while she was in Athens. Subsequently she was admitted to the Ph.D. program in Anthropology and awarded a Graduate School Assistantship.

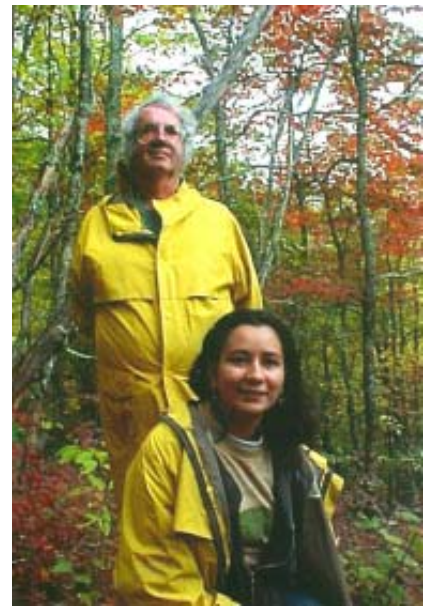
5.5 Ideas for senior thesis for Adriana Rodriguez

Drs. Sherrard and Hernandez suggested that Haines help Adriana Rodriguez (EARTH University, Class of 2003) develop ideas for her senior research project. She was interested in use of natural plant products to control pests in agriculture. Adriana and Haines sketched out short-term experiments that she and her faculty advisor, **Dr. Bert Kohlmann**, could consider implementing during spring and summer 2003. The authors and titles for two potential thesis projects are:

- Rodriguez, A., B. Kohlmann, and B. Haines. Potential control of nematodes and root rot fungi on crop plants by companion planting with toxic sulfur gas emitting legumes.
- Rodriguez, A., B. Kohlmann, and B. Haines. Potential control of leaf-cutting ants by use of toxic plants.

Both of these studies are potentially important in the control of agricultural pests in tropical American agriculture. Further, they are of great interest to Haines, but because he mostly lives in Georgia, he is unable to do these studies himself in the American topics. This proposed collaboration helps each Adriana and Bruce Haines in our career development.

In return for assistance from Haines with her senior thesis projects, Adriana has agreed to help Haines interact with people in Costa Rica who work on hydrology. This means taking Haines to their offices and helping with English-Spanish translations. We hoped that this would become a fruitful collaboration in solving some important agricultural-ecological problems.



(Figure 8) Maria Ruth and Bruce Haines enjoy fall colors and a bit of rain at Coweeta Hydrologic Lab.

5.6 Recognition of plant families: tutorials for Adriana Rodriguez in Botany greenhouses

Adriana was very interested in plant biology but she has yet to learn to recognize plant families. Several visits were made with Bruce Haines to Botany greenhouses with notebooks, plant family books, and a digital camera to help Adriana learn this useful skill.

6. Collaborations between EARTH University and University of Georgia facilitated by Haines while in Georgia during school year 2002-2003.

Mario Giraldo was a graduate student in Geography at UGA. His major professor was **Dr. Fausto Sarmiento**. Mario developed a Geographic Information System (GIS) data base both for his thesis and for EARTH University. This database is comprised of maps of historical land uses and will be a useful management tool for faculty and staff of EARTH University. EARTH University faculty Drs Sherrard, Russo, and Kohlmann reviewed Giraldo's work and offered suggestions for improvement. During spring semester 2003 Giraldo worked on his EARTH University GIS project for course credit in "Special Topics on Botanical Research" under the direction of Haines. Mario graduated with his Masters Degree in Summer 2003. The completed thesis is available on-line at the UGA library web site.

The Fall 2003 exchange students from EARTH University to UGA were **Timothy Mesh**, citizen of Belize, and **Gabriella Anna Leon**, citizen of Guatemala.

Among the activities to welcome them to UGA, Haines took them, as well as scientists from Puerto Rico and Taiwan, to the US Forest Service Hydrologic Lab, North Carolina (Figures 9 & 10). Lively discussions of vegetation and water management occurred in this truly international tour group.

Again, following the earlier suggestion from EARTH University's Sherrard and Hernandez, Haines discussed several senior research project topics with Timothy and Gabriella that they could perform at the EARTH University campus. Learning that Adriana Rodriguez had lost interest in the proposed study, Gabriella Leon decided to perform the study of "Potential control of nematodes and root rot fungi on crop plants by companion planting with toxic sulfur gas emitting legumes."



(Figure 9) The October 2003 tour of the Coweeta Hydrologic Lab included (left to right) Gabriella Leon (EARTH University student, citizen of Guatemala), Dr. Grizelle Gonzalez (US Forest Service, Puerto Rico), Timothy Mesh (EARTH University student, citizen of Belize) and Yu-yun Chen (UGA, graduate student in Plant Biology, citizen of Taiwan).

7. Consultation at EARTH University by Bruce Haines in April 2003

During March and April, Haines participated in the 40th Birthday Celebration of the Organization for Tropical Studies (OTS) in Costa Rica where he gave an oral presentation and several poster presentations about the Haines and Peterson sustainability project at San Vito, Costa Rica. This was followed by consultations with **Emory Black**, Kohlmann, Sherrard, **Jeanne Fossani** (Professor of English),

and Russo. Emory very graciously met me at the main gate, showed me his office where he was negotiating the trade of money from Europe to EARTH University for sequestration of atmospheric carbon in trees at EARTH University, arranged for my lodging and introduced me to Professor Kohlmann. Maps for Giraldo's thesis were discussed with Sherrard, Kohlmann and Russo. A copy of the Haines and Peterson poster about our sustainability research in San Vito was left with Professor Russo. Results of the chronosequence study in San Vito were also discussed with Professor Russo, who offered many suggestions for follow-up studies and said that he was eager to work with us on parallel chronosequence studies at EARTH University.

8. EARTH University people attend Ecological Society of America (ESA) Annual Meeting, August 2003, Savannah, Georgia

Following the urging of Haines, Professor Fossani and Maria Ruth came to Georgia in August. Maria Ruth came to start graduate school, while Jeanne interviewed for admission to graduate study at UGA. Both of them expanded their ecological horizons by participating in the ESA meeting.

9. Haines, Ruiz-Bernard, Peterson, and Cole-Christensen present a research paper at Ecological Society of America (ESA) Annual Meeting, August 2003, Savannah, Georgia

The title of our paper was "Pre-montane forest succession reconstructed from a chronosequence in Costa Rica." Research was performed at Agua Buena, Coto Brus, Costa Rica and was partly supported by the Exposition Foundation, Inc. A manuscript is being prepared for submission to the journal *Forest Ecology and Management* for publication.

10. Future collaboration with EARTH University Faculty: forest succession reconstruction from a chronosequence.

Haines and Peterson plan to work with Russo at EARTH University sometime in April-May 2004 to lay out the sampling transects within the forest patches that were selected earlier for the chronosequence study.

Haines wants to return to EARTH University during part of the fall semester 2004 to work with field assistants or a graduate student to mark, measure, and identify the trees on the sampling transects.

11. Future collaborations with exchange students from EARTH University to the University of Georgia.



(Figure 10) Bruce Haines shows Dr. Grizelle Gonzalez and Gabriella Leon (wearing hat) various sampling devices in a forested watershed at the U.S. Forest Service Coweeta Hydrologic Lab, North Carolina.

Haines plans to welcome each new group of exchange students from EARTH University who come to UGA. Haines' goals are to discover potential mutual research interests, to assist with applications to Graduate Schools, and to maintain long term professional contacts and possible collaborations with those students upon their return to their home countries. Recruitment of Maria Ruth to Graduate School at UGA is a success story. Gabriella Leon has subsequently expressed interest in graduate study at UGA.

12. Acknowledgements

We thank the Exposition Fund, Inc., Atlanta, Georgia for financial support, the faculty and staff at EARTH University for their hospitality and logistical assistance and the staff of the Organization for Tropical Studies for their hospitality and logistical support. We look forward to future collaborations.

