



# TROPICAL RESOURCES

The Bulletin of the Yale Tropical Resources Institute  
2014 Thirtieth Anniversary Special Issue

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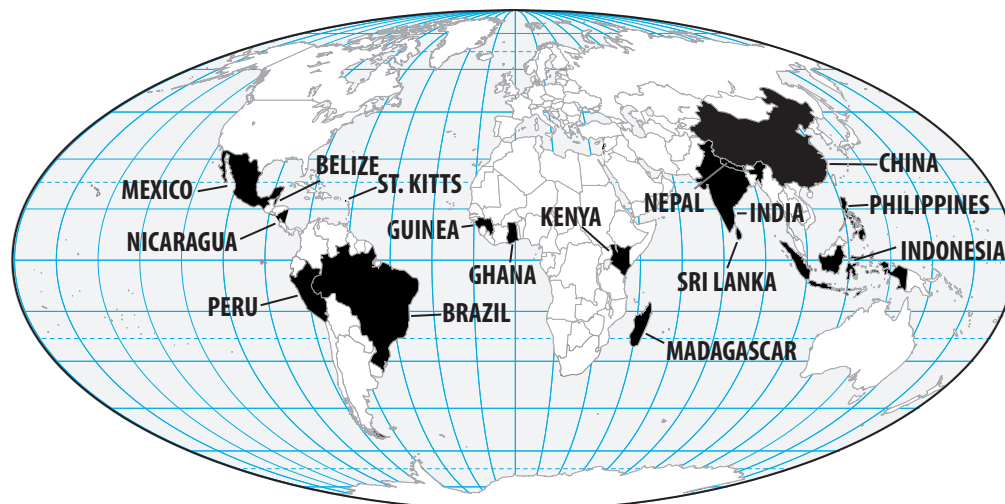


## **Mission**

The Mission of the Tropical Resources Institute is to support interdisciplinary, problem-oriented research to understand and address the most complex challenges confronting the management of tropical resources worldwide. Lasting solutions will be achieved through the integration of social and economic needs with ecological realities, the strengthening of local institutions in collaborative relationships with international networks, the transfer of knowledge and skills between local, national, and international actors and the training and education of a cadre of future environmental leaders.

The problems surrounding the management of tropical resources are rapidly increasing in complexity, while demands on those resources are expanding exponentially. Emerging structures of global environmental governance and local conflicts over land use and environmental conservation require new strategies and leaders who are able to function across a diversity of disciplines and sectors and at local and global scales. The Tropical Resources Institute seeks to train students to be leaders in this new era, leveraging resources, knowledge, and expertise among governments, scientists, NGOs, and communities to provide the information and tools this new generation will require to equitably address the challenges ahead.

## TRI Research Sites Represented in This Issue



|                             |                                      |
|-----------------------------|--------------------------------------|
| <b>Belize:</b>              | Angela Quiros                        |
| <b>Brazil:</b>              | Daniel Nepstad<br>Hugh Raffles       |
| <b>China:</b>               | Janet Sturgeon                       |
| <b>Ghana:</b>               | Dora Nsuwa Cudjoe                    |
| <b>Guinea:</b>              | Stephen Wood                         |
| <b>India:</b>               | Ramachandra Guha                     |
| <b>Indonesia:</b>           | Amity Doolittle                      |
| <b>Kenya:</b>               | William Collier                      |
| <b>Mexico:</b>              | Andrew Mathews<br>Laura Snook        |
| <b>Madagascar:</b>          | Eleanor Sterling<br>Betsy Carlson    |
| <b>Nepal:</b>               | Maureen DeCoursey<br>Anne Rademacher |
| <b>Nicaragua:</b>           | Richard Chávez                       |
| <b>Peru:</b>                | Miguel Pinedo-Vasquez                |
| <b>Philippines:</b>         | Angela Quiros                        |
| <b>St. Kitts and Nevis:</b> | Erin Kellogg                         |

# Foreword to the Anniversary Edition

*Outgoing TRI Director, Michael R. Dove*

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This special issue of the Bulletin of the Tropical Resources Institute commemorates the 30<sup>th</sup> anniversary of the founding of TRI. It offers an apt moment to reflect on three decades of support by TRI of research in the tropics by F&ES students. These have been enormously important decades for tropical peoples and environments. Over the course of these three decades, human degradation and conservation of the tropics both became prominent topics in global science and the popular imagination. This period saw the rise of tropical deforestation and biodiversity loss as major global environmental discourses. Anxiety was fed by the first great conflagrations striking the forests of Sumatra and Kalimantan and enveloping the entire Southeast Asian region in smoke. During this time the global community saw for the first time differentiation within tropical countries as locals battled fellow nationals for control of their own lands and resources, as in the famous Penan blockades of logging roads in Malaysian Sarawak, and in the rise of the rubber tappers' movement in the Amazon, whose charismatic leader Chico Mendes was assassinated in 1988. Such movements led to the development of completely novel global linkages, which involved non-tropical peoples in tropical affairs in new ways, as in visits of political support by the rock musician Sting to the Kayapo in the Brazilian Amazon. This period saw the development of completely novel economic and policy mechanisms to try to help conserve tropical forests – such as timber boycotts and certification – and at the same time assist communities

living in these forests – by means of extractive reserves, the marketing of rainforest products, and collaboration with native peoples to identify plants with medicinal properties.

In short, these were three decades with profound consequences for the peoples and environments of the global tropics, and the conservation and development science and policy devoted to them. During this period TRI came into being and grew into its current status as the most important source of funding at Yale for student field studies in the tropics. We might say, indeed, that over these three decades, TRI, the tropics, science, and policy all co-evolved – as also suggested by Emeritus Professor William Burch Jr., the first Director of TRI, in his own wonderful, lyrical essay in the pages to follow.

A review of the authors reporting on their research in the TRI Bulletin over this three-decade period reads like a 'Who's Who' of tropical studies. Many of today's leaders in academic and policy circles were early contributors to the Bulletin, including several current Yale faculty. The topics studied evolved over the years, in keeping with trends in the academic and policy worlds (as discussed in the following article "Reflections on Reading 30 Years of TRI Bulletins", by the TRI Program Assistants Dana Baker, Sarah Tolbert, and Emily Zink). But they all have one thing in common, which perhaps reflects the mission of TRI's home institution, the Yale School of Forestry and Environmental Studies. F&ES occupies an unusual niche in North American academia, in

purposely linking both natural science and social science, and theoretical study and application or practice. Just as F&ES is dedicated as an institution to crossing these sacrosanct academic boundaries, so too do we see in these articles an analogous effort to cross boundaries or borders. The fundamental dynamic of the research in all of these studies from the Bulletin is based on crossing lines, on linking things that are not usually linked – places, disciplines, topics, methods, observer and observed, nature and culture – and in all cases this becomes a source of special insight.

Thus, in the 1980s we have both Ramachandra Guha and Mark Ashton crossing geographic borders, drawing unusual comparisons between South Asia (India and Sri Lanka, respectively) and North America. Crossing disciplinary borders, we have a pioneering study of urban political ecology in Kathmandu, Nepal by Anne Rademacher, and a study of lemurs in Madagascar by Eleanor Sterling and Betsy Carlson, the former being one of the first candidates in the unique joint doctoral program between F&ES and Yale's Anthropology Department. We also have studies of hybrid topics, which bring together in a single study subjects not typically combined, like Andrew Mathew's study of the political intellectual history of both the forest service and forest communities in Mexico, and Janet Sturgeon's study of the performance under Chinese governance of social forestry approaches developed under very different political regimes.

Perhaps the most common boundary-crossing represented by the studies in this issue is that between different methodologies, producing hybrid methods. While nearly all of the studies reprinted here do this to some extent, there are several especially clear examples: thus, Laura Snook combines local oral history with silvicultural techniques to

date and study stands of mahogany in Mexico; Richard Chávez melds the application of GIS techniques with the Universal Soil Loss Equation; and Hui Cheng brings real-world evidence and insights to bear on her laboratory modeling of a shrimp farm. Other examples involve one of the most recent additions to the list of topics studied at F&ES, which currently dominates the school in some respects, global climate change: William Collier combines approaches from anthropology and history to examine the impact of climate change on agriculture in Kenya; and Stephan Wood combines insights from economics and anthropology to examine the same topic in northern Guinea and southern Senegal.

Most of the studies look at both nature and culture, but some do this systematically: Angela Quiros, Dora Nsuwa Cudjoe, and Maureen DeCoursey each examine impacts (from ecotourism, craft production, and the medicinal plant trade, respectively) on both the environment and the human community. Some of the earlier articles in the Bulletin laid the basis for extremely influential later work by the scholars involved by legitimizing the study of environments showing both natural and cultural influences – that is, 'anthropogenic' environments – the study of which is commonplace today but was not a generation or two ago. Thus, we have Daniel Nepstad's study of pastures that have been cut out of the Amazonian forest and then abandoned; Miguel Pinedo-Vasquez' study of traditional management of forests in the Peruvian Amazon; and Hugh Raffles' study of human-made waterways in the Amazon estuary.

Finally, some of the studies presented here reflect the increasingly blurred boundaries between observer and observed that F&ES students and professors alike now encounter in the field: thus, Erin Kellogg writes

about an environmental NGO that she worked for in St. Kitts-Nevis in the Caribbean; and Doolittle discusses the varying expectations from her own work of the NGOs and local communities with whom she collaborated in Kalimantan, Indonesia.

Taken as a whole, the body of work presented here shows the potential benefits of de-naturalizing the boundaries of tropical studies – asking new sorts of questions, exploring them with new sorts of methods, with new sorts of ends in mind.



# Reflections on Reading 30 Years of TRI Bulletins

*Dana Baker, Sarah Tolbert & Emily Zink  
2013 – 2014 TRI Program Assistants*

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To commemorate the 30th anniversary of the Tropical Resources Institute, we embarked upon a project to explore the evolution and history of the Institute. Delving into past Bulletin articles, research and faculty profiles, and past collaborative partnerships from across the globe, we spent the fall of 2013 reading and cataloguing 260 articles published from 1986 to the present. After indexing each article, we pulled out the major and minor themes, and examined where the research was conducted. The use of wordles, or word maps, gave us the chance to visualize how students' research reflected the changing challenges, understandings, and pursuits in environmental studies. Although this project started with the aim of understanding the history of TRI, our research gave us insight into how conceptions of tropical resources have evolved over time.

In 1986, the publication, then known as *TRI News*, began as a way to disseminate news from research stations across the globe before the time of internet and email. Now the bulletin, known as *Tropical Resources*, gives fellows the opportunity to publish and share summer research findings. Tropical Resources encourages fellows to think creatively about their research. The articles selected for this Anniversary Issue provide a glimpse into the history of the Institute and represent the breadth and diversity of research conducted by TRI fellows.

For 30 years, TRI has given fellows the space to creatively research social, political, and environmental issues in the tropics. Fellows are allowed the freedom to move beyond orthodox science and thus have reshaped and collectively redefined ideas of natural resources, from logging in Amazonia (Nepstad 1989) to a study of whale shark tourism in Belize (Quiros 2005). TRI's presence in this work has taken fellows all over the world, with over 58 countries represented in the published Bulletins since 1986. While the research articles we analyzed are dominated by studies in Latin American countries, fellows have increasingly expanded their research to include countries in Asia and Africa.

One of the most significant transitions we observed was the changing perception of what a natural resource is. In 1986, most student research was rooted in the natural sciences. Research topics were dominated by studies of material physical resources such as forests, wildlife, and natural resource management. However, a noticeable shift occurred as students started to conceptualize natural resources in increasingly abstract ways. While many students continue to study physical resources, current research now incorporates social science frameworks by blending traditional scientific methodologies with ethnographic and social studies. Today, there is a greater emphasis on development and policy, ecological economics,

indigenous knowledge, and climate change in the tropics.

Yet the work does not end there. The challenges facing our generation continue to morph and our education and traditional disciplines must follow suit. Like the fellows before us, we continue to feel a sense of urgency as the breadth of challenges facing the global community grows. Natural resources continue to be extracted in unsustainable ways, communities lack access to clean water and healthy food, species are going extinct, climates are changing, and poverty persists. But as researchers, citizens, and expats who have lived abroad, we remain cautiously op-

timistic. The boundaries of the environmental studies field are expanding and the silos of traditional disciplines are being challenged. We now realize that scientific orthodoxy alone will not solve the social, political, and environmental problems persisting on the global scale. At the beginning of this 30th anniversary of TRI's special edition, we echo the words of TRI's founder, Bill Burch, at the 2014 TRI symposium: we challenge both current and past fellows today to break free from the frameworks of traditional scientific research to create new responses to global problems that cross borders, traditional disciplines, and world cultures.



Countries represented in *TRI News* and *TRI Bulletin* research articles, 1986 - Present

# The More We Circle Back, The More We Circle Back—TRI At 30

*William R. Burch, Jr.*

*Emeritus Hixon Professor of Natural Resource Management*

*Senior Research Fellow—FES Yale University*

## **Legends**

Time markers are one of the most ancient and significant ways by which humans force order upon an ever changing world. In 2014 the Tropical Resources Institute (TRI) will mark its 30<sup>th</sup> year of service. Like other social institutions it cautiously approaches the middle of its life cycle wondering what the past might tell us about its future. Certainly it is a convenient point to recover and emphasize the legends about its origins. Like our families, religious organizations, educational corporations, sports teams and other organizations that we live within we want a consistent narrative that tells us about how our social commons came to be. We want a back story that gives us lessons learned from the mistakes made, hopes lost, visions won, legacies sustained. Like most extended families we have our jokes and anecdotes and stories we tell the next generation so it can follow or re-direct the next phase of the family legend. The stories we share give substance to our identity and strengthen the power of our efforts because they are joined in common interest. All communities whether family or scholarly need legends to sustain their bond and to resist the tendencies, internal or external, seeking their demise.

The narrative about the TRI start-up is certainly one part of its legend. There is no question that your individual work is attributable to your particular wit and wisdom and hard struggle. However, it is wise to re-

member the Hindu tree of learning where all the many people who have contributed to your effort surround you and up near the canopy are all the people who will be dependent upon the work you leave behind. It is that humble fact that informs the TRI legend. As Mercatante (1988:17) notes:

Legend, derived from the Latin word for ‘to gather, select, read,’ and similar to the Greek word for ‘to gather,’ is often confused with myth. As with myth, a legend is an anonymous traditional story passed on from one generation to another. But whereas a myth has gods and goddesses as its main characters, a legend has historical personages, such as Charlemagne, El Cid, Muhammad, St Francis of Assisi, or Billy the Kid.

He notes later that tellers of myths believe them to be absolutely true while a legend is not necessarily true. So our journey here is not the stuff of myth but one part of an ongoing legend to which the present and future will amend and refer to and feel ownership and even a push of pride.

## **Origins**

As the first faculty director of the Institute I have one perspective on the origins, hopes, structures and contributors in its evo-

lution. My part of the legend begins in the late 1970s and ends in the early 1990s. To me it is less a story of particular individuals but rather a coming together of many to form a community dedicated to serving local people in their tropical environment and the training of future natural resource professionals to carry out their practice. I will try to note many of the ideas and persons who made this venture possible and some of the trials and tricks of survival it followed. If I have forgotten some persons or events it is not intentional but more the slide of time passing through an opaque vision filtered by the rear view mirror.

The legend originates with student demand for the School to be a major force in challenging global trends in natural resource conservation. This demand was powered by an angry ecologist, two activist deans and a troop of Peace Corps vets and other revolutionary students that moved a modest School of Forestry fully onto a global stage. My role was as a translator and cheer leader of these several voices.

Ecologist Herb Bormann along with Gene Likens and other colleagues at the Hubbard Brook Long Term Ecosystem study project were demonstrating the global linkages of insults to the earth. They determined that Acid Rain killing lakes in northeastern forests came from energy plants in the Midwest. They saw the biogeochemical impact of many timber cutting practices as non-sustainable and connected this to the high rates of deforestation in tropical forests with critical global consequences. They made ecology an experimental science serving complex human ecosystems. Herb wanted to have more attention given to the tropics and along with Tom Siccama organized student field trips to Puerto Rico over Spring Break to raise awareness and give some empirical base for understanding such ecosystems.

Dean Francois Mergen had been working on forest genetics in tropical forests for some time. In 1969 he led a multidisciplinary team to work with the Bombay Natural History Society on research needs for sustaining the habitat of the last refuge for the Asian lion in the Gir Forest, Gujarat, India. He organized a major conference on Tropical Forestry in 1981 that brought leaders in the field from all over the world. He guided the School toward a broader outlook in changing its name to School of Forestry and Environmental Studies. The idea of environmental studies was to open the participation of students in humanities, arts and social sciences as equal and necessary parts of international ecosystem management efforts.

Dean John Gordon expanded upon the prior efforts and gained a substantial grant in 1983 from the Mellon Foundation to start TRI. He encouraged the recruitment of students from tropical countries and supported our bidding on a major USAID project in Nepal. He encouraged the faculty to appoint experts in tropical ecology from abroad and within the US to spend time on campus. He bypassed the usual faculty dissembling as to why such broadening of the program might not work. He listened, questioned and made things happen. TRI was established.

Drawing upon the prior work of Bormann and Siccama and the good connections in the El Yunque National Forest, the Institute followed the usual colonial approach—establish a headquarters, buy vehicles and equipment and set up shop for faculty and students in Puerto Rico. However, I had been working with the USAID in ways to have more use of social science theory and methods in tropical forest conservation and development projects. Further the student Peace Corps vets back from the frontlines of the tropical countries thought the Puerto Rico venue and the work planned for the TRI

was more like a Club Med for rich kids. We both felt that the developing world was a better venue for training future professionals and connecting with the realities of their future work environments.

I delivered our ideas with some passion to Dean Gordon. He then used his usual tactic of 'turn the whine into doing the time' and appointed me the first faculty director. With his help we moved the whole operation of TRI back to the School, saving a great deal of money. We then went about creating a truly global TRI program with an international advisory committee, linkages to other international programs, improved course offerings from experts in tropical affairs and a whole turning of the effort toward conservation and development that included the skills and needs of local tropical forest communities. There was ample room for pure science but the central tendency of the program was on conserving of the people and forests in the tropics.

This may not seem like a big shift to folk in 2014. However, it was a major change and seemed a threat to traditional practices of foresters and botanists working in tropical forest ecosystems in the 1980s. As Dean Gordon noted (1989:2):

Another important dimension of the Institute's purpose is the theoretically coequal role of social science and policy analysis with biological and physical science in equipping professionals to work effectively in the tropics (or anywhere else)...there was at the outset fairly strong pressure to equate 'tropical resources' with 'tropical botany' or radically, with 'tropical botany, zoology and geography.' We resisted and even named a social scientist as our first Faculty Director.

We should underline the significance of appointing a social scientist as the first Faculty Director which was perceived both in and out of Yale as very radical, indeed. Thus the TRI legend had its birth in very revolutionary and creative challenges to received wisdom as it tried to follow a new and less frequently taken road in training new professionals.

### **Street 'Cred'**

The major challenge was to demonstrate our street 'cred' for the Institute and our graduates from the program. We encouraged students to attend Dr. Harold Conklin's courses that included anthropological insights on swidden agriculture and the role of villagers in maintaining their forests. We made arrangements for scientists, such as Brian Boom, from The New York Botanical Garden to present courses on tropical botany and soils. Ram Guha, author of "The Unquiet Woods," was appointed a visiting scholar teaching social ecology. Mark Ashton's father provided us with a course on tropical ecology. We encouraged a distinguished group of tropical experts to be part of our Board of Advisors (see Appendix for the names). A faculty group served as in house advisors and I had an informal student advisory group who provided regular reality tests on our policies and plans. We signed Memoranda of Understanding with 28 institutions to develop a network of access between our faculty and students with those in tropical programs such as CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) in Costa Rica and the International Centre for Integrated Mountain Development (ICIMOD) in Nepal.

I think the boldest move was our bid on and the winning of a contract with USAID to work with the Institute of Forestry [IOF] in

Pokhara, Nepal to help them restructure their curricula to be more effective with local forest communities. It was the first ever such bid by a Yale Department and was resisted by the grants people as not a 'proper' activity for Yale. It was a five year 8 million dollar effort and has been continued with several renewals since then. I was able to use the Finland Forest Master Plan for Nepal as a course assignment for my social ecology class. They did a most professional critique and the Dean of the IOF used their report in a demanding challenge to the producers of the plan for their failure to understand certain Nepali realities. Realities such as we did not need to produce more graduates, as the plan required, until the recent ones had jobs. Several US Land Grant natural resource departments tried to keep us out of the project claiming Yale did not have the necessary expertise. We won all of those battles and demonstrated the competence of our program and graduates.

## Supporters

A graduate of FES, Bob Clausi, was the IOF project manager and found ways for us to bring IOF faculty to Yale and other US institutions for Masters Degrees. Other critical support in the early development stage of the Institute came from our Assistant Directors, Peggy R. King and Katherine A. Snyder. Both were creative and demanding leaders who believed in our mission. In 1989 Betsy McGean was Assistant to the Director, and along with other staff—Sonia Varley, Jeff Bopp, Alicia Grimes, and Jimmy Grogan—led in the expansion of the program. They along with many of our alums solidified the uniqueness of the Institute and its value in conservation of tropical human ecosystems (including trees, wildlife, water

and other life forms). The late Joe Miller, School Librarian, organized an expansion of holdings in journals and books on tropical matters. At that time the only larger collection was the Commonwealth Forestry Institute at Oxford University.

The early support of the Institute came from a variety of sources. There was the initial Mellon grant and its renewal. An alumnus made a large anonymous gift to support TRI interns working in tropical countries. We gained a grant from the Tinker Foundation for work in Latin America. A program in underground forest microbiology was developed with support from the Mellon Foundation. The Pew Charitable Trusts funded a program for Continuing Education for Natural Resource Professionals. Short courses were developed for wildlife policy management in the tropics.

One side benefit of the TRI was that its work in Asia and Latin America provided a base for discussion about bringing these lessons learned back home. Our Urban Resources Initiative began when Dr. Ralph Jones, newly appointed Director of Baltimore's Department of Recreation and Parks and Burch were part of a Park Service review group. I was telling him about our work in Asia and he said, "How come you are not doing that here in our cities?" And we did under the guidance of John Gordon. Many of our tropical resources students like Erin Hughes, Bhisma Subedi and J.J. Jiler worked in Baltimore and returned to Asia as leaders of a new vision for connecting people to their natural systems. There are many other stories we could tell but that is for another time around another campfire. The legend is organic and will continue to grow though probably by persons other than 'Billy the Kid'.

## Talking the Past, Thinking the Future

I want to draw upon some lessons learned from my work with TRI and URI [the Urban Resources Initiative] to provide some suggestions for future, post middle age TRI activities that the present participants might consider. The first suggests we give some thought on how to build more cumulative learning from the work of TRI interns and other researchers. The second is a consideration of accepting a wider array of report strategies and a logic of inquiry other than the present emphasis upon a pure science model. This latter suggestion will take longer to tell as my intent is to have us build a locally based, expanding population of ecosystem stewards who force a large vision upward rather than waiting for some top down abstractions from planners and policy makers to trickle in with even more abstractions that are disconnected from the daily lives of ordinary people.

I have read and listened to the excellent and hard won nuggets of knowledge our TRI interns have gained over the years. And like so much in academia this probable wisdom often enters some intellectual niche of forgotten good thoughts. Part of the problem is that there is no means of cumulative learning. This person's effort is dutifully reported and this person's effort is dutifully reported and yet there is little connecting thread that joins them together over time and place that results in a unified base of lessons learned. The Urban Resources Initiative has avoided some of that by remaining in the same venue and addressing similar issues over the years. If TRI had a few basic themes so that each unique effort could be joined to another and over time there would be an empirical base for coherent conclusions as to what works

and what does not and how come. Presently, we seem to have excellent reports but they seem to begin and end with one specific fragment rather than combining to provide some general principles. In this sense we are like most development activities—grand ideas run for three years and then it is off to the next project with little or no connection to other interventions that were similar and whose failures and successes might help the next effort. Like the fabled wise people trying to describe the elephant we only concentrate on our own particular fragment. The elephant is only the trunk or the tail or the foot but what we need in human ecosystem policy and management are lessons about the whole elephant, of the whole ecosystem we are working with. Well it is a thought from the past that might help us to build a better future.

The second issue is not accepting the constraint of always pretending we are dependent upon the model of science and that no other will do. I do believe that science in theory and method is necessary for identifying basic mechanisms, however, it does not have sufficient heft for resolving the larger environmental and natural resource issues of this century. There is daily evidence that most of our most important decisions are not based upon the rational choice model. We do important things in certain ways because we are emotionally connected, and that trumps rationality most of the time. So why not be open to other modes of proof and presentation? Of course, some will remain with the science model but others of us might do an even more effective job with a model from disciplines of faith or law or poetry or painting or drama or essays. Suppose 10 or 20 percent of our interns say I do not trust or feel I capture the meaning of what I have learned by simply following the usual science-like way. And we could say, fine lets go

for a photo essay or a video story or a series of poems or a play about gathering water at the low caste village water spigot or planting trees on a common land near the village school. Or work with a local scientist and translate what that person does into the larger consequences or meanings for village life.

If we are to be students, policy analysts, planners or managers of human ecosystems our challenge is often greater than simply adopting the practices of reductive analysis found in physics and chemistry. Much as we might like to we are unlikely to have the same certainty for resolving the complexity of human ecosystems and getting it into a form that motivates persons within the reality of our political environment. Richie Havens who died in April, 2013 was a good friend of the School, he gave a concert in Sage Hall to help us raise money and to support his Natural Guard program for young kids to get contact with nature. He said "I am not an entertainer I am a communicator." He is a better model for many of our ecosystem professionals who need to be not just enumerators but communicators about sharing the enchantments of nature that they feel and why it is so very important for all to share in that enchantment.

Think of all the high level conferences, papers, meetings on global climate change—Kyoto, Rio, Bali, Copenhagen, South Africa and so on and the majority of the world's population remain unmoved or uncertain as to what they can do. Think of the regular reports by climate scientists and the 'inconvenient truth' about how little they have moved our attention. About 92 per cent of the research has been on establishing the biophysical measures of change and the possible causes of these changes. For the most part they have said the causes are human and their continued actions will cause great pain for humans. Yet only the remaining 8 per

cent of research funds have been invested in human studies on necessary responses to these change forecasts. It is as if a bunch of guys in white coats got on an iceberg leaving Greenland with varieties of expensive instruments to measure change. As they head towards the Gulf Current they have excited arguments about so many parts per millimeter of up or down. Meanwhile the iceberg continues to melt. As they drift past New Jersey people on the shore are shouting 'your iceberg is melting, your science is not helping us. What do we do about our homes and communities in these new realities, how do we prepare to meet them and should we not stop air and water pollution just as a sensible practice?' Meanwhile the iceberg and attendant scientists melt into the warmer seas. And we still do not know what specific actions we can actually do in solving these environmental challenges within our frame of capability. The hard evidence suggests that our climate scientists are good calculators but not very good communicators. And that is a loss for all of us.

Our work in Baltimore, New Haven and village Nepal has tried to bring back enchantment with nature. Here our guide and monitor has been an association with artists who can expand our angle of vision and mix it with the depth of street wisdom from our colleagues in local communities. We ask different questions in different ways and give systematic legitimacy to these alternative and complementary sets of proof and data.

There are many examples where art and science complement and enhance our vision of the natural world. For example John Steinbeck goes out of Monterey to the Gulf of Mexico with his friends, marine biologists, on a research cruise where he is a most interested 'gofer' and chronicler of the voyage. In one aside Steinbeck is talking about the genetic imprint of the moon and tides upon our



behavioral rhythms and puts them within a context unique to our species. He says (1941:30):

The imprint lies heavily on our dreams and on the delicate threads of our nerves, and if this seems to come a long way from sea-serpents and the Old Man of the Sea, actually it has not come far at all. The harvest of symbols in our minds seems to have been planted in the soft rich soil of our pre-humanity. Symbol, the serpent, the sea, and the moon might well be only the signal light that the psycho-physiologic warp exists.

This book, along with Rachel Carson's, "Silent Spring" and "The Sea Around Us" and Gifford Pinchot's 1900 "A Primer of Forestry" are other important examples of keeping the science but reaching beyond its fine metrics and rational structure to its larger meaning—a point within our enduring enchantment with the diversity, the beauty, the wonder of nature including our own.

Carson (1962:261-2) closes her detailed examination of the unintended consequences of a narrow use of science in the development of pesticide and chemical additions to our ecosystems. She says:

The "control of nature" is a phrase conceived in arrogance, born of the Neanderthal age of biology and philosophy, when it was supposed that nature exists for the convenience of man. The concepts and practices of applied entomology for the most part date from that Stone Age of science. It is our alarming misfortune that so primitive a science has armed itself with the most modern and ter-

rible weapons, and that in turning them against the insects it has also turned them against the earth.

Steinbeck closes his wondrous science field trip with this note (1941:223):

What was the shape and size and color and tone of this little expedition? We slipped into a new frame and grew to be part of it, related in some subtle way to the reefs and beaches, related to the little animals, to the stirring waters and the warm brackish lagoons. This trip had dimension and tone. It was a thing whose boundaries seeped through itself and beyond into some time and space that was more than all the Gulf and more than all our lives. Our fingers turned over the stones and we saw life that was like our life.

In the forest ecosystem management professions we have wilderness and timber people with rhetorical positions that assume an absolute division of values between them. Yet, it is more one of different poetic visions of the forest ecosystem. Though John Muir and Gifford Pinchot could not agree about wilderness they saw the forest ecosystem as something very different from those who only saw it as a commodity waiting to be fully exploited. Pinchot's utilitarian call of "greatest good, for the greatest number, in the long run" is a means for ensuring the perpetuation of wildlands that is different from a regulatory enactment. As for poetry, Pinchot's "A Primer of Forestry" might seem hard edged and technical yet it is replete with poetic visions of the whole forest. He notes (1900:7-8):

The forest is the most highly organized portion of the vegetable world. It takes its importance less from the individual trees which help to form it than from the qualities which belong to it as a whole. Although it is composed of trees, the forest is far more than a collection of trees standing in one place. It has a population of animals and plants peculiar to itself, a soil largely of its own making, and a climate different in many ways from that of the open country.

He goes on to tally the many uses the forest provides to a progressive social and economic life from water to timber to fuel. Then says,

The forest is as beautiful as it is useful....No one can really know the forest without feeling the gentle influence of one of the kindest and strongest parts of nature. From every point of view it is one of the most helpful friends of man. Perhaps no other natural agent has done so much for the human race and has been so recklessly used and so little understood.

The tropical forest ecosystems see something of their future in the older urban forests in the United States. Here we see a landscape that is part wilderness, part playground, part community neighborhood, part recreation expressions, part large and dying trees with no understory and a necessary and imposed trend of poor management for both beauty and human benefit. This reflects the fact that conservation agencies are usually the first agency to have funds cut and the last to have funds restored. It is also a confused vision of what these spaces should be. Clearly these systems have been more the domain of

horticulture (or the management of single trees) and recreation or tourism planners rather than one of ecosystem management. A consequence of neglect and despair mixes with great love and changing values brought by new migrant populations at the edges and within these forests.

For the essayist trying to understand and report on the future of tropical ecosystems these urban ecosystems provide a forward moving frame where an ever increasing human population with ever expanding expectations rests upon a very finite land base. The fluttering plastic bags caught in debris in a stream in rural Indonesia or Peru find an empirical base for tracking the meaning of future tropical systems with their cousins found in temperate urban ecosystems. These are not scientific proofs but rather metaphors that extend beyond the reach of science. The essayist's systematic method is the weaving of metaphors that give structure and process to a seemingly confounding richness of data.

Paul Ehrlich's wonderful book on "Human Natures, Genes, Cultures, and The Human Prospect" (2000:45) notes:

We know why biodiversity is disappearing—the primary reason is that homo sapiens is destroying natural habitats, and our capability of so doing...is largely due to our cultural evolution. Knowing how a vast array of species, including our own, evolved and how these species shaped one another and their environments may help us to staunch the flow of extinction and even to regenerate some of our lost biological heritage.

The novelist, Cathleen Shine (1999:196) takes these ideas of evolution to a more personal level. She has her central

character, Jane, pondering the characteristics of her own evolution and that of her relationship with her long time friend while on a trip in the Galapagos that includes a visit to the Darwin research center. She says to her friend, Martha:

The research center was a touching, deeply human place. I, of course, saw it as a metaphor for all human endeavor. Martha, of course, objected strenuously to such an interpretation. But what else can you say about a place in which people devote their lives to breeding endangered tortoises other people have spent centuries endangering?...There was a slide show in the visitors' center about the threat of feral dogs to baby iguanas and the threat of feral goats and donkeys to the vegetation the tortoises needed to survive. Mrs. Tommaso was visibly distressed by this presentation. 'the poor'...she stopped, unable to decide which species to worry about first—the iguanas? the dogs? And those sweet-looking donkeys!—stunned by cognitive dissonance as by an electric shock.

We need these different angles of vision if we hope to understand and to work with the eternal complexity of ecosystems. When we first began our work in Baltimore we sought out a local artist who might work with us to both direct and to monitor our work. We were lucky to find Stephe Graham, a photographic artist, who became more and more enthusiastic with her mission and gave us both hope and deeper understanding about our work. She saw the enchantment and the despair and why we could replace some of the latter with much of the

former. By the third year of our work in the neighborhoods she had enough material where we hosted in the Mayor's administrative building foyer her photos of our interns and the kids from the neighborhoods and projects. We found money for transport and brought the kids and parents to this showing. The mayor even appeared and shook hands. Reflections upon reflections that gave purpose and meaning to our data and our work and gave the kids and their families a great sense of real worth. We were not chopping up the system but were part of it.

I think such a vision nicely fits the next cycle of the TRI legend.

### Appreciation

Thanks to the Boething family and the Department of Conservation Biology at Stanford University for stimulating my thoughts on what we have learned and how we might make our enchantment with nature a means for incorporating a world of environmental stewards.

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### **Appendix 1. TRI Advisory Board**

Robert Blake, World Resources Institute; Gerado Budowski, United Nations Peace University; Jeffrey Burley, Oxford Forestry Institute ; Mason Carter, Louisiana State University; David Chalinor, Smithsonian Institution; Hilda Diaz-Soletero, Conservation International Foundation; Marc Dourojeanni, World Bank; John E. Earhart, Tropical Forestry Program, World Wildlife Fund and Chairman of TRI's Advisory Board; Louise Fortmann, University of California—Berkeley; Victor Gonzalez, Celta Agencies, Inc.; David Harcharik, USDA Forest Service; Peter Huxley, International Council for Research in Agro-forestry; John Michael Kramer, International Resources Group; Thomas Lovejoy, World Wildlife Fund-US; Ariel Lugo, Institute of Tropical Forestry, Ghilleen Prance, Kew Gardens; John Sullivan, USAID.

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## TRI ARTICLES FROM THE 1980s



Wordle of Titles of TRI Articles Published in the 1980s

## Shades of Green: Environmentalism in Two Continents

Ramachandra Guha

Visiting Lecturer in Social Ecology

The objective of this study is to provide a historical understanding of the growth of environmental consciousness in a non-Western setting, viz. India, and to contrast the Indian experience with the richly documented American one. It hopes thereby to hasten a union of two scholarly discourses that have run somewhat parallel to each other.

The first discourse is environmental sociology, whose rise in recent decades has been quite spectacular. Its geographical setting is the advanced industrial nations; its practitioners, chiefly English and American scholars; its concerns, the growth of environmental consciousness in the West. The second discourse is the sociology of development, a somewhat older field that emerged shortly after World War II. Its geographical setting is the Third World; its practitioners, both Western and non Western academics; its concerns, the historical and structural factors facilitating - or retarding - industrial development and modernization in "underdeveloped" countries.

While environmental sociology is quite innocent of the dimensions of environmental degradation in the Third World, and especially of social responses to such degradation, the sociology of development, for its part, has barely acknowledged the environmental limits to economic growth. The present study hopes to overcome these limitations by drawing upon the distinctive strengths of the two approaches. Thus the concepts and categories of environmental sociology, while reminding us that humans are not above and exempt from natural processes, are vital to a comparative analysis of environmentalism in industrialized and industrializing countries. Likewise, the analytical frameworks of the sociology of development, particularly strong in understanding relations of power between and within nations, can with a little imagination be used in interpreting environmental degradation in terms of the dynamics of class relations and the role of the state.

One way of fruitfully synthesizing the two discourses is by recasting the environment debate as a debate about industrialization. In my view, the literature on environmentalism has focused rather narrowly on human attitudes towards nature without trying to explore their underlying social bases, or conversely, what implications different social philosophies ostensibly innocent of environmental concerns have for the relationship between nature and humans. However, a study of environmental consciousness claiming, as this one does, to be an exercise in historical sociology must view the development of such a consciousness against the backdrop of its "other", viz. the growth

and maturity of industrialization, not merely as a mode of economic organization but as an overarching social philosophy. The several centuries of the industrial and post industrial revolutions have had a far greater impact on the ecological and social fabric of human society than the preceding millennia of human habitation on this planet. In this sense, the growth of environmental consciousness may justifiably be viewed as an integral element of the wider response to the most far-reaching process of social change since the Neolithic Revolution: the coming of age of modern industrialization. Like socialism, feminism, and democracy - political trends with which it has an elective affinity - ecological thinking has been formed in the crucible of industrialization.

The empirical content of this project will consist of a historical comparison of environmentally oriented thinking in the United States and India. At one level, the two countries have much in common. They are both large and ecologically complex democracies: democracies is the operative word here, for it is not possible to conceive of an environment debate (or any other debate for that matter) in a undemocratic social system (such as the Soviet Union). Moreover, in both countries environmentalism seems to have come in cycles; (i) an early conservation movement associated with key personalities (Muir, Pinchot, Gandhi) concerned with the pace and direction of industrialization; (ii) an intervening period of "ecological innocence" following World War II, when there existed a widespread social and intellectual consensus on the benefits of industrial development; (iii) the reemergence of environmentalism since the 1960's, this time as a social and political movement able to mobilize large numbers of people.

Inevitably, there are significant differences in the ecological and cultural histories of the two countries. The histories of settlement have followed radically dissimilar time frames. For most of recorded history the Indian subcontinent has been dominated by a complex agricultural civilization with relatively high population densities. In contrast, the North American continent was sparsely populated till the arrival of the white man, while the technologies of rapid resource exploitation brought by the European have heralded an ecological transformation of unprecedented scope and intensity. More recently, India was under foreign domination for close to two centuries. High population densities, the history of colonialism, the Hindu-Muslim religious heritage and the fact that it is still dominantly an agrarian society all distinguish India from the most powerful country in the Western industrial world.

These differences and similarities will be elucidated in the comparative analysis. The strategy would be to identify prominent individuals in each country who exemplify a particular social philosophy, and explore the development of their thought against the backdrop of their times. Tentatively, I have identified four major strands: (i) the Agrarian Ideal, e.g. Jefferson and Gandhi, who believed that a society of peasant farmers could escape the moral depravity and rampant individualism of a commercial-industrial culture; (ii) the Pre-Agrarian Ideal, e.g. Thoreau, Muir and the great Indian anthropologist Verrier Elwin, protectors of the wilderness for whom hunter-gatherers and shifting cultivators were the prototypes of ecological wisdom; (iii) Marginal Scientists, e.g. Aldo Leopold, Lewis Mumford, and in India, the pioneering organic agriculture proponent Albert Howard and the advocate of "ecological sociology" Radhakamal Mukherjee. These individuals worked for the most part within the scientific enterprise, but their sensitivity to ecological issues made them marginal to, and subversive of, "mainstream" science; (iv) Imperial Scientists, e.g. forestry experts and irrigation engineers, whose vision of large scale, centralized, and expert controlled resource management held sway for many decades but has recently come under close scrutiny. The analysis of these four strands will bring to the fore their contrasting visions of ecology and society, as well as the different articulation of each strand in the two cultures.

The concluding section of the study will deal with the modern environmental movement. I will argue that while in the U.S. environmental degradation has become a social issue only after a certain level of industrialization, in India (due to high population densities, colonialism, etc.) it is part of the very process of industrialization. Moreover, it directly threatens the livelihood of rural populations living close to the subsistence margin. If in the U.S. environmentalism is primarily a class struggle over access to leisure, in India it is primarily a class struggle over the use of nature between competing groups (typically industry and peasants). I shall explore the manner in which these different motivations for the environmental impulse inform different strategies of political action. Finally, I shall trace the organic links between earlier debates and the growing schisms within the contemporary movement. In the U.S. the mantle of Muir is claimed by the "Deep Ecologists" with their celebration of wilderness and aboriginal populations. Meanwhile, there is also a revival of Jeffersonianism which integrates environmental concerns with the agrarian ideal (e.g. Wendell Berry). And in India, Gandhian style environmentalists are split into two camps, each claiming to be the inheritor of the Mahatma's mantle. One strand, invoking Gandhi's mystical side, rejects Western science in its totality; the other strand, drawing upon Gandhi's social activism and village reconstruction work, believes in a synthesis of modern and traditional technology.

The primary research on the American side is substantially complete, while the research on Indian materials will commence when I return to India in July 1987. I hope to have a draft of the book by end 1988. While the research on Indian environmentalism will be wholly original, my research on American environmental history will hopefully recover the vision of key figures - notably Lewis Mumford - who have been neglected by American environmental historians. Finally, while a comparative history provides its own justification, I would like to enter a special plea for my reanalysis of American environmentalism. For too long have Western scholars studied the Third World without a corresponding interest being expressed by non-Western scholars in the study of Occidental societies. While such an exercise will reveal my own biases, an outsider's appraisal of the American environmental movement may provide a perspective missing in internal assessments.

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## *Growth Allocation Of Co-Occurring Species With Similar Regeneration Strategies Under Contrasting Moisture And Light Regimes: A Comparison Between Two Genera Of Moist Temperate And Moist Tropical Forests*

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Yale School of Forestry and Environmental Studies

### Introduction

Deforestation in the moist tropics is a phenomenon which has been recognized by foresters for a long time, particularly in Asia (Brandis 1897). Only with the accelerated development in the Neotropics in the last twenty years has it become a prominent issue. Moist regions of temperate countries have also suffered periods of severe deforestation as land was cleared for agriculture, though many of these areas, through successional processes, have reverted to forest. These land changes have been well documented by Raup and Carlson (1941), Raup (1944), Rackham (1976), Peterken (1987) and others.

Natural forest management will play a significant role in both temperate and tropical regions where forest area is extensive and population low, and where there is an appropriate socio-political climate. Yet, much more research is needed to further refine the management techniques used in both regions. To hasten this process, scientists are exploring the validity of applying silvicultural knowledge and expertise generated in the management of natural forest from the temperate zones to the tropics and vice versa.

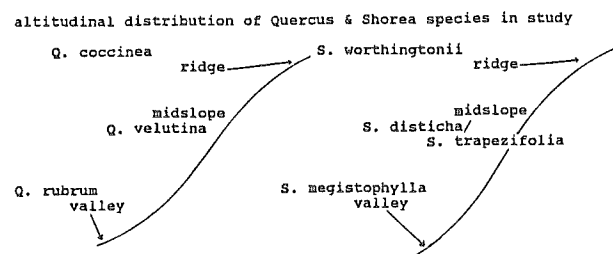
### Study Proposal

A key problem in forest types of both regions is the establishment of advanced regeneration where this is required for future regrowth. The red oaks (family *Fagaceae*; genus *Quercus*; section *erythrobalanus*) of eastern North America and the beraliyas (family *Dipterocarpaceae*; genus *Shorea*; section *doona*) of Sri Lanka have this problem. Moreover, 90 percent of the hardwood timber on the international market is provided by these two genera, which are experiencing extremely heavy exploitation in forests. This study attempts to examine their regeneration strategies in an effort to link physiology with ecology, by conducting controlled growth chamber experiments concurrently with field experiments of seedlings. It proposes to determine the occurrence and significance of physiological specialization of seedlings among three species of red oak (*Quercus coccinea*, *Q. rubra*, *Q. velutina*) and four species of beraliya (*Shorea disticha*, *S. megistophylla*, *S. trapezifolia*, *S. worthingtonii*) with response to different soil moisture and light regimes. For each genus, the study species co-occur together in the

same forest type but on different sites. A summary of the common characteristics of both genera is shown in figure 1. This study provides a unique opportunity to compare two genera with similar regeneration strategies which occur in markedly different forest types. It allows one to ask the question: Are physiological traits that govern species seedling distribution and performance along light intensity and quality and/or soil moisture gradients the same between genera that have similar growth patterns?

FIGURE 1.

A summary of characteristics that certain species of *Quercus* & *Shorea* have in common.



The hypotheses and objectives of the study are listed below:

### Hypotheses

- \* A moisture gradient determines species distribution along the slope, starting in the seedling stage.
- \* Light is a major factor influencing moisture regimes across a particular site. This factor and the shade tolerance of the species determine its performance.

### Objectives

1. Determine, at the end of the growing season, whole plant carbon gain and allocation to roots, stems and leaves.
2. Determine a time series of events for above ground plant growth rates and component growth rates.



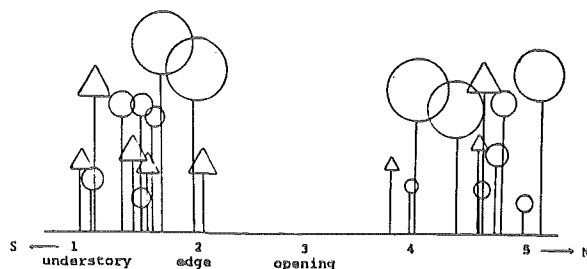
3. Determine a time series of shoot architecture over the growing season by measuring stem height, number of branches, number of leaves, flush rate, number of internodes, leaf area, leaf orientation, leaf life.
4. Test whether population structure and growth rates of individuals in established seedling population, whose soil and light conditions have been measured, confirm the predictions of species performance in the experiments using the controlled growth chamber environment.
5. Relate the anatomy and physiology of each species to their growth performance in the different soil moisture and light regimes.

#### Field Experimental Design

Experiments were started in the fall of 1987 on the beraliyas at the Sinharaja Man and the Biosphere Reserve in Sri Lanka, and in the spring of 1988 on the red oaks at the Yale-Myers Forest in northeastern Connecticut, U.S.A.

Three circular gaps have been created in each forest along the gradient from bottomland (wet) to midslope, to ridgetop (dry). Each gap was made large enough to get the maximum diversity of microclimates across the site. Within each gap, five plots have been laid out along a transect covering the range in microenvironmental regimes. Each plot has one spacing matrix, with four replications, each with twenty five newly germinated individuals for each species (see figure 2). Herbivores and pre-existing vegetation have been excluded. Environmental measurements (light intensity, soil moisture, temperature, relative humidity) for each plot are being made at seasonal intervals. Seedling size, architecture and weight, and their components are being measured at one and a half month intervals.

FIGURE 2.



#### Growth Chamber Experimental Design

The controlled experiments are being conducted in growth chambers in order to compare seedling survival

and growth between and within the species across an array of light and soil moisture regimes. These experiments were started at the same time and location as the field experiments. They are a series of matrix tests comprised of five light regimes, three watering levels, and one spacing level. The light regimes include both quality duration and intensity. Light quality has been altered by using a particular mix of paint pigments added to a varnish base and sprayed on a plastic film (Lee, 1978). Light conditions resembling those of a forest understory were then created. Light intensity was altered by the amount of paint spray applied to the film. Response of seedlings to time exposed to sunlight is also being examined by subjecting seedlings to different durations of full sunlight. This has been done by using different spacings between the slats of Venetian blinds that have been laid horizontally over the seedlings to artificially create forest understory sunflecks. The watering levels range from well watered (continuously moist) to water stressed (periodically dry). The same microenvironmental and seedling measurements are being made in the growth chambers as for the field experiments.

#### Leaf Anatomy and Physiology

Seedlings of each species will be grown in different controlled environments. Two light intensities, full sun and deep understory shade, and two moisture regimes, water stressed and non-stressed, will be created to represent the different environments. Leaves from each species will be sampled from the different growing environments and various anatomical characteristics measured: cuticle thickness; upper and lower epidermal cell size and number of layers; palisade cell size and number of layers; whole leaf thickness; stomata frequency, location and size; leaf hair frequency and size.

Leaf samples from seedlings in the different environments will also be sampled for tissue water content, water potential, conductance and maximum carbon dioxide assimilation.

#### Results

Results should determine the degree of physiological specialization or non-specialization of species that co-occur in the same forest type. They would also provide a better understanding of the maintenance of species rich forests and shed further light on similarities and differences in dynamics between temperate and tropical forest systems.

Findings will also provide a better understanding of the establishment of advanced regeneration and hence allow for a further refinement of the silvicultural systems used.

They also will connect directly with current studies on natural populations that are concerned with predicting *Quercus* and *Shorea* seedling growth and performance in different environments (Sander, et al. 1977, 1984, Ashton 1987). Preliminary information will be provided for their establishment in plantations.

#### Acknowledgements

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## ***Ranching, Logging, and the Transformation of an Amazonian Landscape***

Daniel Nepstad, PhD '89

### **INTRODUCTION**

Human activity is rapidly changing the structural and functional characteristics of Amazonian ecosystems, altering regional hydrology, elevating concentrations of CO<sub>2</sub> in the atmosphere, and reducing species diversity. Strategies to conserve the regulatory functions performed by Amazon forests, and the numerous species of which they are composed, must look beyond the preservation of pristine forest reserves and consider the potential for forest recovery in the wake of the deforestation process. While forest regrowth is relatively rapid following such forms of deforestation as slash and burn agriculture, forest recovery on abandoned, grass-dominated pastures with histories of heavy use can be extremely slow (Uhl *et al.*, 1988).

The significance of semi-permanent, abandoned pastures in eastern Amazonia goes beyond the forests that they displace, for these highly flammable ecosystems increase the likelihood that fire will be a component of this landscape for decades to come. In the Paragominas region of northeastern Pará (Figure 1), ranching and logging activities threaten to reduce the landscape to a frequently burned mosaic of abandoned, grass-dominated pastures and regrowth forests. In this article, I discuss the human activities and ecological processes that underly the transformation of the Paragominas landscape and briefly outline a strategy by which regional forest degradation might be averted.

### **RANCHING AND LOGGING IN THE PARAGOMINAS LANDSCAPE**

Prompted by reports of vigorous grass production following forest conversion to pasture, Brazilian policymakers chose in the early 1960s to subsidize cattle production in Amazonia through low interest loans and other financial incentives (Hecht 1982). Paragominas arose as one of several centers of the burgeoning Amazonian cattle industry that resulted from these incentives. Reputedly fertile soils and the proximity of the Belém-Brasilia highway, paved in 1969, lured thousands of settlers to the area. By 1985, 23% of the Municipality of Paragominas, a total of over 6,200 km<sup>2</sup>, had been cleared and planted in pasture (Brazil, Superintendência de Desenvolvimento da Amazonia, unpublished data).

Grass production rates in pastures of the Paragominas region were often high during the first two to three years after formation, perhaps because of the pulse of phosphorus (P) and other nutrients released into the soil through burning of the forest biomass. The availability of soil P declined rapidly, however, falling to levels of the mature forest within 10 years of formation. As P availability dropped, the nutrient-demanding forage grasses, such as *Panicum maximum*, were gradually outcompeted by opportunistic shrubs (e.g. *Stachytarpheta cayennensis*) and herbs (e.g. *Paspalum* spp.). High stocking densities (>1 animal/ha) accelerated the replacement of forage grasses by weedy shrubs and herbs. By 1988, roughly half of the estimated 10 million hectares (ha) of Amazonian pastures formed on previously-forested land was in an advanced stage of degradation (Serrão and Toledo, in press) and much of this degraded pastureland was abandoned.

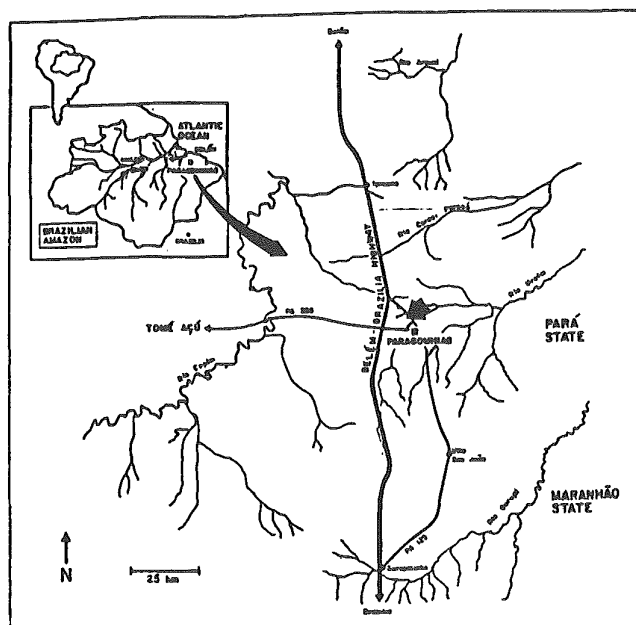


Figure 1. The Paragominas Region. Studies referred to in the text were conducted at Fazenda Vitória ("Victory Ranch") indicated by the short arrow.

Forest recovery following pasture abandonment in the Paragominas region depends on the history of site utilization (Uhl *et al.*, 1988). Biomass accumulation is rapid where pastures are abandoned within one year of formation because of poor grass establishment. In the absence of fire, regrowth secondary forests on abandoned pastures with histories of light use may regain most of the biomass of mature forests in less than a century. However, only a small proportion of the original flora and fauna may be represented in these regrowth forests.

The potential for forest regrowth can be greatly reduced when pastures are reformed through bulldozing or are used intensively, through a combination of high grazing density (>1 animal/hectare for a period of eight years), repeated burning and weeding, and herbicide application. Ranchers bulldoze degraded pastures to clear away logs, stumps and woody debris and to remove the root systems of weedy grasses, shrubs and woody sprouts in preparation for planting. In this process some topsoil is scraped away and relic tree root systems are destroyed. The soil is then disked, fertilized, and planted with the commercial forage grasses *Brachiaria humidicola* or *B. brizantha*. Eight years after abandonment, one pasture near Paragominas that had been reformed through bulldozing, fertilization, and replanting was dominated by weedy grasses and shrubs, contained only 5 Mg/ha of living, aboveground biomass and supported no trees species that were native to the original forest (Uhl *et al.*, 1988).

Since there are numerous impediments to tree establishment from seed in abandoned pastures (Nepstad, 1989), management practices that kill or remove vegetative sources of new tree shoots favor the formation of semi-permanent, abandoned pastures. Although these semi-permanent, abandoned pastures are rare in the Paragominas region, they demonstrate the potential for pasture management practices to yield non-forest ecosystems that may persist long after pasture abandonment. The current trend among ranchers in eastern Amazonia is moving away from light pasture use and abandonment and toward heavy pasture management (Serrão and Toledo, in press). A hidden cost of pasture reformation for sustained cattle production is the risk that, should these systems fail, a highly flammable ecosystem will be produced, one that may fuel regional forest degradation.

While many ranches have failed in the Paragominas region, the lumber industry has expanded. Logging companies gain access to most of the region's forests by extending the infrastructure of dirt roads associated with ranches. In 1986, there were more than 300 registered sawmills in the Municipality of Paragominas which were sawing lumber extracted from mature forests at the rate of ca. 20 m<sup>3</sup>/ha. On one logged site, 46% of the adult trees

were knocked down or topped in order to harvest 3.4% of the trees.

Ranching and logging practices are transforming the Paragominas landscape into a mosaic of active pastures, regrowth forests on abandoned pastures, semi-permanent abandoned pastures, and logged forests (Figure 2). In contrast with the native forests of the region, which may never be ignitable under the current climatic regime, the altered ecosystems are highly flammable. They have an abundance of relatively dry organic matter fuel close to the ground due to a reduced canopy density and increased incident solar radiation. Pasturelands (active and abandoned) are the most flammable ecosystems in the Paragominas region. They can be ignited within one day of a rain event during the dry season. Regrowth forests and logged forests can catch fire within ten days of rain. Since there are annual droughts of at least 30 consecutive days in Paragominas, and numerous droughts of shorter duration (Nepstad, 1989), all of the anthropogenic ecosystems are vulnerable to fire during several weeks each year. During the severe dry season of 1987, roughly half of the secondary growth forest in the Paragominas region burned, mostly by accident, as fires initiated in pastures expanded into adjacent forests (personal observation).

Burns kill tree seedlings and saplings, and favor plant species that sprout following fire. Lianas often proliferate in frequently burned forest because of their exceptional capacity to sprout following stem damage and their rapid elongation under high light conditions. Fires initiated in pasturelands of the Paragominas region therefore set back forest recovery processes and drive the replacement of mature, species rich forest with forests of smaller stature, dominated by sprouting trees and lianas (Figure 2).

#### ALTERNATIVES TO REGIONAL FOREST DEGRADATION

In the likely event that semi-permanent, abandoned pastures expand in eastern Amazonia, it will become necessary for humans to facilitate forest regrowth in these highly flammable ecosystems if we hope to reduce the incidence of fire and the resulting degradation of the region's forests. However, forest regrowth is limited by numerous obstacles to tree seedling establishment (Nepstad, 1989). Tree invasion of abandoned pastures is largely restricted to species that: (a) are disseminated into these ecosystems from nearby forests; (b) have seeds that can escape predation by the abandoned pasture animal community; (c) have seedlings that are unattractive to abandoned pasture herbivores, or can sprout following shoot removal; (d) are tolerant of drought; (e) root deeply soon after germination; and (f) are resistant to fire

damage. All of these characteristics can be found within the tree flora of the Paragominas region, but few species possess all of these traits. Several tree species of regrowth forest and treefall gaps are disseminated into abandoned pastures by bats and birds, but many of their small seeds and seedlings fall prey to abandoned pasture animals. The large seeds of some mature forest tree species escape seed predators, and their robust seedlings survive herbivory, tolerate drought, root deeply and sprout following fire. These species, however, are not disseminated into the abandoned pastures. Apparently the only tree species that can produce new shoots in grass/shrub vegetation are those that were present prior to pasture abandonment and expand clonally through root sprouting. These include *Solanum crinitum*, *Stryphnodendron pulcherrimum*, and *Vismia guianensis*, or the small-seeded trees species that are disseminated into the abandoned pasture in sufficiently large numbers to occasionally escape the numerous post-dispersal barriers to establishment (e.g. *Zanthoxylum rhoifolia*).

The establishment of a treelet or a mature tree in the abandoned pasture can improve the probability that other trees will also invade. Initially, the mature tree can facilitate additional invasion by providing perches and food (if it is fruiting) for frugivorous, seed-carrying bats and birds, thereby increasing the diversity and number of tree seeds that are deposited beneath its crown. As the mature tree expands through crown growth or root sprouting, grasses are shaded out and tree invasion is further enhanced. This occurs because dry season soil moisture deficits are less severe and root competition/ interference encountered by new seedlings may decline. With the reduction of these limitations to dissemination, seedling survival and seedling growth, tree invasion beneath the mature tree increases, and a new "island" of trees begins to form. As tree islands expand and coalesce, more seed carriers will move between nearby forests and the abandoned pasture, fuel production (by grasses) will decline, and the ecosystem will become less flammable.

Strategies for reforesting semi-permanent, abandoned pastures should be designed to minimize the required inputs of capital and maximize the contribution of ecological processes. Abandoned pastures may be reforested cheaply if techniques for catalyzing tree island formation can be developed. The initial goal of reforestation strategies should therefore be the

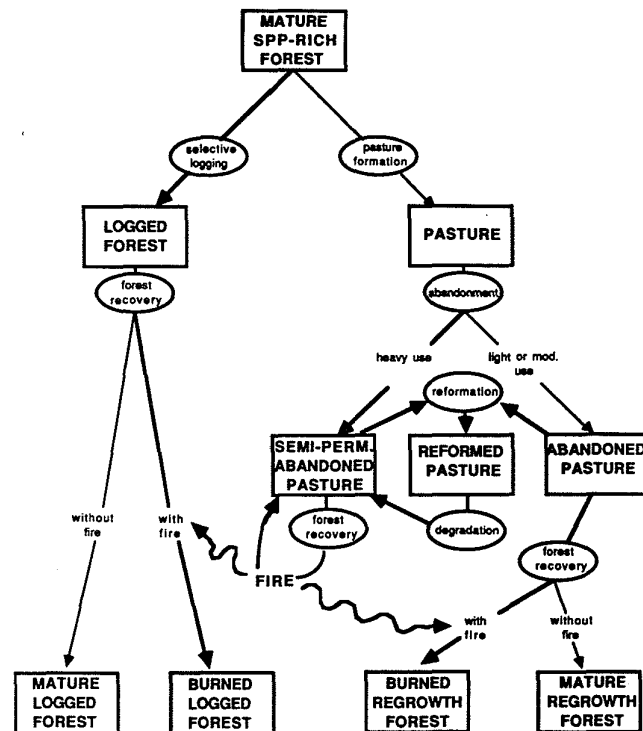


Figure 2. Suggested pathways of ecosystem transformations in the Paragominas landscape.

establishment of trees that attract a wide variety of seed-carrying animals. Several fruit trees native to eastern Amazonia may be good candidates for planting in abandoned pastures. For example, *Platonia esculenta* ("bacuri") is a large-seeded, deep-rooting forest tree that sprouts vigorously from its roots and produces a high quality fruit that is easily marketed in Belém. *Radlkofarella macrocarpa* ("guajará preto") exhibited 100% survival in grass/shrub vegetation at Fazenda Vitoria. It produces an edible fruit, and is common in mature forests of the Paragominas region. *Spondius mombin* ("taperebá") is a vigorous sprouter, produces a large-seeded, marketable fruit, and can be propagated from stem cuttings.

The viability of a reforestation strategy for semi-permanent, abandoned pastures in eastern Amazonia depends on the economic decision-making of the region's land owners. The ranchers who now control this land spend money to eliminate trees from pastures, and they have little economic incentive to finance tree-planting projects. Ranchers have two specific reasons for not wanting to reforest grass-dominated, "abandoned" pastures. These pastures provide a source of emergency forage during the dry season when high-quality forage supplies are depleted (Serrão and Toledo, in press), and unforested lands are easier to hold against expropriation than forested lands (Hecht *et al.*, 1988).

The most appropriate audience for strategies to reforest abandoned pastures is the future generation of land holders. As lumber supplies are depleted in the Paragominas region, ranchers will lose the revenue needed to finance pasture reformation and land may become available for other uses. Several land-uses may replace ranching and logging, such as charcoal production from residual wood in logged forests, or shifting cultivation. Both of

these practices would intensify the process of forest degradation in the Paragominas landscape (Figure 2).

A third land-use scenario includes the establishment of tree cover on abandoned pastures in the Paragominas region while providing a livelihood for many more people than are currently supported within this area. In this scenario, innovative farmers establish agricultural systems on abandoned pastures to produce a variety of tree crops, such as fruits and latex. The development of tree-based agriculture in the Paragominas region would reduce the flammability of the landscape by establishing tree cover on abandoned pasture, the most flammable ecosystem of the region. Tree-based agricultural systems would also reestablish mechanisms of forest regrowth in abandoned pastures, so that if these systems are eventually abandoned, forest recovery would proceed rapidly. The tree-based agricultural systems of Japanese immigrants in Amazonia may provide a model for the agricultural development of semi-permanent, abandoned pastures.

#### CONCLUSION

Highly flammable, semi-permanent abandoned pastures are fueling the degradation of the Paragominas landscape. Knowledge of the barriers to forest regrowth can

serve as a basis for developing strategies to reforest these ecosystems. Reforestation techniques should be designed to overcome barriers to tree seedling establishment and to catalyze natural forest regrowth processes. There is little incentive for ranchers to reforest abandoned pastures. Reestablishment of tree cover on abandoned pasturelands may depend on the installation of tree-based agricultural systems by a future generation of enlightened land holders.

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## **THE SEARCH FOR SUSTAINABLE TROPICAL SILVICULTURE: Regeneration and growth of mahogany after disturbance in Mexico's Yucatan forests**

Laura C. Snook, Doctor of Forestry Candidate

### **INTRODUCTION TO MAHOGANY AND SILVICULTURE**

To be sustainable, timber harvesting in natural forests must not exceed the replacement rate of the desired trees through growth and regeneration. By integrating knowledge of ecological processes into the design of harvesting practices and other treatments, silviculture not only ensures the sustainability of yields but can also maximize them by stimulating faster growth and encouraging more abundant regeneration. A major obstacle to the practice of silviculture in the tropics is the lack of basic ecological information on most tropical hardwood species, including Honduras mahogany (*Swietenia macrophylla*), the most important neotropical timber.

Honduras mahogany is native to the dry and moist tropical forests of eastern Mexico and Central America, the Atlantic slope of northern South America, and the Amazon Basin. A large buttressed tree which may reach 3.5 meters in diameter and 70 meters in height, mahogany grows as a canopy emergent at densities of one to two trees per hectare in both primary and secondary forests. In Mexico, mahogany is abundant in the semideciduous forests of Quintana Roo, a state in the southeastern quadrant of the Yucatan peninsula (see map). Up to 50% of the tree species in these forests, including mahogany, drop their leaves during a portion of the three- to six-month dry season.

Durable and easily worked, mahogany timber has been harvested for hundreds of years from the natural forests of Mexico and Central America. By the beginning of this century, European and American shipbuilders and furniture makers were concerned about the future supply of mahogany. In what was then British Honduras (now Belize), the Office of the Conservator of Forests was established in 1922 to encourage natural regeneration of mahogany in the forest. Elsewhere foresters took an agronomic approach to assuring future yields, planting mahogany in monospecific plantations throughout the tropics. Most of these plantations have failed due to disappointing growth and poor tree form resulting primarily from infestations of a nightflying moth, *Hypsipyla grandella*, whose larvae bore into the terminal shoot of young trees. Because the moth apparently flies at



**The Yucatan Peninsula**

random searching for its host plant, it has trouble locating mahogany trees growing within a matrix of other tree species. Consequently, silvicultural management of natural forests may be the most efficient way to produce sustainable yields of mahogany.

Mahogany is a pillar of the economy in central and southern Quintana Roo, where the government recognizes forestry as a more sustainable land use and stimulus for rural development than clearing the shallow soils for agriculture or cattle ranching. In 1983, ten communities with 125,000 hectares of forest land were integrated into a model community forestry project called the 'Plan Piloto Forestal'. The communities involved care about sustainable management of their forests because they have permanent rights to their land. They realize that the future of their forest industries depends on balancing the extraction of mahogany with natural replacement through growth and regeneration.

## THE STUDY OF STAND DEVELOPMENT

In order to establish silvicultural guidelines which ensure and maximize mahogany harvests, two basic questions must be answered. First, how fast does mahogany grow in mixed natural stands? Second, under what circumstances and at what densities does mahogany regenerate in the forest? The interactions between mahogany and associated species are integral to both questions. It seemed that the answers could be found through the study of stand development, using a conceptual framework and methodology developed at the Yale School of Forestry and Environmental Studies by Professor David M. Smith and several of his students, notably Dr. Chadwick Oliver.

Studies of stand development focus on the role of disturbances in initiating or releasing regeneration, and subsequent changes in relative abundance, height and dominance among different individuals and species of trees growing in aggregations. Because forest stands take decades or centuries to develop from the seedling stage to maturity, only brief intervals in this process can be observed chronologically. Instead, most stand development studies reconstruct and analyze patterns of past growth or compare stands of different ages to elucidate how a stand has developed over time. Stand development studies have so far been carried out only in temperate forests, where the ages and past growth rates of trees can be determined by counting and measuring annual rings. The difficulty of aging tropical trees has proven an obstacle to this kind of research in the tropics.

While it seemed likely that a marked dry season would lead to the formation of annual rings in at least some species, two additional features of the Quintana Roo forest made it possible to determine tree ages. Periodic drastic disturbances have destroyed patches of forest, defining starting points for the development of new forest stands. In addition, because local people have hunted and harvested subsistence and commercial products in the forest for generations, they know when and where different kinds of disturbances have occurred.

## DISTURBANCES IN THE FORESTS OF QUINTANA ROO

The forests of Quintana Roo grew up on former agricultural lands and urban centers abandoned by the Mayans when their culture collapsed beginning about 1000 years ago. These forests have been affected by an array of disturbances, both natural and anthropogenic. An average of two hurricanes a year slam into Quintana Roo. Since 1955, three of these storms have caused massive destruction, affecting hundreds of square kilometers of forest. Hurricanes are 'top down' disturbances which

blow down individuals and groups of trees. Defoliation and crown damage kill others gradually, but the understory is left relatively intact.

Agriculture in Quintana Roo, based on a shifting system of clearing, burning, cultivation, and subsequent abandonment of small fields in the forest, dates back thousands of years. In addition to creating clearings, agricultural practices have also caused fires which periodically burn thousands of hectares of forest. Both agricultural clearing and fires affect forests 'from the bottom up', killing trees from the base and destroying seedlings and other understory plants.

Another cause of disturbance in the forests of Quintana Roo is timber harvesting. Selective felling of individual trees opens holes in the canopy, while extraction of logs creates skid trails through the forest and clearings scraped clean by bulldozer blades to serve as loading areas.

## FIELD METHODS

The forests of Quintana Roo represent a mosaic of 'natural experiments', patches which grew up after different kinds of 'treatments' at particular times in the past. With the assistance of the community of Noh Bec (Mayan for 'great tree') in whose forests this research is being conducted, sample plots were established on sites with known histories: burns dating to 1945 and 1974, a 1955 hurricane blowdown, and log-yards opened up over the past 40 years during selective harvesting operations. Evidence used to confirm site histories included burn scars on residual trees, sprouting, crown breakage, uprooted trees, stumps, and rotting logs.

On each plot, trees were identified and mapped, and their diameters, heights, and crown radii were measured. These data on numbers and sizes of different species of trees and their horizontal and vertical distribution on each type of site will be analyzed and compared for insights into the regeneration potential and growth rates of mahogany and its associated species. Sites will be compared according to types of disturbance to reveal how the density and species of survivors and initial environmental conditions favor or impede regeneration. Harvesting systems or silvicultural treatments could then be designed to imitate the post-disturbance conditions which are found to give rise to the highest densities of mahogany.

Where the date of an initiating disturbance is known, tree ages can be determined. Average growth rates are derived from age and diameter measurements. This provides a point of reference for defining cutting cycles and rotation lengths. Comparing the sizes and numbers of different tree species among stands of different ages provides





*Swietenia macrophylla*  
Honduras mahogany

additional information about growth and reveals changes in density and dominance among species over time. This provides an estimate of the number of young trees which are likely to survive to commercial size, and indicates how they are affected by interspecific competition.

To determine whether trees produce annual growth rings, an increment borer was used to extract cores from mahoganies and several other species which were 1) soft enough to core, and 2) revealed visible rings. Checking the number of tree rings against the hypothesized stand age serves to confirm the stand history and indicates whether or not tree rings in a given species are annual.

#### INITIAL OBSERVATIONS

While the data have yet to be analyzed, certain useful observations have been made already:

- 1) Mahogany became established naturally in clumps at densities equivalent to 60/ha on sites affected by drastic disturbance, as compared to the average density of 1-2/ha. This implies that silvicultural practices which imitate natural disturbances can probably increase the density of mahogany trees in the forest.
- 2) Some mahoganies have reached commercial size at 40 years of age.

3) Several species of trees have been found to produce annual rings in Quintana Roo. This permits determination of ages and growth rates, which in turn can be inferred for associate trees if stands are even-aged.

4) The complex, multi-strata tropical forests of Quintana Roo include many even-aged or two-aged stands (which include even-aged regeneration of residual trees surviving the initiating disturbance) like those commonly found in the forests of the United States. Although tropical forests are inherently complex due to their high species diversity, their patterns of development appear to correspond to familiar models.

#### ACKNOWLEDGEMENTS

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## ***THE AYE-AYE LEMUR OF MADAGASCAR: Feeding ecology, social behavior, and microhabitat***

**Eleanor Sterling, PhD Candidate  
Betsy Carlson, MFS '89**

Four hundred kilometers off the southeast coast of Africa lies the isolated island continent of Madagascar. Having separated from the African mainland at least 200 million years ago, Madagascar appears to have been in its present relative position for the last 120 million years (Rabinowitz *et al.* 1983). It is unlikely that plants or terrestrial animals have crossed the channel between Madagascar and Africa for at least 40 million years. This long isolation from the mainland along with the wide diversity of available habitats on Madagascar have resulted in the survival and radiation of ancient genetic lineages. Ninety-three percent of the island's primates and 80% of its flowering plant species are found nowhere else in the world (Jenkins 1987). Tragically, forest habitat on this unique island is fast disappearing, even before some of the most preliminary of field studies can be completed. At least 14 lemur species have become extinct since humans arrived about 1500 years ago (Dewar 1984), with approximately 24 species remaining on the island. All but the four smallest living species are listed as threatened in the IUCN Red Data Book (IUCN 1980-1985).

One such species is the aye-aye (*Daubentonia madagascariensis*), the only living member of the primate family Daubentoniidae. An animal of great taxonomic interest, the aye-aye displays a suite of morphological features which distinguish it from all others. Once described as being made from "the spare parts of other animals," the aye-aye's peculiar morphology includes bat-like ears, rodent-like continuously growing incisors, claws on all digits but the first toe, a fox-like tail, a foreshortened face, and a filiform middle finger. It is about the size of a house cat and weighs 2.5 kilograms. This combination of features resulted in arguments over the aye-aye's taxonomic position for nearly a century following its discovery by scientists in 1780. Owen's (1863) anatomical study finally placed the aye-aye in the Order Primates.

As a consequence of its taxonomic uniqueness and endangered status, conservationists consider the protection of the aye-aye one of the highest conservation priorities in the world. This profile describes an on-going two-part study based on the PhD thesis work of Eleanor Sterling. It combines a study of aye-aye feeding behavior and ecology with a botanical evaluation of its microhabitat preferences.

The study area is the Special Reserve of Nosy Mangabe, an island located in the Bay of Antongil off the northeast coast of Madagascar. This 520-hectare reserve was set aside in 1965 as an enclave of natural habitat for the aye-aye, then thought to be verging on extinction. In 1967, nine aye-ayes captured in forests on the mainland were released on the island by Dr. Jean-Jaques Petter and colleagues. The island supports a moderately high forest canopy (30-35 meters), and evidence collected from this study thus far suggests that the founder population has thrived. The rain forest is characterized by steep slopes, boulder-strewn ravines, and thick liana tangles. Many tree species in this diverse flora are from such families as Lauraceae, Burseraceae (*Canarium*), Clusiaceae (*Garcinia*), Sapindaceae, Sapotaceae, Rubiaceae, and Ebenaceae (20 or more species of ebony, *Diopyros*). A variety of mammals shares the forest habitat with the aye-aye, including four other primate species.

Despite the aye-aye's endangered status and unique morphology, no long-term study has been undertaken of this animal in the wild. The main objective of this work is to investigate the behavioral ecology and social system of the aye-aye over a period of eighteen months. Eleanor Sterling is focusing on the role of the aye-aye's digits and dentition in food acquisition, its diet in the wild, and its social interactions. In collaboration with Betsy Carlson (MFS '89), microhabitat preferences and population density of aye-aye are being assessed on Nosy Mangabe, as well as in nearby forested regions on the mainland of Madagascar. This study will contribute to our understanding of four general issues in primate ecology: 1) the interaction between morphological and ecological specialization; 2) the relationship between body size and diet; 3) the degree of sociality in nocturnal primates; and 4) seasonal patterns of fruiting and flowering in tropical plants. Data collected will also be useful for developing a conservation management plan for this endangered species.

To assess aye-aye ecology and feeding behavior, Sterling and two field assistants conduct all-night focal animal samplings of radio-collared individuals. So far, five animals have been captured and affixed with collars, and the trapping effort continues. Ethological data are recorded on the minute at five minute intervals. Size,



*Daubentonia madagascariensis*

height and nature of supports are noted to determine patterns of substrate use. The researchers then retrace their steps during the day in order to plot activity ranges and confirm identification of food sources. As many animals as possible are tracked each day to their nest sites to aid in determination of home ranges and sleeping associations. Samples of all food sources are being collected for identification and subsequent nutritional analysis.

A series of 10x10 m plots are being surveyed to evaluate the forest structure. One set of plots is being placed at aye-aye nesting and feeding sites, and the other set is being placed randomly within the study area. The availability of different microhabitat types will be assessed using the latter, and will be expressed as a proportion of total forested area on the island. Plots established around feeding and sleeping sites will be compared to these estimates of microhabitat availability in order to determine microhabitat selectivity by aye-ayes. Within the plots, each tree over 10 cm dbh (diameter at breast height) is identified, mapped, and measured for height, crown diameter, and dbh. Forest structure is described by combining these measurements with an inventory of seedlings, small trees, dead trees, lianas, and epiphytes. A comparison will be made with neighboring mainland forests using similar methods.

Phenology—time of leaf formation, flowering and fruit formation—is a major determinant of food availability.

This aspect of the botanical study focuses on tree species already known to be important to other lemurs on Nosy Managabe, particularly *Varecia variagata variagata*. A permanent phenology trial has been established by marking individuals of these and other common species. Food sources utilized by aye-aye are added to the study as they are discovered by Sterling. Flowering, fruiting and leaf-flush times are recorded monthly to provide a general picture of seasonality and insight into possible keystone food species of this tropical forest. This information is supplemented by plant materials collected every two weeks from fruit traps placed throughout the study area. The construction of the trials and collection of first year phenological data have been done in collaboration with Dr. George Schatz of the Missouri Botanical Garden, who is currently working on a flora of Nosy Mangabe.

One of the most important forest trees found on Nosy Mangabe is *Canarium* (Burseraceae). This tree is used extensively by humans and by a variety of wildlife. Local people cut boles for the construction of dugout canoes and process sap to make a glue for patching wooden boats. The fruits are heavily consumed by humans, lemurs, and wild boars. The branches provide sleeping sites for some lemurs. Because of *Canarium*'s value as a food source, Carlson is taking a closer look at the fruit production of this species. Thus far, the understanding of *Canarium* in Madagascar is poor; its taxonomy needs revision and its phenology is unrecorded.

The analysis of forest structure and phenology will facilitate the estimation of the distribution and relative abundance in space and time of different food sources, as well as the availability of different microhabitat types. Together, these data and observations of the behavior of the animals themselves will be used to answer basic questions about aye-aye ecology and to identify variables important in the selection of habitat by aye-ayes. This information is also important as it can be used in developing potential translocation schemes for individuals threatened by hunting or habitat destruction on the mainland.

*Eleanor Sterling is a candidate for a joint PhD in Anthropology and Forestry and Environmental Studies. Her work is being supervised by Profs. Alison Richard and Steven Beissinger. She has received grants from the following: National Science Foundation (with Dr. Richard), National Geographic Society, Wenner Gren Foundation for Anthropological Research, World Wildlife Fund, Fulbright Program, and Enders Fund. Betsy Carlson received her Master of Forest Science degree from Yale F&ES. She is supported by the Royal Botanical Gardens, Kew.*

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## ***NEVIS, AN ISLAND MICROCOSM: THE UNIQUE ENVIRONMENTAL CONCERNS OF SMALL ISLANDS***

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In recent years, large international aid agencies and regional environmental groups have recognized the vital role that local non-governmental organizations (NGOs) play in balancing environmental and economic concerns. The Island Resources Foundation (IRF), a private, non-profit environmental organization focusing on Caribbean issues launched an ambitious NGO institution-building campaign in 1989 with a five year matching grant from the U.S. Agency for International Development (USAID).

The program aims to strengthen the NGOs' organizational management skills, improve the planning and implementation of major projects (including grant writing, budget preparation, evaluation and monitoring) and increase the NGOs' capacity for collecting, archiving and distributing information. As part of this program, IRF places natural resource graduate students in selected NGOs throughout the Caribbean. With a matching grant from the Mukti Fund, I travelled to the island of Nevis in the Eastern Caribbean in the summer of 1990 to work for the Nevis Historical and Conservation Society (NHCS).

Nevis, the smaller of the two islands that constitute the Federation of St. Kitts-Nevis, lies just northwest of Antigua, at the same latitude as Belize in Central America. A cloud-shrouded, 1075 m (3,000 foot) volcanic peak dominates the 93 sq. km. (36 sq. mile) island which is fringed by long coral beaches and occasional rocky headlands. Census takers estimate the population of Nevis at just under 10,000, the majority of whom are descendants of African slaves. Like many of the Caribbean islands, Nevis was colonized by European sugar planters in the early 1600s. The British and French vied for control of the island, with the British retaining final hegemony. St. Kitts-Nevis remained a Crown colony of Great Britain until 1983 when residents successfully fought for independence.

Several prominent Nevisians founded the NHCS in 1980, primarily to preserve the historical heritage of the island. In the mid-1980s the Society's constituents and Board recognized the need to add environmental conservation to its agenda and adopted a dual natural and cultural conservation mission. Two former Peace Corps volunteers and one Nevisian currently administer the society as curators. Like similar Caribbean organizations, the NHCS must

take special care to balance the concerns of its native Nevisian and expatriate constituents. The NHCS operates the two museums on the island and works actively with a group of talented primary and secondary school teachers to promote environmental education in the public school system and through programs at the public library.

While Nevis' economy was agriculturally based for three and a half centuries, in recent years it has shifted to tourist-related service industries. Touted as the unspoiled "Queen of the Caribbees", the island has catered to a more upscale clientele, most of whom stay in former sugar cane plantations which have since been converted into inns. The beginning of this year marked the opening of a 200 room luxury hotel operated by the Four Seasons chain and an adjacent 18-hole championship golf course — both firsts for the small island. The Four Seasons hotel is built on a three mile stretch of undeveloped beach that is among the most beautiful in the Caribbean. The Nevis Island Administration has plans for another hotel and residential development on the beachfront contiguous to the Four Seasons hotel. My original project was to evaluate the development plan and establish a baseline environmental monitoring system for the site. As often happens in small, active NGOs, however, another more pressing project arose.

USAID must develop Country Environmental Profiles (CEPs), a "state of the environment" report, for all recipients of USAID funds. The profiles help the agency prioritize projects for funding and provide a comprehensive but succinct review of environmental issues for the local governments. The Agency contracted with the Caribbean Conservation Association (CCA) to produce the CEPs for six Caribbean islands, and the CCA in turn hired IRF as the technical research and writing team for the project. IRF, recognizing this as an excellent opportunity for its NGO strengthening program, selected a local NGO on each island to serve as research and documentation centers for the project. The NGOs benefitted in three ways: they broadened their understanding of the environmental issues on their islands; they strengthened their relationships with the government agencies that provided much of the information; and they remained permanent repositories of the collected materials. IRF chose the Nevis Historical and Conservation Society to be the

documentation center for the Nevis CEP. Unlike other NGOs, people under the NHCS umbrella actually wrote the CEP. This was an affirmation of the quality of the NHCS's work as IRF hired off-island consultants to write the Environmental Profiles for other islands. It also gave the NHCS an excellent opportunity to involve members of the island community in the project.

The CEP for Nevis attempted to cover several central themes. It described the natural resource base of the island including flora, fauna, water, mineral, cultural and historic resources. The discussion then centered on issues related to pollution, environmental health, land use planning and development control in relation to these resources. All of this information was placed within the context of Nevis' institutional framework. Writers identified problems in each area and proposed recommendations for mitigation and solution. My role was to research and write the chapters on water resources, agriculture, forestry and watershed protection, as well as pollution and environmental health. I also edited and contributed to several other chapters. The water resources chapter included water supply and demand projections as well as a discussion of catchment area and wellhead protection measures, water pollution problems and water management and legislation. Solid waste, sewage and liquid waste, oil pollution as well as mosquito control programs were among the topics covered in the pollution and environmental health chapter. The agriculture section contained discussions of land classification and capability, land use patterns and farming systems, land tenure, soil erosion and agro-chemical use. The extent and condition of forests and major watersheds and forest product utilization were described in the section on forest resources.

Because of time constraints and the objectives of the project, the research involved extensive review of existing information, rather than collection of new field data. I studied the reports of a seemingly endless parade of consultants and extracted the important and consistent information. My most difficult task, however, was integrating this information with the perceptions and concerns of the Nevisians working in the various sectors. To this end I conducted personal interviews with the heads of the Water, Agriculture and Public Health departments as well as officials in the Planning, Electricity and Customs offices and private industry representatives.

Over the years the NHCS has built a cooperative working relationship with the government of Nevis. The Island Administration now solicits the Society's review of development projects for environmental and historical impacts. The CEP project, by highlighting environmental

problems, had the potential to seriously strain this relationship. The challenge for me was to work closely with the department heads to identify and define the environmental problems facing the island without losing the objectivity of an outside observer. This challenge was confounded by the problem that the department heads reported to elected ministers who did not always share their views.

Edward Towle, the president of IRF, wrote an intriguing paper in 1985 ("The Island Microcosm") in which he outlined the issues and institutional arrangements characteristic of small island systems. Nevis' environmental problems and opportunities are greatly influenced by this "island effect." Nevis developed as an export-destined monocrop plantation. Every inch of the island to within 300 m (1,000 feet) of its central peak produced sugarcane. A few vegetables were grown to support the population, but most food and commodities were imported. Three centuries later, after periods of high agricultural exports, the island has once again become a net importer of food items, and today is only self-sufficient in eggs. Years of sugarcane and cotton production along with livestock overgrazing have eroded much of the topsoil. Opportunities in the construction and service sector have also wooed Nevisians away from agricultural labor. Small islands like Nevis are caught between the need to maintain an equitable balance of exports and imports, and the rapidity with which their very limited and spatially bounded resource bases can be overtaxed. Islands, like small towns, feel the exaggerated effects of the boom-bust cycles which often result from this tension.

The natural resource base of Nevis remains largely unstudied and unquantified. Science education in the public school system does not inspire or prepare students for work in this field, and opportunities are extremely limited. Due to its size, Nevis has not attracted many foreign scientists to its shores and forests although interest is increasing. With so little known about the biophysical characteristics of the island, management decisions are difficult to make. On the other hand, Nevis is fortunate that it has not yet experienced some of the serious pollution problems facing many of its neighboring islands. Cash monocrops like sugarcane and bananas usually require high fertilizer and biocide inputs. Since sugarcane and cotton became unprofitable on Nevis long before many of the other Caribbean islands, the agricultural sector diversified and Nevisian farmers now use comparatively low amounts of these substances.

Industrial pollution is not a serious threat as there is no heavy industry and very little light industry on the island. The effects of what little pollution does exist are not carefully monitored so potential problems could easily go

undetected. A growing problem is the disposal of solid and liquid wastes, particularly automotive parts, waste oil and derelict vehicles. Space and money for proper land disposal is limited so open burning and ocean dumping are commonly practiced. Treatment or proper disposal of waste oil on-island is often prohibited by economies of scale, yet high transportation costs constrain the development of a regional facility to serve all the Caribbean islands.

The problems mentioned above are not atypical of those found in many parts of the world today. Small size, however, has a marked and confounding effect on the biological and physical functioning of island ecosystems. Watersheds are much shorter so that any contaminants are likely to reach coastal waters in less time and in more concentrated form than on larger land bodies. Tolerances to biocides can develop more rapidly in the smaller target populations found on islands. Nevisian farmers already note a sharp decline in the effectiveness of a pesticide brought into wide use only a decade ago.

Equally profound are the effects of size on the socio-economic and political institutions of islands. A population of fewer than 10,000 within a 93 square km area leads to a peculiar brand of politics characterized by

“intense face-to-face personalism and kinship ties that reduce objective decision-making, inhibit confronting serious (polarizing) issues, and reinforce the status quo” (McElroy et. al., 1987). Leaders often wear many hats and travel in convergent professional and social circles. Bureaucracies become disproportionately large. Boom-bust cycles spawn parallel cycles of emigration and immigration. The Caribbean islands have a long history of inter-island migration and Nevis is no exception. Well-educated, ambitious Nevisians continue to emigrate to the United States, Canada and Great Britain and send money and consumer goods back to relatives on Nevis. These remittances constitute a major portion of the island’s economy, but their exact contribution is next to impossible to quantify. Construction and farm laborers from other Caribbean islands immigrate and fill jobs on Nevis creating cultural tensions.

The CEP project confirmed many of these previously held beliefs about the social, political and environmental milieu of islands in general, and Nevis in particular. It also served to point out discrepancies between the accepted opinions and recommendations of consultants and realities on Nevis. For example, consultants recommended that Nevis operate one sanitary landfill, but the topography of the island limits transportation to a ring



*Nevis, the smaller of the two islands that constitute the Federation of St. Kitts-Nevis.*



road encircling the central peak. Safety and logistical problems probably make two or three small facilities a better option. Similarly, several agricultural assessments of Nevis identify land tenure as a major constraint when in fact an extremely high proportion of the population owns enough land to provide for their family, but not enough for commercial production. The CEP also identified gaps in government record keeping such as biocide imports, the amount of charcoal produced from the forests, and basic health statistics. Other environmental factors such as the amount of waste oil improperly disposed of from the two generator plants (3,000 gallons a year) were quantified for the first time.

Islands may have simple, undisputed borders, but patterns of social interaction, institutional structure and resource dependence are very complex. Natural resource managers must be sensitive to these patterns and to the ways in which they differ from continental societies. Incremental changes can have an exaggerated effect on the social and natural environments of small islands. Fortunately, local NGOs are forming throughout the Caribbean, with the support of active regional groups like IRF, and are working towards positive changes in the quality of life and the quality of the environment for Caribbean islanders.

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## DIVERSITY AND TRADITIONAL MANAGEMENT OF FOUR AMAZONIAN VARZEA FORESTS IN THE LOWLAND PERUVIAN AMAZON

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### BACKGROUND

Lands within the floodplain or *varzea* are believed to have the most fertile soils in the Amazon Basin. Intensive agriculture is often considered the most suitable land use for these areas. However, planting many of the most desirable Amazonian crops, such as plantains and manioc in the floodplain, is very risky because annual floods are irregular in timing and unpredictable in height (Chibnik 1986). Because of these risks, as well as other factors, management of *varzea* forests is an important, and yet rarely discussed alternative to agricultural development.

In *varzea* areas, several different kinds of forest are predominantly characterized by the abundance of one, two or three tree species. Peters et. al. (1989) identified and described two of these kinds of forests: those dominated by the camu-camu shrub (*Myrciaria dubia*) and those where the dominant species is the acai palm (*Euterpe oleracea*). In addition to these two kinds of *varzea* forest, four more are commonly classified as economically important in the Iquitos region: yarinales, moenales, capinurinales and capironales.

Information about these four kinds of *varzea* forest is scarce even though they are exploited regularly for both subsistence and commercial production by the rural population. In this paper, I present a general description of these forests, their uses, and traditional management patterns. I conclude with a few remarks about the need for further study if the economic potential of these forests is to be realized.

### YARINALES, MOENALES, CAPINURINALES AND CAPIRONALES

Yarinales are *varzea* forests where the yarina palm (*Phytelephas* spp.) is abundant. Four species of this palm have been reported in the Amazon: *P. tumacana*, *P. schottii*, *P. macrocarpa*, and *P. seemannii* (Barfod 1988). The species *Phytelephas macrocarpa* predominates in the *varzea* forest near the city of Iquitos.

Natural dense stands of *Phytelephas macrocarpa* in the Iquitos region thrive on natural levees or *restingas altas* close to ox-bow lakes. Forming less dense stands, yarina palms also grow between old river streambeds and swamps. People from the region have long collected

several different yarina products especially fruits and leaves. Immature yarina fruits are collected for consumption and for sale in the Iquitos' market all year round (Padoch 1987).

When its fruits mature, yarina produces tagua (vegetable ivory) which in the 1940's was sold on the international market for the production of buttons, dice, chess pieces, umbrella handles, and jewelry. With the recent world ban on elephant ivory, vegetable ivory has been rediscovered as a substitute for the animal product. This situation presents an opportunity for managing natural stands of yarina in the Peruvian Amazon.

Moenales are found in natural stands on high and low natural levees, as well as close to swamps and old riverbeds. In this kind of *varzea* forest, the most abundant tree species are those known collectively to local villagers as *moena*. These include trees of the genera *Aniba*, *Endlicheria*, *Nectandra* and *Ocotea* of the Lauraceae family. These genera include some of the most valuable timber species of the Amazonian forest.

Capinurales are *varzea* forests where the most abundant trees are of the species *Clarisia biflora* and *Clarisia racemosa* (Moraceae). The demand for these two species in the regional plywood industry has increased in the last twenty years due to the scarcity of the previously favored lupuna (*Chorisia insignis*). Both capinure species grow in the region forming dense natural stands on low levees near river meanders and ox-bow lakes.



Mature yarina fruits are used for the production of tagua, vegetable ivory.



*Indigenous people use moena trees for making canoes.*

Varzea forests dominated by the genus *Calycophyllum* (Rubiaceae) are called capironales. Three species of this genus are found in the Iquitos region: *C. spruceanum*, *C. acreanum*, and *C. obovatum* (Vasquez 1989).

Capironales are exploited for fuelwood and roundwood. At the beginning of this century, much fuelwood for powering river steamers was extracted from capironale forest. The commercial extraction of fuelwood from capironales led to establishment of many villages along rivers in the region (San Roman 1975).

#### PRESENT AND FUTURE MANAGEMENT OF YARINALES, MOENALES, CAPINURALES, AND CAPIRONALES

Traditional management of natural resources in the lowland Peruvian Amazon has been only superficially studied. Management of swidden-fallows for the production of native fruits and construction materials for subsistence and marketing is known in the region (Denevan and Padoch 1988). Peters et. al. (1989) report that natural forests in the Amazon are rarely managed. However, rural people of the Peruvian Amazon have managed the four varzea forest types more or less intensively for a very long time.

In the Iquitos region rural people either plant or protect natural stands of yarina. The extraction of leaves and fruits of the palm is often controlled by community rules. For instance, the collection of leaves from young yarinás is prohibited. It is also forbidden to collect the four or six youngest leaves from an adult yarina palm. The majority of communities have protected their yarinales, prohibiting their cutting for agriculture.

Management of yarinales differs in both method and intensity from the management of the other forest types:

moenales, capinurales, and capironales in the Iquitos region. Moena, capinuri, and capirona trees are not planted but they are protected. Methods of protecting these species differ from one another. For instance, people select and protect young, healthy, and straight-stemmed moena trees. Each tree is cleaned of vines and marked with the name of the family that owns and manages it. These trees are harvested when they reach 25 cm DBH and are sold as timber or are used for making canoes.

People protect capinurales, on the other hand, as stands rather than as individual trees. Capinurales are usually managed by controlling the fast growing emergent species of the genera *Ficus* and *Hura* (Moraceae). These species tend to suppress and kill capinuri trees. The control of these trees is done by peeling and burning the bark in the base of their stems.

Capinuri seedlings and saplings are also protected from fast growing shrubs species of the genus *Inga* (Mimosaceae); these shrubs are commonly pruned once or twice until the young capinuris reach the understory.

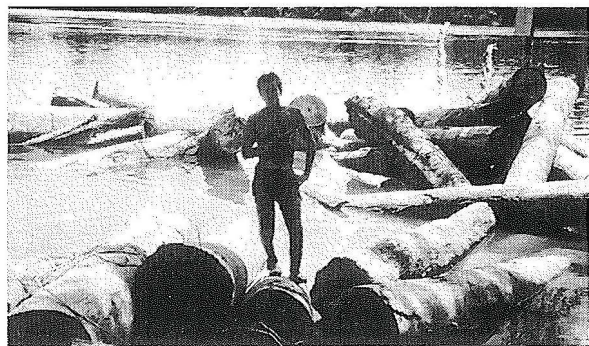
The most common management practice for capironales is to leave and protect the seedlings that invade old agricultural fields. Roundwood is extracted after two years and fuelwood after four years. Trees with the best stems are sold as roundwood while trees with deformed stems are used as fuelwood. Capironales usually are cut and converted to agricultural fields when they are seven years old or when all usable capironas are exhausted.

#### CONCLUSION

Local knowledge of management methods of the four varzea forest types represent an important, underutilized

resource. Management plans that are based on local knowledge can attract the participation of local people, a key to any kind of successful development in the region.

Yarinales, moenales, capinurales, and capironales are only four of the most economically important varzea forests in the Iquitos region. Ecological economic studies of these and other kinds of varzea forests need to be conducted. These studies should give us better understanding of their ecology, management, and current and potential role in market and subsistence economies, and help prevent the destruction or over-exploitation of these Amazonian resources. Conservation and development of these important varzea forests cannot be overlooked for long.



*Varzea forests provide highly valued timber.*

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## SOCIAL FORESTRY IN CHINA?

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### INTRODUCTION

Spurred on by the problems social forestry has faced in arranging for local management of forests, I decided to look at a village forest management system in China where villagers own shares in the forest. My experience with social forestry programs and reading in the literature had convinced me that even when social forestry seems to take hold, local leaders often derive most of the benefit, and poor people most of the cost, of these systems (Fortmann 1988). Had the share-holding system in China solved the problem of maintaining equity in the distribution of benefits?

Sanming Prefecture in Fujian Province, China was declared a national experimental reform site for forestry in 1987, based on seven years of experience with a village share-holding management system to promote forest production and protection. The Sanming Municipal Forestry Committee is proud of its reforestation success in Sanming. The forested area is over 30% greater now than in 1981, and the area is still increasing. Production forests on village collective land are managed by village organizations, with villagers owning shares in the standing forests. Village forestry organization comes under the township, county, city and provincial levels of the forestry department.

My interests in looking at the Sanming system were three: to find out to what extent this system is truly managed at the village level; to get a sense of whether the share-holding system, which is fairly sophisticated, is based on historical precedent in this area; and to discover if the system represents a negotiation of policy between local people and the government.

### METHODS

To answer my questions, I used interviews, archival research and village visits. The interviews were with forestry staff at the prefecture, county and township levels. The most valuable materials were reports and local histories from the prefecture forestry department. I also visited the library of the Forestry College in Nanping and the Provincial Library in Fuzhou.

Forestry department staff arranged for me to visit six villages in three counties. In each county I talked with county and township level forestry staff, and in each village I had discussions with the elected local forestry committee. I was also able to interview, in their homes, three to five households in each village. In all cases these were semi-structured interviews based on a series of questions that I had discussed

in advance with my research companions. We would then follow up with questions related to the particular characteristics of the system in each village.

### RESULTS

#### *History of Property Rights in Forests*

Forested areas have undergone rapid redefinitions of property rights and levels of management since the Chinese Revolution in 1949. Before 1949, forest property in Sanming was divided among landlords, lineages, and the government. In Youxi County, for example, landlords held 30% of the land, lineages held 40%, and the government held the remaining 30%. In landlord/tenant relationships, 60% of the profit from the trees went to the planter and 40% to the landlord.

During land reform in the early 1950s forest areas were redistributed to the government (13.8% of forest area), townships and villages (22.2%), and the remaining 64% to peasant households. Through collectivization (1956) and the establishment of communes (1958), peasants lost the personal use and management of forest land except for plots around the home and land for personal needs, where peasants grew fruit trees and pines. From 1966 to 1976, with the Cultural Revolution, peasants' personal use trees became "tails of capitalism", or evidence of an inappropriate attitude toward property. Even personal use trees became property of the commune, and in angry response to this step, local people cut many trees (*Sanming Linye Zhi*).

In 1979 and 1981, early in the economic reform period, the State Council established policies to protect forests and promote production, with a general principle that whoever planted and protected trees had right to their use. Under this very broad guideline, the Fujian People's Government began to establish property rights in forests. They faced a climate in which peasants feared further changes in property rights and party officials feared further chaos (*Sanming Linye Zhi*).

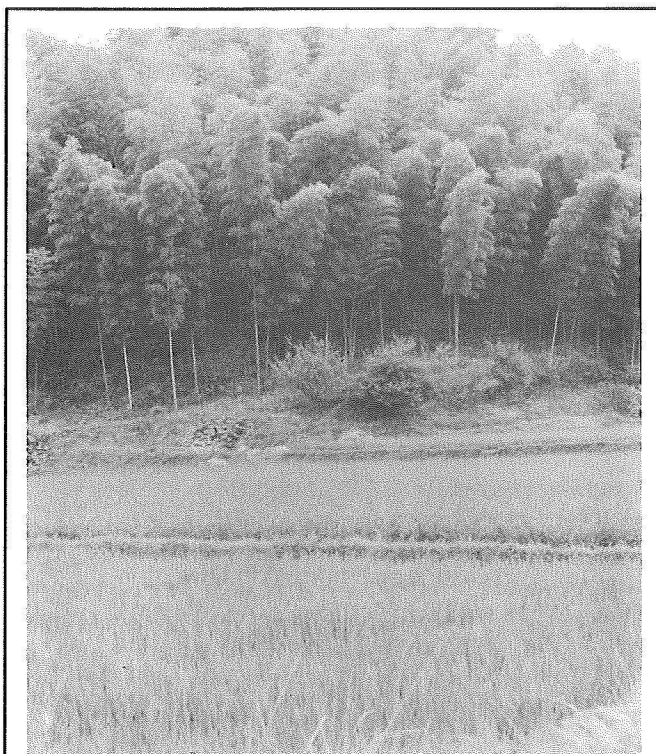
At that time there were debates nationwide as to whether forest land should be allocated to individual households in the same way as agricultural land. The head of Fujian Province and the head of forestry in Sanming, a close friend of Deng Xiaoping, thought that the nature of forestry, with its long rotation period and long period of risk, was unsuitable for management at the household level (Wang 1994). What evolved was a system of unified management of village collective forest land, with shares in the forest distributed equally to all household members. In 1984 the State Council approved share-holding organizations as a means for manag-

ing collectively-owned production forests. At that point Sanming decided to expand the area under collective share-holding management, a system that now covers the whole prefecture (*Sanming Linye Zhi*).

#### *Share-Holding Forest Management*

So much of the literature and excitement about Sanming is devoted to the share-holding forestry system that it is surprising how few forest villagers make their living from forestry. The income from forestry supports the share-holding organization, village roads, schools, power lines and so on, all of which, since the production responsibility system was initiated, villages must provide for themselves. In this sense, forestry supports the whole village.

Apart from the collectively-owned land (*jitishan*) managed by the village, individual households are allocated field land (*tian di*) and freehold land (*ziliushan*), based on household population at the time of allocation, for contracts of 15 to 20 years. On the field land, villagers grow rice and a variety of vegetables. Many households interviewed sell vegetables and some also sell grain for part of their income. On freehold land, households plant some combination of bamboo, citrus trees, tong and tea oil trees, tea and tobacco. From the bamboo, households derive income from both the dried bamboo shoots and bamboo culms. Some villagers also rent collective land, on which they may plant bamboo, fruit trees or fir trees. The products of field lands and freehold land can either be used by the household or sold.



Rice on field land (*tian di*) and bamboo on freehold land (*ziliushan*), Fujian Province, China

For the collectively-owned production forests, the Sanming Forestry Committee decides the annual cut for the whole prefecture. This cut is then allocated from the county to the township forestry stations, and finally to the share-holding organization in each village. Members assured me that they decide what kind of trees to cut where and how the cut will be made. They also decide what kind of trees to plant where, choosing among *Cunninghamia lanceolata* or *Pinus massoniana*. If they allow natural regrowth, a mixed hardwood forest will regenerate.

When I asked how much villagers receive in dividends at the end of the year, the amount varied from about 20 to 105 *yuan* (one US\$ currently = 8.63 *yuan*). There was usually some confusion over the answer, because at the same time of year villagers must pay an education fee, a security fee, a peasant household tax, a fee for families with someone in the military, a fee for road construction, and a tax on agricultural production. It was not clear whether the 20 *yuan* was the household's dividend before or after fees and taxes. In one case villagers mentioned an airport construction fee for a facility they will surely never use. Villagers said taxes were too high, especially taxes for producing trees.

#### *Historical Precedents*

Although some village leaders in Sanming claimed there was no forest management before 1949, others I interviewed said that there were share-holding forestry companies in the 1930s and 1940s. Two older foresters mentioned that beginning in this century, there were *mu shan hui*: companies to manage the felling, transportation, and sale of timber. These timber suppliers were share-holding management companies that moved logs from Sanming to Fuzhou by river to be sold to Shanghai, Hong Kong, Taiwan, the Philippines, Malaysia, Singapore and other ports in Southeast Asia (Zhang 1994).

In the Provincial Library in Fuzhou I found management documents from two *mu shan hui* dating from the 1930s. These document the share-holding arrangements between the forest manager and the timber company in the sale of timber.

#### ANALYSIS

From these interviews and observations, I made the following conclusions regarding my three research questions.

Does the share-holding system represent true village-level management? The answer is mixed. Villages can decide what kind of trees (within a limited range of species) to plant and where. They are locked into a production forestry system, although they can choose — to a certain extent — where to sell their timber. Villages cannot decide, though, to change to an agroforestry system on their collective land. And the amount to cut each year is decided for them. Although in many ways beneficial to villagers, the system is largely designed to meet

the production and reforestation goals of the Sanming Forestry Committee.

For historical precedents, the evidence about the *mu shan hui* suggests that local people had experience with share-holding operations related to forestry. Further research is needed to determine how closely the current system is modeled on previous share-holding companies.

Regarding negotiated policies between local people and the government, the *History of Forestry in Sanming*, the gazetteer of the municipality, recounts that in 1983 investigation teams found a share-holding system and a unified contract management system in local villages, and decided to combine these into one system. This story needs further investigation, but close study of the period from 1981 to 1987 would probably reveal a sequence of negotiations between local people and the municipal government, with the State Council approving plans after they were already implemented.

#### DISCUSSION

In each village it was clear that some households were faring much better than others. Some households lived at a subsistence level whereas others had built new houses, invested in cottage industries, and bought large TV sets and other appliances. My hypothesis is that some households at the time of land allocation in the early 1980s had a more favorable configuration of family members by age and gender. For example, a household with a middle-aged father and two or three sons old enough to plant trees could have taken rapid advantage of freehold land for bamboo, orange trees or other perennials. Quick production and sale of products would have generated funds to invest in other ways, leading to rapid increase in household income. Households with female heads or lacking labor power would not have fared nearly as well.

At a larger scale, it was clear that areas along the railroad and near larger cities in Sanming received the bulk of attention from the forestry department, and were experiencing the most rapid economic development. In these areas new share-holding systems were emerging to link production, purchasing, and resale of timber products. There were also new share-holding companies to rent cars and other vehicles needed by the forestry department. While forestry staff were excited about these developments, and remarked on the flexibility evident in the system, I experienced uneasiness at the growing disparity in incomes between rapidly developing areas of Sanming and those more on the margins. It is unclear to me how this increasing stratification among areas will influence the willingness of villagers to participate in forest protection and production when wealthier areas receive a much greater share of the benefits.

Following my stay in Fujian I spent a week at Nanjing Forestry University, where I was able to read Paul Chandler's dissertation, *Ecological Knowledge in a Traditional Agroforest Management System among Peasants in China* (1992). Chandler looked at indigenous knowledge of *Cunninghamia lanceolata* cultivation among peasants in Fujian Province. Through hundreds of years of practice, these peasants have found conclusively that *C. lanceolata* in monoculture cultivation cannot grow for more than three rotations. In mixed hardwood stands, however, *C. lanceolata* can be grown indefinitely. Chandler points out that forest scientists in China have come up with the same findings. The implications of this limitation for the Sanming system are rather serious, since monoculture *C. lanceolata* forms the backbone of forest production.

#### CONCLUSION

The Sanming village forest management system, although it does not solve problems for social forestry worldwide, offers some interesting property arrangements. Where the forest land is collectively owned, and the income from forest production supports the infrastructure of the whole village, villagers certainly have an incentive to manage well both forest protection and production. The increased stratification among villagers resulted from different ability to use and profit from land allocated to the household. From the collective forest, though, the distribution of benefits seemed reasonably equitable.

#### ACKNOWLEDGMENTS

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## HEALING FOREST AND AILING ECONOMIES: NON-TIMBER FOREST PRODUCTS IN NEPAL

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### INTRODUCTION

Hanuman, the mythical monkey god of the Hindu pantheon, knew a good thing when he saw one. As the story goes, Hanuman's knowledge of wild flora and its medicinal properties saved the life of Laxman, the famous warrior of the Indian epic, the Ramayana. Upon learning of Laxman's injury, Hanuman took to the skies and brought down the mountain of Kailasa, with its impressive display of Himalayan biodiversity. His efforts were rewarded: his earthworks included four *samjivini*, or life-giving herbs. Laxman was saved, and Hanuman went down in history as one of the Himalaya's earliest naturopaths. In the thousands of years that followed, subsequent reincarnations of Hanuman searched out new plants with useful properties. This time, however, the motive was profit, not panacea. The trade in Himalayan flora grew into a vast, yet secretive marketing network that continues to flourish today, providing critical economic inputs to forest-dependent peasants in Nepal, India, Bhutan, and Tibet, and fueling multi-million dollar industries in India, China and beyond (Aryal 1993).

This study examines the trade in Himalayan flora in the Annapurna region of Nepal (Fig.1, below). Over a period of eight months, information was gathered on several aspects of harvesting, management, marketing and ecology. The main objectives of the study were to gather baseline data on the social and biological aspects of the trade, and to investigate potential methods of improving rural incomes and biodiversity conservation through better reserve management and marketing systems. The study was designed to parallel similar studies in eastern and western Nepal in order to develop a replicable methodology with compatible aims and results, and to improve understanding of the non-timber forest products (NTFP) trade in the national context.

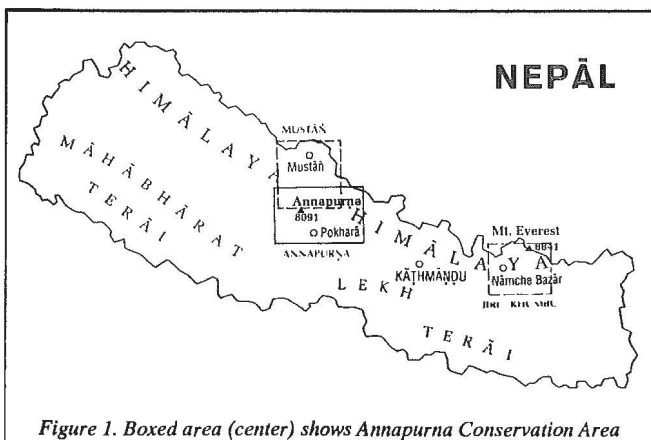


Figure 1. Boxed area (center) shows Annapurna Conservation Area

### BACKGROUND

Each year, from every ecological zone across Nepal, thousands of tons of seeds, bark, fruits, leaves, roots and other plant parts are collected in the wild for the purposes of trade to India. Over one hundred products are involved, used as raw materials for the production of essential oils, resinoids, spices and herbal medicines. Collectively known as *jaributi*, these products reach their destination through informal marketing channels, passing through the hands of numerous middlemen. Recent research indicates that in the rural sector alone over 10 million dollars are generated annually, distributed among a large number of collectors, porters and small traders (Edwards 1993).

### MATERIALS AND METHODS

This study was divided into three main components: literature review and background policy/program research; market survey, including both small intermediary traders and large wholesalers; and field investigations. The difficult terrain, lack of roads and communication, dispersed settlements and collecting areas prompted the development of a research strategy focused on market towns at the end of the road, known as roadheads (Edwards et al. 1993). Such markets act as funnel points that "drain" a relatively discrete area in which plants are collected and traded, similar in concept to a hydrological catchment. Roadhead *bazaars* can be areas of intense trading activity and are a useful point of departure for gaining a regional picture of product availability, quantities, prices, historical trends, marketing pathways, and collecting hotspots.

Data collection relied heavily on rural appraisal (Poffenburger et al. 1992) and ethnobiology (Bellamy 1991) techniques. At the village level, information was gathered from a wide cross-section of people, including women and children, female birth attendants, village headmen and elders, various castes and economic classes, forest management committees and traditional healers. Considerable effort was given to documenting indigenous plant knowledge and collecting voucher specimens.

### STUDY SITE

The Annapurna Conservation Area (ACA), gazetted in 1989, is a multiple-use protected area co-managed by numerous village development committees and the ACA Project (ACAP) staff. Founded on the principles of participatory management, ACAP has the dual management objectives of conserv-



ing biodiversity and promoting environmentally sound rural development. ACA's 7000 km<sup>2</sup> ranges in altitude from 1000 to 8000 meters, and provides a representative swath of central Himalayan biodiversity containing a variety of ecological zones, from sub-tropical monsoon forest to alpine steppe. It is also a region of remarkable cultural diversity; over 40,000 people comprising at least nine distinct ethnic groups reside here. The Annapurna region not only provided a fertile research site, but involved people who were truly interested in the findings.

#### PRELIMINARY RESULTS

##### *Products and Volumes*

In 1992, at least fourteen products were collected in large quantities (Table 1, below). According to local informants, ten trucks containing approximately 40,000 kg left the Besi Sahar roadhead. Products collected in the greatest volumes included the bark of *Cinnamomum tamala*, a small subtropical tree, and the tubers of *Dioscorea bulbifera*. *C. tamala* is

Edwards (1993) observed that market prices for jaributi correspond to the distance between collection area and roadhead and the degree of difficulty encountered while harvesting. High altitude products tend to fetch higher prices, whereas low altitude products tend to be priced more cheaply. While this is somewhat true for the Annapurna region, the prices appear to be elastic in response to market demand.

##### *Markets and Marketing*

Traders at the roadhead and along the main trails are the critical link between jaributi and the market. They receive market information on species and price along with cash advances from large wholesalers near the Indian border, and they are the first major point of transaction for local collectors. There are at least seven permanent traders who double as shopkeepers, lodge operators, and farmers. In addition, a number of opportunistic buyers from large Indian firms periodically visit the region in search of more direct supplies.

Resident traders have their own territories based on kin relations or other historical ties. They are of different ethnicities and have varying levels of business savvy and political influence. At times they may work in collusion, but most operate independently. As such, roadhead prices can be competitive, and a collector is free to sell as he pleases. Contrary to popular notions, the relationship between resident traders and collectors is not necessarily exploitative. Traders can play a very important role in village economies by providing a needed source of credit, cash and marketing assistance. Traders and collectors may also be bound

**TABLE 1. MAJOR COMMERCIAL NTFPS COLLECTED IN THE ANNAPURNA REGION, EASTERN PORTION, 1992**

| <u>Latin name</u>               | <u>Family</u>    | <u>Local name</u>    | <u>Part used</u> | <u>US\$/kg dried**</u> |
|---------------------------------|------------------|----------------------|------------------|------------------------|
| <b>Sub-tropical/temperate</b>   |                  |                      |                  |                        |
| <i>Trichosanthes</i> spp.       | Cucurbitaceae    | indreni ko biu       | seed             | 2.00                   |
| <i>Swertia chiretta</i>         | Gentianaceae     | chiraito/tithe       | leaves, stem     | 2.00                   |
| <i>Piper longum</i>             | Piperaceae       | pipla                | fruit            | 2.00                   |
| <i>Valerianna walichii</i>      | Valerianaceae    | sugundhawala         | root             | 0.70-2.00              |
| <i>Paris polyphylla</i>         | Liliaceae        | satuwa               | root             | 1.00                   |
| <i>Cinnamomum tamala</i>        | Lauraceae        | dalchini/sincauli    | bark             | 0.50-1.00              |
| <i>Rubia cordifolia</i>         | Rubiaceae        | majito/cheroot lahar | stem             | 0.20                   |
| <i>Dioscorea bulbifera</i>      | Dioscoreaceae    | kukur tharul         | tuber            | 0.20                   |
| <b>Sub-alpine/alpine</b>        |                  |                      |                  |                        |
| <i>Delphinium</i> spp.          | Ranunculaceae    | nirmasi              | tuber            | 2.00                   |
| <i>Nardostachys grandiflora</i> | Valerianaceae    | jatamansi            | rhizomes         | 1.20                   |
| <i>Aconitum spicatum</i>        | Ranunculaceae    | bikh                 | tuber            | 1.00                   |
| <i>Rheum emodi</i>              | Polygonaceae     | padamchal            | root             | 1.00                   |
| <i>Picrorhiza kurroa</i>        | Scrophulariaceae | kurtki               | rhizome          | 0.70                   |
| <i>Orchis latifolia</i>         | Orchidaceae      | panchaunle           | tuber            | 4.00                   |

\*\*prices converted to equivalent in US dollars

used as the main adulterant of true cinnamon (*C. zeylanicum*); *D. bulbifera* is used for treating gastro-intestinal ailments. Two new products also emerged on the market: the leaves of *Taxus baccata*, the Himalayan cousin to the Pacific Yew, famous for its anti-cancer properties, and *Saussurea gossypiphora*, an alpine herb whose end-use is unknown but is used locally for medicinal purposes. The value of trade in 1992 at the Besi Sahar roadhead is estimated to be on the order of US \$15,000.00.

together by a mutually beneficial ritual brotherhood called *mit*. On the other end of the scale, certain powerful traders may force collectors to sell exclusively to them. All these arrangements were observed in the study area.

The jaributi market is volatile and erratic. *Swertia chiretta*, known for its bitter taste and fever reducing qualities, was until recently a low value species fetching only NRs15/kg

(US\$0.20). Its alleged use in a new Indian beverage raised the price to over \$2.00/kg in today's market, stimulating larger and earlier harvests, cultivation experiments and localized attempts to control the harvest and protect the growing stock.

### *Tenure and Management*

Tenure and management vary widely across the study area, influenced strongly by the level of market information, historical trade links, culture/ethnicity of participants and degree of government intervention. Collection areas fall into two overlapping categories of ownership and control: government land and community land. Due to the shortage of government forestry staff and the rugged terrain, this distinction is often ambiguous. Community land can be divided further into official and customary. Official community land is that which has been sanctioned and demarcated through the government Community Forestry Program; customary land may or may not have official sanction, but local people retain historical access rights. The recent incorporation of the study area into the Annapurna Conservation Area superimposes yet another layer of claims upon the jaributi resource.

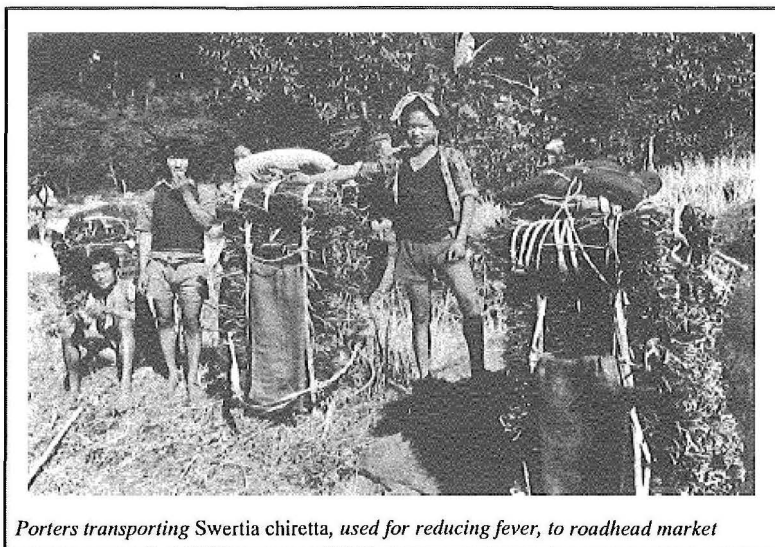
Management is equally variable, determined to a large extent by feasibility. Government management is limited to the collection of royalties and periodic harvesting and export bans. At the local level, management mainly takes the form of access control, commonly accompanied by a token payment to a community fund. In practice, however, much of the region is unrestricted. Management is also hindered by the lack of market information by those controlling access, thus limiting their ability to make sound management decisions.

### *Biodiversity Conservation*

Across Nepal, the largest concentrations of plants with useful compounds occurs in the subtropical zone (53%), followed by the tropical (49%), temperate (36%), subalpine (18%) and alpine (7%) (IUCN 1991). Over 700 species are known to have therapeutic properties. Herbs may experience a high level of endemism due to the formidable topography and microclimates which inhibit migration and induce speciation. This is relevant to the jaributi trade because large-scale

collections could inadvertently cause extinctions.

Depending on the product, collection can have various effects on local plant populations. Collecting herbs, roots and tubers destroys the individual plants, whereas harvesting vines, seeds and fruits causes minimal immediate damage. Recent trends indicate that as prices and markets increase, collection occurs earlier in the season, before the plants have had a chance to seed. Unmanaged harvesting, combined with periodic market booms, appears to have had a significant negative effect on local populations.



Porters transporting *Swertia chiretta*, used for reducing fever, to roadhead market

Burning, grazing, planting, collecting forest products, and hunting have been a part of the Annapurna landscape for over four hundred years, shaping the mosaic of communities we see today. The anthropogenic nature of this landscape has important considerations for management of jaributi and biodiversity conservation.

### DISCUSSION AND CONCLUSIONS

Widespread poverty, rapid population growth, environmental degradation and lack of employment opportunities characterize life throughout most of Nepal. With per capita GNP at less than US\$180/yr, new sources of income must be developed to meet the growing economic needs of Nepal's citizens, yet are compatible with its unique cultural and biophysical characteristics. Improving the jaributi trade may offer one alternative, especially at the primary stages of extraction and exchange. Improvements could take the form of harvesting and marketing cooperatives or village-based processing facilities. Cultivation of threatened species is certainly warranted, although potential benefits will be limited to those with the necessary land, labor, capital and time.

Common property management — instigated by villagers themselves or through government and NGO-sponsored social forestry and protected areas programs — is promising, yet many issues remain problematic. Lack of ecological data precludes the development of silvicultural prescriptions to maintain/increase productivity. The social aspects of the trade are equally formidable. Controlling poachers, establishing reliable markets, gaining access to market information and by-passing Indian hegemony are all important considerations. Given that current trade patterns are the

result of regional histories, politics, ecology and culture, site-specific issues need to be incorporated. These include appropriate mechanisms for distributing jaributi benefits and responsibilities among community members and protecting access rights of the poor.

The jaributi trade is an ancient Himalayan enterprise which has expanded dramatically over the past few decades. There is great potential to improve economic benefits and forest management, but it is important to remember that collecting NTFPs for trade is only one of many strategies people employ to manage their needs; it is not a panacea. The Annapurna study describes the trade in one area only and is not generalizable. It does, however, demonstrate the complexity of the issue, potential problems, and prospects for development. The future lies not in the hands of mythical gods like Hanuman, but in those of mere mortals, from illiterate mountain peasants to sophisticated businessmen.

#### ACKNOWLEDGMENTS

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## ANTHROPOGENIC LANDSCAPE TRANSFORMATION IN THE AMAZON ESTUARY

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### INTRODUCTION

Local people have radically transformed the landscape of the Amazon estuary over the past thirty years and continue to do so. Preliminary fieldwork shows that major waterways previously thought to be natural are, in fact, anthropogenic, opened by farmers to improve access to agricultural fields and forest products. This report describes ongoing doctoral dissertation fieldwork in the Amazon estuary and addresses data gathered through semi-structured interviews with local farmers. A complementary ecological study to quantify stream increment and distinguish between human and “natural” processes is not described. Instead, I present four examples of landscape management carried out by local farmers who have cut streams (*igarapés*) from tributaries of the main river channel. It should be emphasized that although these interventions may have initially occurred at what appears to be a fairly small and localized scale, incremental erosion of river banks and diffusion of the techniques within the population have given them a significance such that today’s landscape is apparently quite different from that of thirty years ago. Furthermore, although research up to now has focused on those manipulations specifically associated with the community of Ipixuna Miranda and which form the subject of this report, I believe that these interventions are widespread in the estuarine *várzea* (floodplain).

### LOCAL ECONOMIC HISTORY

Ipixuna Miranda is a *várzea* community of approximately 25 families located on the Rio Ipixuna, near its confluence with the Amazon, about 5-6 hours by motor-launch northeast from Macapá, the state capital of Amapá (fig.1). As is common throughout the lower Amazon floodplain, people in the community support themselves through hunting and fishing, marketing shrimp and the palm-fruit *açaí* (*Euterpe oleracea*), and cultivating and selling bananas and other agricultural produce.

As with other floodplain areas relatively close to the urban markets at Belém and Macapá, modern economic and environmental histories have been closely bound to the rise and fall in demand for extractive products. In the early twentieth century this meant the extraction of timber, particularly *muritinga*, *cedro* and *virola*. By the 1940s, interest had shifted to seed extraction of *murumuru*, *andiroba* and *pracaxi*, animal skins, and to rubber, the latter under multiple stimuli of the US-sponsored battle for rubber during the Second World War. Much of this trade operated under structures derived from the old-style credit-and-supply *aviamento* system originated during the late nineteenth-century rubber

period and tied the area to capital in Belém and Macapá, intermediate links in a chain leading across the Atlantic to Europe.

The 1950s saw the increasing importance of commercial fishing, particularly of catfish and shrimp, and the introduction of banana cultivation. By the 1960s, as in much of northeastern Amazon, *açaí* extraction, both for fruit and palmito, was becoming increasingly important, establishing a pattern which still persists, in which *açaí* and shrimp are the most significant goods produced locally for exchange.

This period, from 1960 to the present, is of particular interest for a history of landscape change and provides the focus of the present study. With the increasing valorization of minor forest products and the expanding market in bananas, permanent settlement began in the area. The first *fazendeiro* (large landowner) arrived in the early 1960s, bringing four families from his home district on Marajó Island.

### LANDSCAPE TRANSFORMATIONS I: INTERVENTIONS IN THE 1960S

The landscape local people remember from the 1960s is startlingly different from that visible today. Movement between the two major tributaries, Rio Ipixuna and Rio Pedreira,

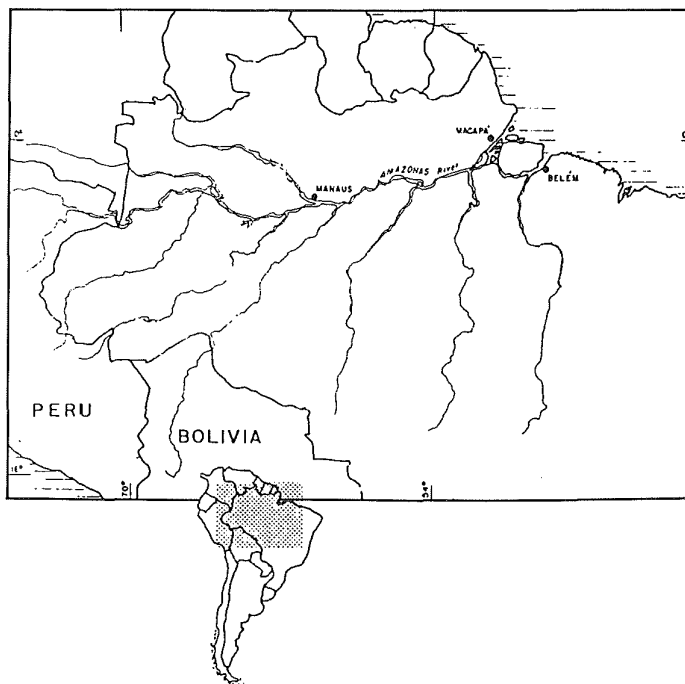


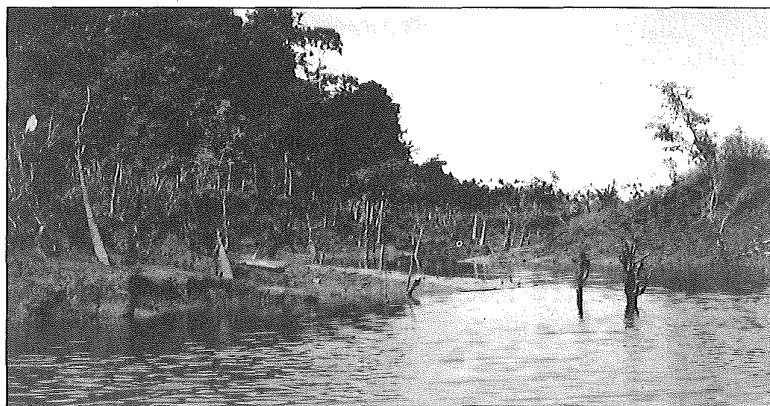
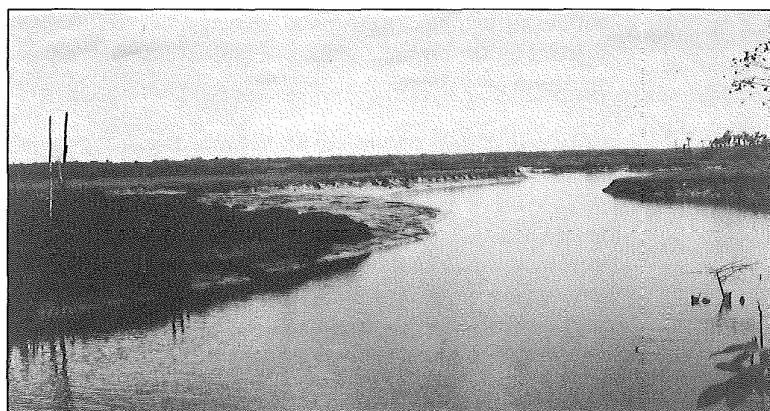
Figure 1. Brazilian Amazon: Study site located northeast of Macapá

for instance, appears not to have been possible. The complex network of streams and broad waterways that now typify the area was not present in the 1950s and early 1960s. The first interventions in the landscape can be documented from this period, when permanent modern settlement took place, along with human activities directed towards the extraction of forest products. Local farmers have described two episodes in detail:

*i) Igarapé Coleira*

This stream today extends for somewhat more than 3 kilometers, and is close to 100 m across at its widest point. It enables collectors of forest products to pass from the Rio Ipixuna into an area from which timber and palmito have been extensively harvested over the past thirty years (figs. 2 and 3, below).

Construction of Igarapé Coleira was organized by the local *fazendeiro* in the early 1960s. Work-teams from the four



Figures 2 & 3. Even at low tide (top) Igarapé Coleira provides easy access to the Rio Ipixuna. Forest valued for extractive resources (at left of bottom photo) border the Igarapé Coleira.

families then living in Ipixuna removed the dense vegetation of the aroid *aninga* (*Montrichardia arborescens*) and *taboa* grass (*Cyperus giganteus*) to open a channel approximately 2 m wide, enabling canoes to pass at high tide. The *aninga*, which reproduces vegetatively, was uprooted and the *taboa* cut close to the ground. Subsequent erosion that produced today's broad channel has occurred without further human intervention: the intent of this management, as in all cases so far documented, has been to alter the fluvial regime at the micro-

level, initiating a process of accelerated stream increment.

*ii) Igarapé Pracaxi*

Igarapé Pracaxi is a smaller channel than Igarapé Coleira. However, it is of interest to the present study for two reasons. First, although it was constructed by *caboclos* (smallholders) during modern settlement, it was opened independently from the *fazendeiros*. This is significant for a period in which local *caboclos* were compelled to sell their produce exclusively through the large landowner. Second, it is the site of current resource conflict, indicating ways in which disputes over access to resources are tied to control over the landscape.

This *igarapé*, which now extends approximately 500 m, was constructed from a narrow, seasonal channel by one *caboclo* family over several months. Again, the purpose was to improve access to forest products. In this case, people were particularly interested in extracting large timber species.

LANDSCAPE TRANSFORMATIONS II:  
RECENT INTERVENTIONS

Techniques involved in landscape management have been adapted to changes in local social relations. A critical moment in the environmental history of this area was the introduction by *fazendeiros* of large numbers of water buffalo in the 1970s; heightened local tension can be correlated with the appearance of these animals. Water buffalo are difficult to control: they swim across rivers and often enter fields and destroy crops. *Caboclos* also complain of the buffalos' negative impact on water quality and fish harvests. The exacerbation of lateral erosion due to persistent grazing by buffalo on *aninga* is highly probable.

*i) Igarapé Ipixuna*

Despite the negative effects of buffalo on *caboclo* livelihood and the unremitting antagonism expressed towards them by local people, *caboclos* have been able to generate some compensatory effects from the animals through creative management. Specifically, channel opening since the 1970s has involved *caboclos'* utilization of buffalo belonging to *fazendeiros*, in what appears to have been a semi-clandestine fashion. The *igarapé* which connects Rio Ipixuna and Rio Pedreira, and which therefore now links communities on the Ipixuna and Macacoari rivers with a recently-completed road to Macapá, was opened by a team of *caboclos* in an effort to improve transportation routes in the area. They first cut a 2 m wide channel through *campo lagado* and then repeatedly drove buffalo through the opening. Informants have suggested that all *igarapés* formed in recent years have been opened in this way.

## ii) Igarapé Abacate

In 1974, a team of 30 *caboclos*, organized under their own management, spent a total of 30 working days clearing a 5 m channel approximately 2 kilometers through a dense covering of *aninga* and *taboa* to facilitate a family's access to their banana field. As with Igarapé Pracaxi, this route had previously been passable only in a small canoe, with great difficulty, and then only in the rainy season. In August, for instance, it was impassable. The rest of the year it was possible to travel a certain distance on foot, continue a little further by small canoe, before finally switching to a larger vessel. In 1984, in response to higher prices for bananas and to valuable harvests spoiling in inaccessible fields, the same channel was extended a kilometer further, providing access to several more farms.

## POLITICAL ECONOMY AND RESOURCE CONFLICT

The specificities of how and by whom stream management is carried out have varied across time and space. The different forms of labor mobilization apparent during the history of landscape management in Ipixuna can be linked to the local and regional political economy. Shifts in landholding structure and accompanying changes in the relations of production established the conditions for different forms of labor organization, at times either cooperative or quasi-coercive. Notwithstanding these differences, both large and small farmers have built channels as a way to benefit from the increase in market value of particular agricultural and extractive commodities. In turn, the markets in forest and agricultural products have been influenced by the shape of the landscape, which increases the flow of goods and may accelerate the depletion of extractive products. Moreover, changes in the landscape have complicated the local landholding structure by disturbing property boundaries and affecting the value of individual holdings.



Figure 4. Igarapé Pracaxi currently terminates in an impassable barrier of *aninga*

With the recognition that local economic history is dialectically related to the shape of the landscape, it also becomes apparent that stream manipulations are an important factor in local resource conflict. For example, the resolution of ongoing conflict over *açaí* in Ipixuna will depend on the capacity of people in the

area to exercise control over the landscape. *Açaí* has a central symbolic and nutritional place in the peasant diet and importance as a subsistence and cash crop (Anderson and Jardim 1989). However, for more highly-capitalized landowners the value of the tree lies in the destructive harvesting of the palm-heart for export. Current conflicts therefore center on the increasing scarcity of the palm. Igarapé Pracaxi, described above, is an example of a disputed channel which, if extended, would provide access to remaining wild stands of *açaí*. Despite pressure from local landowners, *caboclos* have prevented the landscape from being changed in this way, and, at present, the stream ends in an impassable thicket of *aninga* (fig. 3).

## ECOLOGICAL CONSIDERATIONS

The fluvial landscape in this area is subject to three types of "unnatural" disturbance: large-scale human stream construction through manual labor, stream opening in which both humans and buffalo are involved in the initial clearing process, and erosion induced by the physical impact of buffalo and their repeated predation on *aninga*.

In the undisturbed system, erosion is limited by dense stands of *aninga* and *taboa*, present either monospecifically or in association. When these are subject to continuous disturbance, degraded areas are initially colonized by an unidentified vine, and then by a dense covering of the thorny shrub *aturia*. This second plant is aggressive and highly competitive and makes land unsuitable for either pasture or cultivation. An alternative pathway after the loss of *aninga* is a landscape denuded of all vegetation except close-cropped grasses and subject to rapid erosion. It is assumed that this latter system develops in locations with higher densities of buffalo in which *aturia* cannot become established.

The ecology of stream management in Ipixuna is therefore complicated by two inter-related processes: the widespread, destructive activities of the buffalo herds, and the powerful erosive forces of the rivers themselves. In this context, it is important to re-emphasize that human interventions are concerned with the *location* of streams as modes of access to resources, rather than with the *rate* at which streams open and the landscape changes. Nevertheless, farmers do exert control over the rate and scale of stream-opening and development by their selection of location in relation to tidal flows of varying strengths. The relatively rapid growth of Igarapé Ipixuna, for instance, appears to be the result of its position as a link between the two major tributaries.

## IMPLICATIONS

An important aspect of this study lies in its assertion of local human agency in relation to the Amazonian landscape. The elaboration of an anthropogenic Amazon allows us to question the familiar reading of the Amazonian landscape as a natural space and to emphasize the identity of the landscape as a cultural product of its population, one with a history of human management like any other. By documenting the extensive and transformative human

impacts on what has previously been considered a landscape subject only to natural ecological processes, we can begin to undermine the popular, academic and policy construction of the Amazon as a pristine domain. In this way, the present research builds on a body of Amazonianist literature which has emerged in the last decade and has documented the wide-ranging effects of traditional forest management (e.g., Posey 1985, Denevan and Padoch 1987, Balée 1989, Denevan 1992).

#### ACKNOWLEDGEMENTS

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## Restoration and Development: Landless migrants and urban river management in the Bagmati Basin, Kathmandu, Nepal

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It is estimated that by 2025, two-thirds of the world's population will live in urban areas (World Resources Institute 1996–1997). Human populations are increasingly concentrated in cities, particularly in developing regions. The environmental implications of the massive rural to urban transition underway in many parts of the world have received growing attention in international policy and development arenas. Donor-assisted programs and policies to define and promote ecologically sound urban growth are increasingly at the center of international development dialogue.

This research project examined the connections between rapid urbanization, river system degradation, and human migration and settlement patterns in the Bagmati Basin in Kathmandu, Nepal. A statement of research objectives and methodology appeared in the spring 1998 *TRI News*. This article presents some key insights from the project.

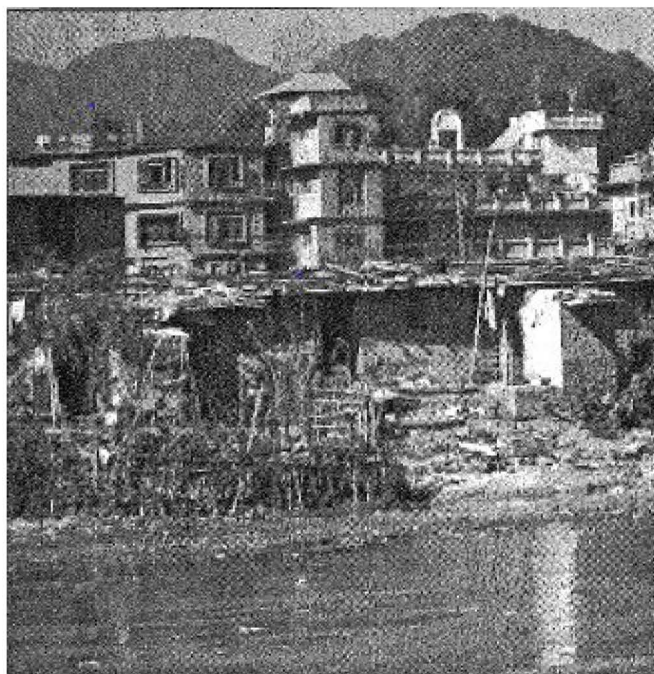
### Background

The principle rivers of the Kathmandu Valley section of the Bagmati Basin, the Bagmati and Bishnumati, suffer severe ecological degradation inside the urban area of Kathmandu, conventionally delineated by Ring Road (see Figure 1). Characteristics of river degradation include reduced water quality and changed physical dimensions as well as, some argue, loss of the cultural and religious values traditionally attributed to the rivers. Ecological deterioration of the rivers is commonly described as having dramatically accelerated over the past ten years, a time of rapid urban growth as well as democratic transition in Nepal.

River degradation in Kathmandu has been linked to many interconnected factors. Comprehensive studies identify the main causes of river pollution inside the urban area as the discharge of untreated sewage and widespread dumping of solid waste into the rivers and their banks. Excessive sand mining in river beds, which supplies mortar and cement to the city's booming construction industry, is blamed for severe morphological and flow pattern changes. In addition to these factors, most policy and development discussions of river degradation identify human encroachment on the banks, floodplains, and river beds exposed by falling water levels as a further factor in the degradation process.

Illegal settlement on marginal riparian urban lands is a growing issue in the city. Urban growth in Kathmandu—at 6.5 percent the highest annual urban population growth rate in South Asia and double the average growth rate for the region (United Nations Population Fund 1995)—has catalyzed rapid urban development over a large area and increased population density throughout the city.

Despite a construction boom, housing supplies are insufficient to meet the overwhelming demand and rent prices have become



*The small, semi-permanent structures along the Bishnumati riverbank mark land claims made by squatters in Kumaristhan. Large legal homes are seen in the background.*

inaccessible to many. For new migrants and poorer city residents, participation in the current land and housing markets is impossible.

As a result, many new migrants and long-term Kathmandu residents employ a strategy of “squattling”: occupying marginal land illegally and claiming it through the construction of shelter. The resulting settlements and their occupants are referred to in Nepali as *Sukumbassis*. These settlements are growing at 12 percent annually, a rate twice that of the city itself; at this rate it would take less than ten years for the entire riparian corridor of the Bishnumati River, shown in Figure 1, to be claimed by Sukumbassi settlement (His Majesty's Government of Nepal and Asian Development Bank 1991).

In the fall of 1997, the time of this research project, the total number of settlements characterized as Sukumbassis in Kathmandu was 54. Half of these settlements were riparian, situated on the banks of the Bishnumati, Bagmati, or one of their larger urban tributaries (Tanaka 1996). Of the total population of Sukumbassis in the Kathmandu Valley in 1996, close to nine thousand (Tanaka 1996)—69 percent—lived in riparian settlements and about two-thirds of those occupied settlements on the Bishnumati or Bagmati Rivers. Figure 1 illustrates the location of most of these settlements.

The severity and complexity of river degradation in Kathmandu has led to extensive official dialogue focused on planning the restoration of the Bagmati and Bishnumati Rivers. International aid organizations and Nepali government agencies have produced a variety of reports which propose policy and projects to promote river restoration. Restoration efforts acknowledge the immense strips of human settlement present on the city's river banks—and, in some cases, on exposed bed. But almost always, the imperative solution to the “Sukumbassi problem” is identified as unconditional eviction,



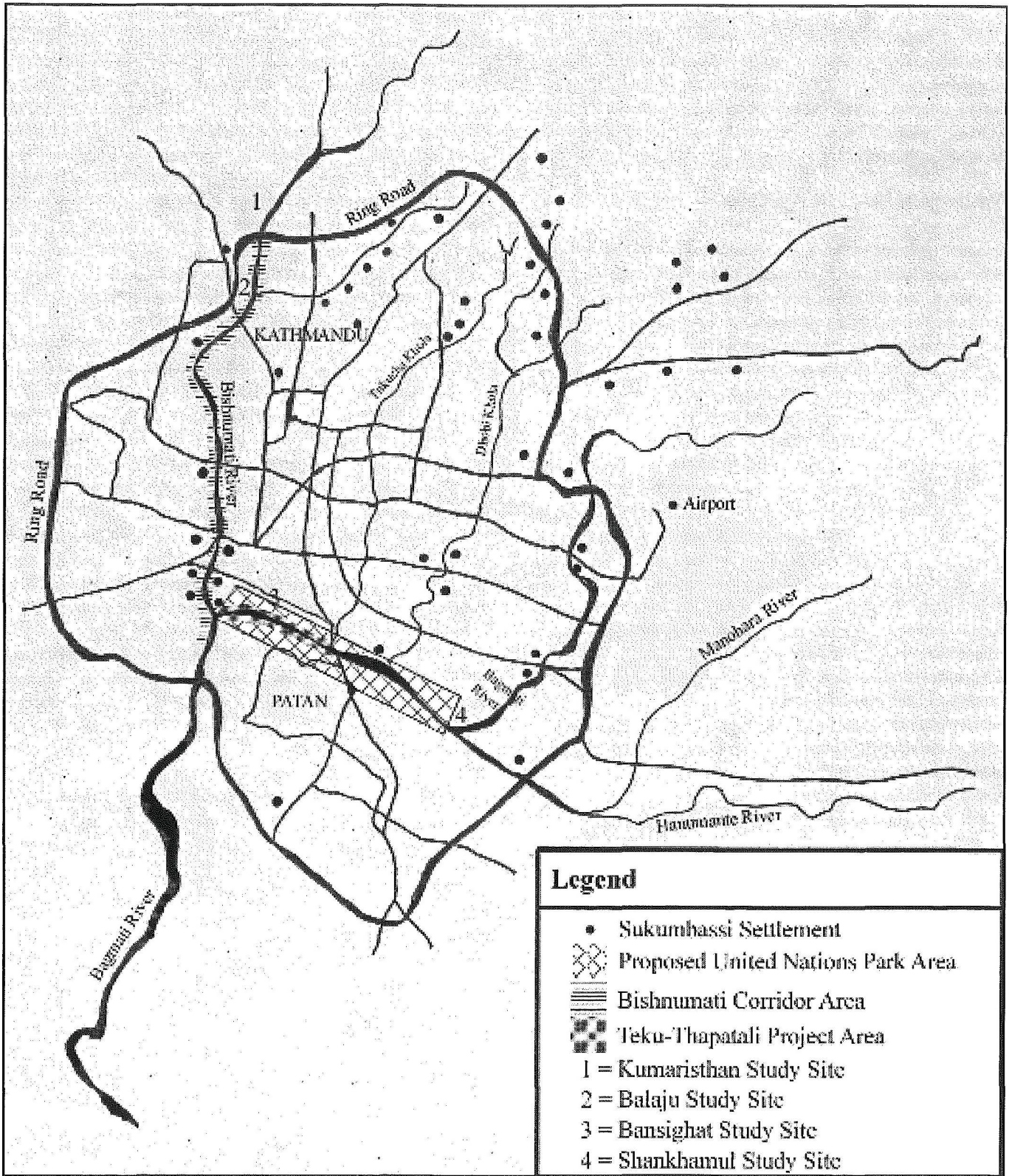


Figure 1: Sukumbassi settlements and major project sites in the Upper Bagmati Basin. (Twelve Sukumbassi settlements are not mapped.) Source: Tanaka 1997.

justified through claims ranging from undesirable aesthetics to the ecological integrity of the system to property rights and legality issues. Suggestions of eviction can be implicit or explicit, and they usually do not address the need for resettlement of Sukumbassi populations elsewhere. Projects designed to engage and involve the “local community” in river restoration activities nearly always exclude Sukumbassis.

## Findings

Methods employed in this research included the review of policy documents related to river restoration initiatives on the Bagmati and Bishnumati, key informant interviews among Sukumbassis, NGO representatives, and policymakers, and an interview survey administered to a 5 percent sample of Sukumbassi community residents.

Policy documents that discuss river degradation in the Bagmati Basin generally concede that there is an overwhelming lack of biophysical data on which to base restoration initiatives. This lack of data and the prevalence of biophysical uncertainty in this case makes an analysis of power, problem representation, and the use of “restoration” as conceptual tools of development critical. What can be known and predicted scientifically is admittedly limited, leaving great liberty for social forces to exercise other agendas under the guise of river restoration. This has clear material consequences for those most proximate to the resource and, in many ways, the least powerful in its transformation.

Certain assumptions about Sukumbassis’ attitudes, knowledge, and practices vis-à-vis the rivers are used to rationalize the exclusion of Sukumbassi communities from community-based initiatives associated with river restoration. Project documents that make assertions about riparian Sukumbassi attitudes regarding the condition and future of the rivers claim that the settlers’ transient status and presumed instability prevent them from establishing a clear connection to, understanding of, and willingness to act on behalf of the river system. As a consequence they are either explicitly or implicitly ignored as stakeholders in the planning and execution of river restoration initiatives.

These policy assumptions were tested in a survey interview administered to a 5 percent sample of the riparian Sukumbassi population. Hypotheses driving the survey design were based on the assumption that if policy characterizations of Sukumbassi attitudes are true, one should be able to demonstrate that: 1) in a sample, Sukumbassis generally express low levels of awareness, concern, and action for the river to which they are proximate; 2) among Sukumbassis, the more recent the migrant the lesser her/his expressed awareness, concern, and action for the condition of the river. These assumptions should be evident in both the sample and the population.

The survey analysis found that both in the sample and in the population the data does not support the popular contention that Sukumbassis would, by nature of their status, express generally low levels of awareness or action with respect to the condition of the river. In each of the four dependent variables measuring attitudes about the river, high sample frequencies of responses indicating awareness, concern, and independent action to improve the river’s

condition, regardless of status, were observed. Overall, the results of the study strongly support a challenge to the popular representation of Sukumbassis as unaware, unconcerned, and inactive regarding the condition of the Bishnumati and Bagmati Rivers. Sample results suggest that the vast majority of Sukumbassis are not only aware of river conditions and find them intolerable, but they are also locally active in trying to manage the resource for a cleaner, healthier living environment.

Perhaps most important from a river restoration standpoint is the micromanagement documented in most riparian settlements. Many Sukumbassi communities are actively engaged with the river resource, performing tasks either collectively or individually which constitute efforts at management and improvement, as well as simple survival:

- Planting vegetation—from trees to grasses—is a common practice. Settlers interviewed were adamant about the potential stabilizing effects of planted vegetation.
- Settlers often described patrolling their settlement for illegal riverside dumping (practiced widely by the municipalities) and suggested that they should have more authority to watch for and halt direct solid waste dumping on the banks.
- Building riverbank retaining walls—to prevent flooding and further bank erosion—is a widespread practice. Several settlements had community-constructed toilets and services like water and electricity that were acquired through community action.
- The survey sample showed that 68 percent of Sukumbassis said that they had taken action to improve the condition of the river. In most cases, investments in river-related practices were made at personal expenses of time, money, and labor.

It is important to note these actions not simply as indicators of awareness, activity, and interest, but also as symbols of the extent of property claim common in the settlements. The extensive investments made in the communities and their environmental context illustrates the Sukumbassi belief in their own permanence on the landscape; this finding sharply contrasts with predominant policy representations of instability and impermanence. Rather than assert that every Sukumbassi is active in riverbank management and directly concerned with the river—which can be shown not to be the case—my intention is to highlight that which indicates that Sukumbassis are stakeholders in the condition of the rivers, from both a human habitat standpoint and a river restoration standpoint. Some of the most effective small-scale stewardship may very well be taking place where river meets people; in Kathmandu, that interface is nearly always at a Sukumbassi settlement.

## Conclusions

Both quantitative and qualitative data collected in this study indicates that there may be severe misperceptions about Sukumbassis and their knowledge, attitudes, and practices related to Kathmandu’s river system. These misperceptions have serious consequences for both the settlers themselves and for the restoration effort in general.

By current policy, rather than being engaged as stakeholders in the condition of the river system, Sukumbassi communities are excluded from river initiatives and threatened with eviction. More research and a careful review of the assumptions on which this programming is currently based are needed.

These findings indicate that, particularly over the short term, the restoration effort would benefit from the acknowledgement and incorporation of Sukumbassis into planned and ongoing projects. Even if the ultimate policy goal is the resettlement of migrant communities elsewhere, an inclusive policy would prove beneficial in the short term. Activities already underway in the settlements, including vegetation planting, retaining wall construction, and solid waste patrolling, can be strengthened and incorporated into current restoration activities. While the most significant restoration components, namely sewage treatment, are being planned and built, there exists a significant window of time to include Sukumbassis in restoration activities.

More broadly, it is essential to recognize that ecological restoration, particularly but not exclusively on an urban landscape, is a social, cultural, and political process. What is often represented as benign and technical in nature in fact entails social processes and transfers of power that dictate what is ecologically desirable and realistically feasible. The development narrative in the Bagmati Basin case reveals that underlying an ecologically focused agenda can be a host of complex social and political goals. As urban environmental restoration initiatives command more attention and international donor funding, attention to the social and political dynamics of urban ecology are increasingly critical considerations for resource managers.

*A full report of project methodology, data, and analysis can be obtained as a TRI Working Paper entitled "Restoration as Development: Urban Growth, River Restoration, and Riparian Settlements in the Upper Bagmati Basin, Kathmandu, Nepal."*

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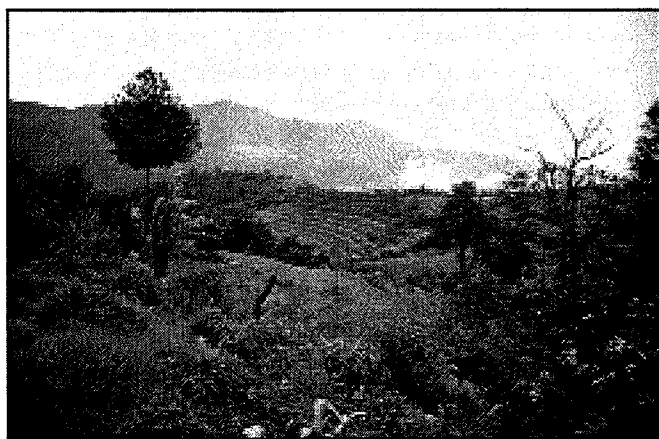
## Mexican Forest History: Ideologies of state building and resource use

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### Introduction

Throughout its history, forestry has been closely associated with state projects of resource control in the countryside, and foresters have acted as agents of a centralizing state (Scott 1998). During the nineteenth and early twentieth centuries, one of the main justifications for protection of forests was the globally reproduced myth of desiccationism, which connected climate with forest cover (Grove 1995). Forest removal was said to cause declines in rainfall, lower water tables, and declines in river flow. As a scientific theory, desiccationism has generally been discredited since the 1920s (Smith et al. 1986), although in certain circumstances (e.g., cloud forests) condensation on trees can amount to about 20 percent of total precipitation (Larcher 1995). However, as a political myth desiccationism has remained the justification for forest management, long after it has ceased to be supported by science (Saberwal 1997).

In this paper I look at the relations between forest science, forest politics, and wider political history in Mexico. I link narratives of forest decline and management with political narratives of social reform and development and of indigenous conservationism, looking at two key episodes in Mexican forest history: the closure of the Mexican forest department in 1940 and the move towards community forest management in the 1980s. The political history and experiences of the participants in forest management continue to affect how they perceive the forests. Using interview data I collected in Mexico in the summer of 1998, I trace the links between present day struggles over forest management and the historical experiences and political locations of the different stakeholders.



*Terracing near Capulapam, Sierra Juarez, Oaxaca 1998, pointed out as one of the “failures” of the Papaloapan watershed project of the 1950’s. The story is probably more complex: who is keeping those terraces clear?*

## Early Mexican Forest Conservation

A key figure in the history of Mexican forestry is Miguel Angel Quevedo (1862–1946) (Simonian 1995). Quevedo founded the Mexican forest service and fills a similar historical position to that occupied by Gifford Pinchot in the United States. Quevedo was trained as a civil engineer (with a specialization in hydraulic engineering) in France in the 1880s, at a time when desiccationism was a well-accepted scientific theory both in France and in Mexico. On his return to Mexico he noticed environmental degradation caused by deforestation, attributing flooding in the valley of Mexico to deforestation on the surrounding hills. In Mexico the mountainous terrain and erratic rainfall makes deforestation a much more catastrophic event than in temperate Europe. Quevedo was all the more aware of possible human impacts upon the environment as a result of his involvement in large-scale projects to drain the lakes of the valley of Mexico.

Quevedo warned of the negative effects of deforestation on climate. The human interactions with nature that he observed would have negative repercussions upon society, and only conservation and forest protection could prevent it. Between 1901 and the outbreak of the Mexican Revolution in 1910, Quevedo was successful in increasing public parks in and around Mexico City and in founding tree nurseries.

In general, the Diaz regime was not sympathetic to managing forests, as forest concessions were in the hands of large foreign corporations and Mexican elite capitalists (Lartigue 1983; Espin Diaz 1986). Diaz seems to have been primarily interested in parks near cities as a measure of public hygiene and an effort to beautify and modernize Mexico City. However, Quevedo succeeded in gaining support from the Mexican government, ultimately founding a forestry school with French forestry professors in 1908. The Mexican Revolution forced Quevedo into exile in 1914, and forced the forestry school to close.

In the 1920s Quevedo continued his support for forest protection, founding the journal *Mexico Forestal* in 1923. This journal was to be an influential voice for a group of desiccationist conservation scientists for the succeeding 20 years. A statement in the first issue of *Mexico Forestal* summarizes the thinking of this group:

the conscientious citizen must think of the future and thus “must clamour against the silence in our country against the national suicide that signifies the ruin of the forest and the scorn of our tree protector.” (*Mexico Forestal*, p. 82, cited in Simonian 1995)

This statement shows the way Quevedo and the conservationists were using a narrative of destructive human/environment interactions to claim legitimacy for certain environmental politics: protection of forests. The forest is described as the “tree protector” which should not be “scorned.” This moral language placed nature as an agent that protected society, and forest scientists claimed the right to speak for this agent.

The forest scientists convinced the Calles government (1924–1928) to pass a forest law in 1926 which regulated forestry activities on private lands, required plans for forest activities, and pledged the federal government to create a forest service, reestablish



*Ixtlán community forester Sergio Pedro looks at a recently treated pine stand, Ixtlán de Juárez, Oaxaca, 1998. The foresters had applied a prescribed burn after the overstory removal, and he was worried about the lack of regeneration.*

the forestry school, and establish tree nurseries. However, this law was not enforced, and the forestry school was closed again in 1927. At a time when the Mexican state was just beginning to establish itself in rural society, the implementation of the law was neither politically nor financially possible.

## Forest Conservation and Agrarian Reform

Genuine efforts to enforce the law and train foresters remained on hold until the administration of Lázaro Cárdenas (1934–1940). Cárdenas had become aware that forest degradation and soil erosion were serious problems during his time as governor of Michoacán from 1928 to 1934. However, his governorship of Michoacán was also a starting point for his program of agrarian reform that was to collide with his interest in conservation. In Michoacán he had actively supported the creation of links between the government political party and peasant groups, creating a contract of mutual loyalty and support. He nominated local leaders who would organize the *agrarista* (agrarian) land reform factions in the rural communities, and they moved to claim land that had been alienated from the community. The *agrarista* leaders were tied into a system of obligations of clientage to Cárdenas, the peasant unions, and the institutions of the Mexican state, especially the *Instituto de Reforma Agraria*, which oversaw the repartition of large land holdings and the allocation of legal titles to land. Cárdenas's period in office was marked by the transfer of control of vast areas of land to a new legal form of community, the *ejido*. In distributing land, Cárdenas created a myth which supported the legitimacy of the Mexican state: that it had fulfilled the promise of the Revolution, and given land to the landless. When Cárdenas turned to forest protection in the late 1930s, he risked treading on that myth, with potentially explosive results.

In 1935, Cárdenas created an autonomous Department of Forestry, Fish, and Game, with Quevedo as its first head, using as a rationale the desiccationist discourse which Quevedo and the conservationists had been adhering to for so long. Quevedo then set about implementing the program of forest conservation he had advocated for so many years. The forestry school was reestablished and over a thousand foresters were trained. They were given the responsibility

of enforcing the 1926 forestry laws, restricting logging, resin tapping, and conversion of forests to agriculture. Large numbers of trees were planted and educational programs were set up to teach landowners how to plant trees and protect their land. In his efforts to enforce the forestry laws, however, Quevedo soon ran into political opposition. Poor peasants needed to exploit the forest to survive, and in 1938 Cárdenas made exceptions for them, allowing them to exploit the forest free of taxes. Cárdenas's supporters also informed him that the complete ban on forest extraction was untenable, and he gave legal authorization to the ongoing pine resin extraction (Espin Diaz 1986).

In 1939, Cárdenas closed the Department of Forestry, Fish, and Game, and passed its responsibilities for forest protection over to the Ministry of Agriculture. There was to be no independent forest department until 1951 (Mejia Fernandez 1988). Quevedo had been denounced for misconduct and administrative errors. The accusation which carried the most weight, and which was probably the reason for his loss of power, was that he had failed to allow the proper development of natural resources, and therefore held "anti-revolutionary" beliefs. Quevedo did not favor Cárdenas's land reform program because he feared that peasants would expand their fields at the expense of the forests. In disagreeing with land reform Quevedo had threatened the legitimacy of the Mexican state, which Cárdenas was trying to build. Subsequent to Quevedo's loss of power, desiccationism was attacked by agronomists whose central focus was agriculture, not forestry. The 1926 forestry laws remained largely unmodified, but they generally were not enforced. Agriculture was the focus of government attention; forest concessions were often used as political rewards for powerful supporters.

When forestry rose again in the 1950s, it rose in a new form, and explicitly repudiated forest protection as a rational policy, advocating industrialization and technical forestry instead. The official silvicultural system chosen by the Mexican state in the 1950s was the *Metodo Mexicano de Ordenación de Montes* (Snook 1997). This diameter limit selection system removed technical judgement from the forester; his only responsibility was to see that small trees were not taken (which was, in any case, unprofitable). This system made the forester a bureaucratic functionary who did not claim any particular ecological expertise. Claims of expertise had to be linked to the project of building a modern bureaucratic state, not to an independent ideology of environmental degradation.

## Logging Concessions and Exploitation

In Mexico during the 1950s and 1960s, forest exploitation was in the hands of concessionaires, both foreign and national. Local level utilization of forest products was officially forbidden, although cutting for charcoal, firewood, and timber continued. State functionaries blamed forest destruction upon "irrational peasants," and later upon foreign timber concessions. Many areas of forest were theoretically closed to extraction, but little effort was made to enforce these bans, which provided a source of income for corrupt local officials and for forest entrepreneurs who colluded with them (Simonian 1995; Klooster 1997).

During the 1960s the Mexican state set about remedying this

situation by setting up forest exploitation industries. These were large parastatal corporations, which held monopolistic purchase powers and logging concessions over large areas of forest. In 1958, 261,000 hectares of forest in the Sierra Juarez of Oaxaca were given in concession to the parastatal Tuxtepec Paper Company (FAPATUX) and the private Oaxaca Forestry Company (Bray 1991; Chapela and Lara 1995). By far the largest concessionaire was FAPATUX, with over 240,000 hectares (personal communication, Ramirez Santiago, 1998). FAPATUX extracted timber for pulp production from the oak/pine forests of the Sierra Juarez, negotiating yearly contracts with the communities who nominally owned the forests. A government commission set the prices for timber and kept them artificially low, thereby inflating profits for FAPATUX (personal communication, Escarpita 1998). To add insult to injury, what revenues were received as logging dues were paid into a central fund administered by the government. Communities had to apply to this fund for money for approved activities such as building schools and roads. The communities that owned the forests received few benefits as a result of logging (Bray 1991; Klooster 1997).

During an extended interview during the summer of 1998, Jaime Escarpita, a former director of FAPATUX told me:

We built the roads for each community. Half were tar roads, for all season supply. They were well built, and we would also negotiate to build schools and churches in return for a contract [annual permit to extract timber], but that isn't recorded in history.

Escarpita describes the relationship between FAPATUX and the communities as a paternalistic one. The communities had no choice but to sell timber to FAPATUX. They received benefits in kind from FAPATUX, and some *comuneros* (community members) got to work as loggers for the company. However, in the view of the former director of FAPATUX, the *comuneros* had no experience or knowledge about the forests: "they learned how to use chainsaws from us." The official view was that the *comuneros* had no useful knowledge about the forest and that their political agency and technical knowledge was irrelevant to managing the forests.

However, the inhabitants of the Sierra Juarez had a long history of resistance to central government claims over natural resources. In 1944, massive flooding in the Papaloapan valley was blamed on deforestation in the watershed, and the Papaloapan Commission was set up to coordinate development of the region (Tamayo and Beltran 1977). The project was not a success; villagers resented being asked to build terraces and change agricultural practices which they saw nothing wrong with. When I asked about this period, a village leader pointed to some abandoned terraces as remains of the project: "It failed, and actually it caused more problems than it solved, as erosion is not really a problem up here." What this project did teach *comuneros* was that the government viewed their land use as potentially damaging and that the government might use arguments of forest destruction to justify development projects. The government could claim land from peasants both because they deforested it and because they were not developing it properly. The linkage of forest protection and development was to reemerge in the discourses used by local communities to claim control of the forests.

## Peasant Communities and the Narratives of Local Control

During the 1960s, the government tried to relocate settlers who had been displaced by the enormous Miguel Alemán Dam on the lower Papaloapan into the Sierra Juarez. The communities of the Sierra Juarez protested vigorously. They said "they were there to defend the forest, and that the forest was theirs; no outsider had a right to control it." (personal communication, Ramirez Santiago, 1998). In the end, the government backed down, and the settlers were relocated elsewhere. These experiences taught *comuneros* that the quality of their management of the forest was a political tool, and that they could claim control of the forest by claiming to be the legitimate guardians of the forest.

By the 1970s, discontent with FAPATUX had boiled over; the community of San Pablo Macuiltianguis organized 14 other communities to boycott FAPATUX. Initially, these protests were aimed at securing a better deal on the logging contracts, but as the concessions came up for renewal in 1983, an organization was formed to claim control of the forests. The name of the organization was *Organización en Defensa de los Recursos Naturales y Desarrollo Social de la Sierra de Juarez* (Organization to Defend the Natural Resources and Social Development of the Sierra Juarez). The name alone shows how the *comuneros* were self consciously adopting the government rhetoric of development and protection of natural resources to support their claim to the forests. A vigorous protest was launched with the grassroots magazine *Tequio* (Communal Labor). A statement from the first edition summarizes the aims of the organization:

We will no longer permit our natural resources to be wasted, since they are the patrimony for our children. The forest resources should be in the hands of our communities, and we will struggle for greater education that will permit rational expansion. (*Tequio*, cited in Bray 1991)

The *comuneros* were adopting the rhetoric of rational use and environmental protection in order to support their claim to the forest.

The grassroots movement for control of the forests came to a head when there was a group of reform-minded bureaucrats within the forest service, including Cuauhtemoc Cárdenas, the son of Lázaro Cárdenas, director of the forest service from 1976 to 1980 (Mejia Fernandez 1988). The reformist bureaucrats had a number of justifications for their policies, but one important strand was the ideology of *indigenismo*: the belief that the indigenous communities were ecologically sensitive guardians of nature and should be given land to compensate for their past sufferings. This ideology is reproduced in international policy documents, national level policy statements (Chapela and Lara 1995), and at local levels in the Sierra Juarez. In my conversations with the *comunero*/biologist Gustavo Ramirez in the summer of 1998, he repeatedly stated that indigenous communities were the best protectors of biodiversity and the forests.

The reformist bureaucrats succeeded in pushing through the cancellation of most of the concessions between 1983 and 1986, so that the forest could potentially be handed over to the communities which theoretically owned it. However, the government still

required that the forests come under management plans written by foresters. A rapid succession of forestry laws since 1983 has served to assert the rights of communities to own and manage their forests (Bray 1996). There is a wide range in the degree of organization of the communities, from those that sell standing timber to outside contractors to those that employ their own foresters and process the timber in their own sawmills.

## The Future of Mexican Forestry: Ideology and conflict

The experience of struggle to gain control of forest resources has created a particular understanding of the forest for the communities of the Sierra Juarez. I have only been able to interview foresters, but the disputes between foresters and *comuneros* over forest management reveal quite different understandings of what the forest is and how it should be managed. In 1998 I interviewed foresters in two communities in the Sierra Juarez. Both foresters told me that a key problem for them was getting the communities to accept the seed tree system of regeneration that they were trying to apply in the pine forests. This system requires the removal of 60 to 80 percent of the adult trees, leaving a scattering of parent trees to produce seeds, which germinate on the scarified soil below. Pines are light demanding pioneers, so the seed tree regeneration system is designed to mimic the ecological requirements of the species. The previous selection system only took a few large trees, but prevented regeneration, and encouraged non-commercial oak species to proliferate at the expense of the pines (Snook and Negreros 1987).

In the eyes of the two communities, the seed tree system was unacceptably harsh: one community fired their forester; in another, the foresters repeatedly told me that the silvicultural system was the greatest source of friction between them and community members. In some meetings the foresters had been heavily criticized by the *comuneros* for overcutting. Why the conflict? Although I have not interviewed any *comuneros* on the subject, I have a tentative explanation.

The history of struggle for control of the forests has taught the *comuneros* that they can gain control of the foresters by being ecological guardians and by preventing deforestation. Deforestation has become a political symbol used to claim control of the forest. The *comuneros* have gained control of the forest by claiming to be its guardians. They are, therefore, unwilling to give up this moral high ground by adopting what they see as destructive practices. The foresters have a very different understanding, based upon the idealized history of the silvicultural system they are trying to apply and the scientific facts they derive from it. If they are accused of irrational deforestation, they can defend themselves by showing that the forest has remained intact. In one community a process of negotiation appears to be taking place. The *comuneros* are watching the regeneration on trial stands. If it goes well, they may let the foresters carry out the orthodox seed tree treatment.

In this section I have looked at the way forestry is contested and created in the Sierra Juarez, and the way the narratives (scientific or political) of the different stakeholders affect how forest management is applied on the ground. I do not have enough data to do more than

gesture toward the narratives of *comuneros*, but I suggest that they are different from those of foresters, and that they are related to the political history of struggle for control of the forests. The *comuneros* have gained control of the forest by claiming to be its guardians and linked to the land in a special way.

I have a better idea of the way foresters see nature: they claim to understand it and to have the ecological knowledge to manage it wisely. Ironically, the foresters are applying a silvicultural system that is based upon Finnish experience of pine management, which is not necessarily the most socially or economically appropriate for the Sierra Juarez. They too bare the scars of past history: since the closure of the forestry department in 1940, foresters have had little training in the then-controversial ecology, which was linked to the discredited doctrine of desiccationism. Thus, their relative lack of ecological knowledge is in part the product of the battle between Miguel Angel Quevedo's conservationism and Lázaro Cárdenas's agrarian reforms.

## Conclusions

In this paper I have linked the historical experiences of the different stakeholders in Mexican forest management with their present day interpretations of how the forest should be managed. I have shown how technical knowledge is interpreted within a wider political and economic context, and how a lack of awareness of the political context can result in the rejection of foresters and forestry. This points towards the need for a more politically astute forestry. Foresters need to self-consciously analyze the histories and political narratives of the people they work with if they are to succeed in building the broad consensus that is essential to successful forest management. Rather than bewail the politicization of forestry, we must recognize that science has always had to contend with competing political narratives. Foresters, if they wish to achieve their goals, must also be competent political actors.

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## Finding a new direction during a participatory community mapping project

Amity Doolittle, Program Director Tropical Resources Institute

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### **Introduction: tensions between academic and participatory research**

Many students, scholars and practitioners of sustainable resource use believe that successful resource management projects must include the active participation and support of local communities. But how do we best achieve participatory research within the boundaries of academic work? Ideally in participatory action research (PAR) the community's and the researcher's objectives are compatible. However, the reality is that PAR is fraught with obstacles. Success in the academic world is based on the researcher's ability to collect unique data that can be used to test hypotheses, build compelling case studies and ultimately advance theoretical models. As a result it is not always easy to align the researcher's objectives with community priorities. Therefore, at a very basic level there is tension between participatory and academic research models. Yet, another overriding tension still drives many academics to attempt PAR: in addition to academic goals, many scientists are dedicated to empowering the people they work with and to finding real world applications to their research. The following case study demonstrates an example of how these tensions play out on the ground.

### **Community mapping: working with NGO members**

In the summer of 2002, I was invited to join Dr. Lisa Curran's long-term research project exploring the influence of humans, land use change, fires and climate on forest dynamics and carbon sequestration in West Kalimantan, Indonesia. The main goal of this NASA-funded project was to document the rate and extent of

land cover change in West Kalimantan and to explore the causal factors driving the change. As part of this research project Dr. Curran asked me to work with several local Indonesian NGOs and a local village on a community mapping project. Her objective for this component of the project was to equitably involve communities and local NGOs in gathering research data in order to promote positive changes in environmental management. The Indonesian NGOs involved in this project already had considerable experience and technical skills working with global positioning systems (GPS) and geographic information systems (GIS). My objective as a social scientist was to work with Dr. Jeff Fox (a geographer from the East-West Center) to train the NGO members in social science research methods that can be used to understand property rights systems, document oral histories of landscape change, and to look at contemporary patterns of land use and land conflicts. Our goal was to convey the notion that the landscape and the maps you make of it can be seen as "social histories of geography", not just symbolic representations of physical geographic features.

We began our training exercises in a classroom setting with Indonesian members of 15 different local NGOs from West Kalimantan. In the context of Indonesia and the current political instability associated with de-centralized governmental authority, community maps hold strong currency to individuals and communities trying to document their rights to land. These NGO members were all interested in supporting indigenous peoples in their struggles over land rights. Our first step was to facilitate discussions about the capacity of community maps to empower and the

importance of understanding social meanings attached to natural resources. In the context of the larger research project, we emphasized skills needed to document changes in land use patterns within village territory. This data would be particularly valuable for determining the ability to predict land use regimes from remote-sensing images and scale up local observations to the province of West Kalimantan. Specifically, we were interested to see if differences between advanced secondary forest and managed fruit and rubber orchards could be determined from remote sensing images (Landsat ETM+ 30 m resolution). The answer to this question has powerful implications in terms of land rights. There are instances in Indonesia when government officials make decisions about boundary placement for plantations and forest concessions based on forest cover determined from satellite images. In these circumstances, their ability to recognize the signs of managed lands (such as fruit orchards and rubber tree gardens) and the existence of local use rights is crucial. If such a distinction could be made from satellite images, there is the potential to reduce land conflicts between indigenous people and concessionaires.

The classroom discussions quickly heated up as we worked through the broader implications of dealing with native customary law and community mapping in a political climate where traditional claims to land rights are often not legally recognized. The participants expressed concerns that a seminal court case in Sarawak, Malaysia, where community maps were not allowed as evidence of native people's ownership of customary forests, might have implications for Indonesia. We debated the pros and cons of re-invigorating or codifying native customary law, which by nature is designed to be flexible and responsive to political and economic changes. Given these discussions, it seemed as if all participants had similar objectives for this community mapping project.



### **Community mapping: working with the community**

One of the NGO leaders had organized the entire field exercise and handled all the communications with the village. As a result, Dr. Fox and I had no prior knowledge of the region or community participating in the mapping workshop, which turned out to be a communication gap that hampered the progress of the project. One explanation for this communication break down is that the lead NGO, in an effort to gain legitimacy and increased power in the region, effectively co-opted the mapping exercise and attempted to control as much of the information flow as possible, for their own purposes.

As soon as we arrived in the village, two events occurred which indicated to me that the community had an agenda of which I was not previously aware. First, village elders greeted us with a ritual cleansing ceremony, which is traditionally used throughout Borneo to “cleanse” outsiders of evil spirits before they enter the village, and to gain permission from the deities for our visit. Several young men and women performed traditional dancing and we were offered rice wine from a water buffalo horn. It appeared as the villagers were placing considerable importance on our arrival, which suggested to me that this project was more important to the village than I had anticipated.

Second, I saw several young men wearing a tee shirt that said, “Give us back Bukit Bunga-Bunga (Flower Hill).<sup>1</sup> This indicated to me, as I later confirmed through interviews with villagers, that the village was well-organized on issues of land rights and they had a vested interest in the outcome of our mapping exercise. This community seemed mobilized for social action at a level we had not anticipated. While this was a welcome discovery, it did alter our first impressions of our role as facilitators. A better understanding of the roots of this collective action was key for us to be valuable facilitators of the mapping process.

We started the following morning by working as a group (facilitators, NGOs members and

villagers) to identify key topics that we might like to explore in interviews about land rights and resource use. These topics included agricultural cycles, gender differences in resource use, oral histories of landscape change, resource use conflicts, village resource-based economics, and so on.

Over the next few days as I interviewed villagers, I learned about the central issue that was motivating both the villagers and the NGOs in their participation in the mapping exercise. In 1992, a massive oil palm plantation had been planted on land that the villagers felt was their territory. The plantation owner had arranged compensation for the village; each household had the right to manage and harvest palm fruits on a small plot of the plantation. However, 30% of the profits from the fruits had to be returned to the company. To many villagers, this seemed less like compensation, and more like coerced sharecropping on their own land. Villagers were determined that the land, known locally as Bukit Bunga-Bunga, should be returned to the village. We were aware of the conflicting claims resulting from the plantation prior to this mapping exercise. But since the plantation and village had reached a settlement over a decade ago, we had not anticipated that this conflict would still be considered unresolved by villagers. Yet it was this very conflict that was motivating the villagers to produce a map showing the village territorial boundaries. They hoped that a map could be used as evidence of ownership to reestablish their rights to village territory. Their desire to map the perimeter of the village meant that our interests in mapping land use patterns, the social history of land use changes and other “social” aspects of the landscape were not compatible with those of the community members. In fact, our research objectives seemed irrelevant in the current context of village life. We felt that knowledge of the social processes surrounding resource use and ownership were important for the village and local researchers in their negotiations with outsiders who have encroached (with state sanction) on their territory.

NGO and village researchers, however, were more concerned with a different type of knowledge production: the mapping of their territorial boundaries.

Following the spirit of PAR it was our role to provide the villagers and NGO members with the tools to reach their objectives. Yet in terms of obtaining the data that was valuable to the larger research project, it was our job to try and map land use regimes inside the village boundaries, and to train the NGO members to be able to replicate this work in other villages. While we wanted to conduct interviews and transect walks, most participants wanted to walk the village boundaries with GPS units. How could we reconcile or bridge these differences?

As facilitators, we chose to make ourselves available to any community members and NGO members who wanted to conduct interviews with villagers in order to gain a social understanding of the landscape. A small group stayed with us each day to interview people, conduct transect walks through gardens and managed forests, and visit places of ritual and historical importance to the village. A much larger group, however, met each morning to mark the village boundaries with GPS technology. In the evenings, both groups would meet and share data. The group that conducted interviews would share their key findings with the larger group and the ones that collected GPS points would translate that data to a GIS database to be overlain on the satellite image. In order to fulfill our objective of emphasizing the social nature of landscape change, we would focus our discussion on why a social history of the landscape was valuable in terms of long-term management of the village’s resources. By providing the community with this knowledge, we were hopeful that we could provide them with tools that would increase their power and authority in future community efforts to validate their historical ownership and claims to their land.

## Conclusions

Several interesting conclusions can be drawn from this case study in PAR. First, there were

many obstacles to the success of this project. One obstacle was the early communication failure between all the groups involved. Open communication is absolutely necessary for the success of any project. We did not know that the village had a clear objective prior to our arrival. If we had known about the strength of the villager's opposition to the settlement from the oil plantation, we would have realized the importance of resolving external boundary conflicts for this village. Instead, we focused our early exercises on understanding internal village dynamics over resources ownership and management. It is not uncommon for Indonesians not to correct outsiders when they are wrong or operating under incorrect assumptions. Therefore, it took us some time to understand why the villagers' interest in this topic was not high. Once we did reach this understanding, we were able to refocus our group activities to meet village priorities. Reaching these kinds of hurdles in research is the relatively common; this example emphasizes the need to be self-reflexive in the field.

Another obstacle was our limited time with the village and NGO members. If we had more time to stay in the village to continue this work it might have been much easier to fulfill both the village's and our objectives. It would not have compromised either objective to have two different groups gathering different types of data and meeting in the evenings to share their findings. But since we were there for less than two weeks, ultimately we had ensure that the villagers' goals were the primary objectives, even though it meant that ours were sacrificed. The final product of our research was a map of the village perimeter. We only collected very basic data on the land use regimes, resource management systems and the social history of the landscape. And we were not able to map the variations in land use within the village boundaries.

A second conclusion can be drawn from this case study: this is a clear example of the community (and the organizing local NGO) using "experts" (western social scientists) in a political

manner to support their position in a century-long struggle over land rights. It is not unusual for governments and conservation groups to use western experts to support their goals, but it is a turning of the tables for an indigenous community to use western researchers in this way. It seems appropriate for the positions to be reversed, given that this was a PAR project, designed to empower community members.

Third, this case does give us the opportunity to reflect on the positive outcomes of PAR, even when the project struggled over differing objectives. All the data were left with the community and the NGOs involved in the project. Access to and ownership of this data create opportunities for empowerment for these groups in future struggles over boundaries. And finally, while we did not create a map of the land use regimes within the village, we did take an initial and necessary step toward that objective by training a few NGO members in social science methods. Given the political and economic realities in Indonesia, mapping the perimeters of the village should be the first step in a long process of staking claims to land and resources. Only once these boundaries are defined can land use regimes with the territory be mapped. The villagers and NGO members that we worked with are certainly positioned to work on that mapping exercise when they feel that information would be useful.

There are three broad lessons that can be drawn from this case study about PAR as a methodology. The first is the notion that PAR methodology cannot be universally applied to all research projects. Certainly many of the tools from the PAR approach can be valuable for any research project. Clearly PAR is tremendously valuable in defining community priorities when external interventions by the state, NGOs, or multi-national corporations are involved. But the commitment to facilitating the community in identifying the research objectives and engaging in research activities as partners is not always possible when the outside researcher has defined goals in mind. All researchers, however, can learn from the

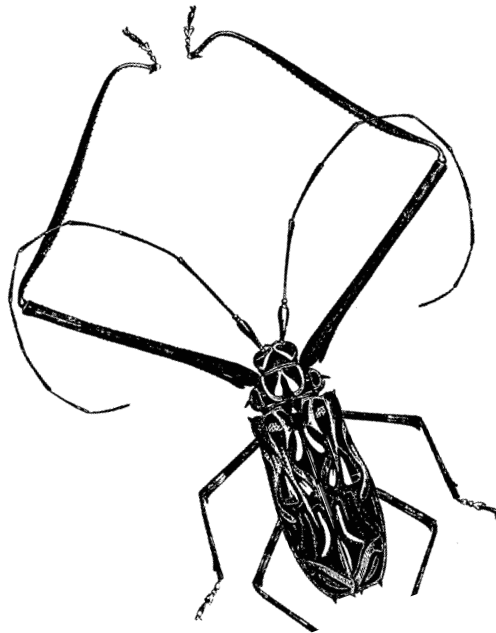
ideological underpinnings of PAR, by offering the community information as freely as the community shares it with them. In this way research becomes less extractive in nature and more mutually beneficial for communities that might otherwise be treated only as “subjects” in a research project.

The second important lesson from this experience touches on the length of a research project. If this mapping exercise had been a one-time, two-week long workshop, the PAR approach would clearly be a losing strategy. However, the larger project that this workshop is a part of is a three year project and, thus iterative. As researchers, we can learn from the mistakes made in this field experience and build these lessons into the next mapping exercise. This self-reflexive approach to research is crucial as we encounter events or discover knowledge in the field that challenges out assumptions.

The final lesson is that working in complex situations, with divergent objectives and time constraints requires long-term investments in sites and regions. Students from F&ES who are beginning summer research projects will experience the range of the conditions described above and need to be prepared to modify their research plans in the field. Furthermore, many students will go on to implement long-term inter-disciplinary projects for NGOs, governments and science, and all the issues raised in the article will need to be considered. Short-term experiences, such as the case described above and summer research projects, are valuable no matter what they produce - especially if one learns and incorporates those lesson in future endeavors.

#### Notes

1 Following anthropological conventions I am using a pseudonym for local place names.



From James Castner, 1990. *Rainforests: A Guide to Research and Tourist Facilities at Selected Tropical Forest Sites in Central and South America*. Gainesville, Florida: Feline Press.

# Whale Shark “Ecotourism” in the Philippines and Belize: Evaluating Conservation and Community Benefits

by Angela Quiros, MEM 2005

## Introduction: Donsol and Placencia

Whale shark tourism all over the world is a highly lucrative industry based on an ecologically vulnerable species (Norman 2000). In the Philippines, Donsol is a popular destination for local whale shark tourism. In Belize, international divers visit Placencia to observe whale sharks in Gladden Spit Marine Reserve. Other sites of whale shark tourism are Ningaloo Reef in Australia, the Seychelles, and Isla Contoy in Mexico. Although these sites have different environmental, social, and economic contexts, all can benefit from adopting ecotourism best practices.<sup>1</sup>

The initiatives in Donsol and Placencia support literature on the variable role that ecotourism plays as a conservation development tool. In a study that tested enterprise strategies for community-based biodiversity conservation, Salafsky et al. (2001) found that an enterprise strategy will not lead to conservation at all sites. Rather, various conditions – including the nature and benefits of the enterprise and the identity of the stakeholders – influence the probability that a particular strategy will lead to conservation. To conserve whale sharks while improving residents’ socioeconomic status, community-based ecotourism was initiated in Donsol, Philippines and Placencia, Belize. In this article, I present qualitative results of

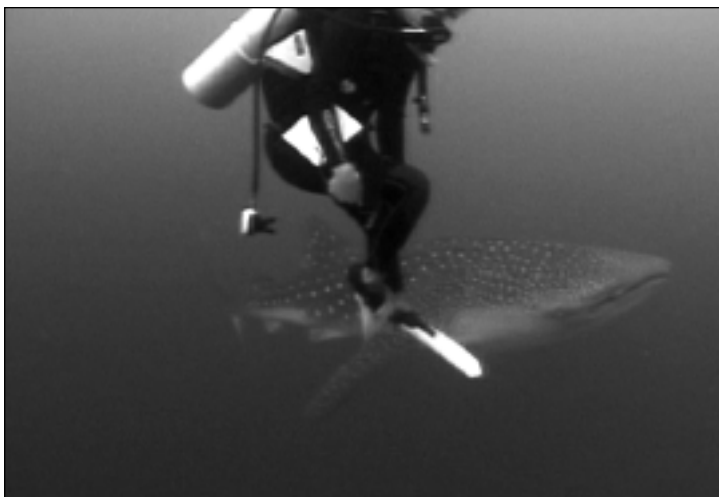
research conducted between January and August of 2004, where I studied and evaluated impacts of these projects on whale sharks and the communities involved.

## Context

In January 1998, whale sharks attracted to plankton blooms were discovered in aggregations off Donsol, a fishing village in the Philippines. This event attracted tourists, poachers, media and government agencies interested in obtaining a piece of the whale shark pie. In the wake of the discovery, poachers killed seven sharks; Donsol waters were subsequently declared a whale shark sanctuary, and related hunting and trading was banned throughout the Philippines. However, local fishermen were commissioned to take people on their boats to swim with the whale sharks, even though Donsol had no official tourism infrastructure (Yapinchay 1999). WWF-Philippines started the Whale Shark Research and Conservation Project to provide ways for Donsol to protect whale sharks through responsible tourism and fishing practices. In 1998, they worked with the local government and the Donsol Municipal Tourism Council to develop a community-based whale shark sanctuary and ecotourism program, to set regulations and fees, and to organize and train guides and boatmen (Yapinchay 1999). Registered tourism arrivals were up to 3,175 between December 2003 and May 2004, and in 2003, the Department of Tourism of the Philippines built a Tourism Office that coordinates all whale shark tours.<sup>2</sup>

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*Angela Quiros is from the Philippines and has prior experience in marine conservation issues in the Philippines and the Caribbean. She plans to continue working with marine wildlife and ecotourism in the context of protected areas.*



The author diving with a whale shark in Gladden Spit, Belize.  
*Photograph by Shayne Peche.*

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Whale sharks have congregated at Gladden Spit on the Belize Barrier Reef as long as the oldest fishermen can remember. Whale shark tourism, however, was not considered until 1997, when the community discovered that during the ten-day period around the full moon in April and May, whale sharks eat the eggs and sperm from spawning cubera snappers (FoN 2002). Whale shark tourism in Placencia, the nearest town to Gladden Spit, grew from one to 22 tour operators between 1997 and 2004, and the tourism market grew from 500 visitors in 2002 to 1,299 visitors in 2004. (Jones 2004). Official management did not start until 2004, when Friends of Nature, a Belizean conservation organization worked with The Nature Conservancy and the Placencia community to train and register whale shark guides, to establish and implement regulations, and to designate a Whale Shark Zone in Gladden Spit.

### **Challenges**

Challenges to successful ecotourism ventures in Donsol and Placencia originate from the unique biology of whale sharks, socio-economic concerns of communities, and tourism management. Adopting eco-tourism best practices would minimize effects of tourism on whale sharks and benefit local communities.

### **Impacts to the whale sharks**

Whale sharks' sensitive nature, aggregation at specific times of the year, slow maturation rate (30 years to reach sexual maturity) and migratory behavior all make them susceptible to anthropogenic impacts (IUCN 2004). The IUCN classifies whale sharks as vulnerable based on past records of declining catches and abundance (Norman 2000). This evidence supports the need for low-impact activities at whale shark sites to promote sustainability of the industry.

Observations of whale shark tourism in the Philippines and Belize indicate that whale shark behaviors include feeding, diving, and basking on the surface. Some behaviors are categorized as "avoidance behavior," such as diving away from swimmers, changing direction, and banking (Colman 1997). Since Gladden Spit and Donsol waters are both feeding grounds for whale sharks, disturbing them while they feed could reduce the sharks' survival by diverting their energy from feeding to avoidance behavior (Sorice, Shafer, and Scott 2003; Hammitt and Cole 1998). In Donsol, management practices and tourist behavior significantly increased the probability of whale sharks exhibiting avoidance behavior, such as directional changes and diving in response to humans. Significant predictors of a whale



BIO holding on to whale shark in  
Donsol, Philippines  
*Photograph by Cristina de León.*



shark's directional changes were path obstruction of the whale shark and proximity of a swimmer to the whale shark. Significant predictors of a dive response were first-time sighting and path obstruction of the whale shark.<sup>3</sup>

#### ***Social and cultural changes***

There are benefits and drawbacks to whale shark tourism. On one hand, commercial sectors are thriving, as evidenced by the proliferation of small stores and restaurants in Donsol, and resorts in Placencia. Both towns take pride in being known for whale sharks. The yearly Butanding Festival<sup>4</sup> held in Donsol every April is testament to that fact. On the other hand, tourism has brought little infrastructure development. Good roads are needed at both sites.

Whale shark tourism comes to Placencia at a time when tourist visitation is low, providing an important off-season income. However, only a few licensed tour operators and dive guides in Placencia benefit from this highly lucrative industry, with dive tours reaching US\$200 a person. In Donsol, 26 active guides, or Butanding Interaction Officers (BIOs), and 60 members of the Boat Operator's Association (BOA) work on a rotational basis. A whale shark tour boat in the Philippines costs US\$50, which can hold up to seven people. The lower fees in Donsol and greater membership translate to

lower returns, as compared to Placencia.

Certified guides and tour operators in both locations aim to keep membership low to provide more income for those already involved. In Donsol, BIO training has not been conducted since 1998, and recent attempts by WWF-Philippines to organize training for new BIOs have been halted due to conflicts among stakeholders.<sup>5</sup> In Donsol, whale shark tourism is an alternative to fishing and farming, and efforts by the local government are underway to provide alternative means of tourist income, such as firefly watching and island hopping. However, these activities are not enough to provide full-time employment.

Tourism development has changed some underlying values in the community. Stakeholders chose to have a protected area in their own waters, but with the coming of tourism, attention has shifted from eco-tourism for whale shark protection to tourism for commercial gain. The race to maximize profits has resulted in crowded conditions at the whale shark aggregation sites. One tour operator in Placencia has stopped conducting whale shark tours because he thought that there were "too many people" in the water. Tour guides and operators are placed in the difficult position of juggling between conservation and lucrative tourism activities.

## Alternatives

If whale shark tourism management continues in its current state at these sites, increased impacts on the whale sharks may decrease sightings and increase conflicts that affect the experiential quality of the tour. In a tourist survey at Gladden Spit, visitors said that they would not return if crowded conditions did not improve (Lindberg 2004).

Whale shark ecotourism can work. In Ningaloo Reef, Australia, the industry has been prospering since the early 1990s due to proper monitoring (Colman 1997) and adequate financing for the management of resources. One alternative for creating a more sustainable product is to institutionalize ecotourism by changing rules and regulations, properly financing tourism management, and monitoring tourism impacts.

### *Changing rules and regulations*

Rules and regulations in Donsol and Gladden Spit were adopted from those in Ningaloo Reef (Colman 1997). However, site-specific characteristics make it impractical to have identical regulations. In Donsol, for example, visibility varies between three to six meters, while visibility in Ningaloo Reef reaches up to 20 meters (Kurtz 2004). Ningaloo's rules mandates that swimmers be at least three meters from the head and five meters from the tail – a rule that, if obeyed in Donsol, means visitors will not be able to see the whale shark! Thus, BIOs bring swimmers less than one meter away from the shark, breaking the regulations.

The same is seen for the “no touch” rule. Between March and June 2004, I observed 99 touch incidents from 776 interactions. BIOs touch whale sharks, and rarely reprimand visitors for breaking those rules, giving conflicting messages about the “no touch” rule. Visitors watch an orientation video that clearly lays out rules. When visitors enter the water, however, it is not uncommon for them to be encouraged to touch the whale shark by the BIO.

Two main themes of conflict in Donsol are boat approach and crowding. Interaction guidelines specify a maximum of one boat per whale shark, but when whale sharks are scarce, several boats “share” one individual, crowding around it and dropping their swimmers in the water immediately after the previous boat. This results in shouting exchanges between the BOAs and BIOs.

Whale shark tourism in Gladden Spit is concentrated during the 10-day period each month between March and June. In Gladden Spit, whale shark guides have reported up to 80 divers in the water. Whale shark tourism in Donsol, on the contrary, starts as early as January and runs until August each year, for every day of the month. Although crowding associated with very short seasons can be avoided in Donsol, weekends and holidays have the same crowding intensity as Gladden Spit. There is a 15-20 boat a day limit in Donsol, but during peak season, the only limiting factor is the number of boats and guides, available for trips. During Easter in 2005, ten uncertified guides led tours because BIOs were occupied on two or even three trips per day, and the Tourism Office recorded 76 boat trips in one day.

To address some of these crowding issues in Placencia, Friends of Nature (FoN) formed a working group in October 2004, composed of whale shark guides and tour operators, to change regulations at the Whale Shark Zone. Changed regulations involve instituting a formal rotation for whale shark dives with strict time slots to minimize crowding in the area. Applying changes in the 2005 season has the potential to improve the management of tourism at Gladden Spit.

### *Financing*

One of the greatest challenges to a self-sufficient and functional protected area is having stable capital inflows to cover management, especially personnel costs, maintenance, and

FoN Rangers and  
Community Researcher  
on patrol in Gladden Spit  
Marine Reserve  
*Photograph by Angela  
Quiros.*



infrastructure. Gladden Spit Marine Reserve was one of the sites selected by The Nature Conservancy to participate in a program that utilizes tourism user fee mechanisms for protected areas. This initiative sought to put an economic value on services in protected areas through income generation mechanisms (TNC 2002). In March 2003, Friends of Nature (FoN) determined levels for the user fee system at a community consultation meeting as US\$15 per person. Donsol has a similar user fee system, in which locals pay US\$2 and foreigners pay US\$6.

Government, conservation organizations, and local institutions influence the appropriation and misappropriation of revenues from whale shark tourism. Stakeholders are involved in this decision-making process, although to varying degrees and to varying levels of continuity. The Local Government Unit (LGU) in Donsol manages and finances whale shark tourism in Donsol. Entrance fees were established in 1998 and are collected and held by the LGU and are not specifically used for tourism management. All funds collected in 2003 were collected by the LGU and re-allocated to the Butanding Festival in Donsol, a yearly celebration of the coming of whale sharks in April.<sup>6</sup> In Placencia, alternatively, whale shark tourism is

co-managed by Friends of Nature and the government of Belize. Funds used to manage Gladden Spit come from external grants awarded to FoN. In 2004, funds collected from whale shark tickets were handed over to the government of Belize. While the majority of revenues remained with the national government to support other protected areas in Belize, a portion of those funds were returned to FoN and used to purchase a new boat motor for patrolling and research activities along the reef.<sup>7</sup>

In Donsol and Placencia, revenues from entrance fees are not used specifically for managing whale shark tourism. Funds generated from entrance fees should stay within the site, and fees should be priced at a level that will help finance management. At both sites, however, revenues are insufficient to cover the cost of management, monitoring and improvements to the site, and, therefore, ongoing outside funds will be required.

#### ***Tourism impact monitoring***

Monitoring tourism impacts on wildlife, environment, and community are an important and neglected part of tourism management. Monitoring is not typically accounted for in tourism management plans and must be financed by external funding.

Anthropogenic effects on wildlife have been studied in the context of activities like swim-with-manatee tourism in Florida, USA (Sorice, Schafer, and Scott 2003), and swim-with-dolphin operations in New Zealand (Constantine 2001) and Australia (Scarpaci, Dayanthi, and Corkeron 2003). Whale sharks have been monitored around snorkelers in Australia (Colman 1997) and in 2004, I initiated a pilot monitoring project in Donsol, which is ongoing for the 2005 season. The crowded conditions in both Donsol and Gladden Spit necessitate monitoring and a strengthening of regulations.

In Gladden Spit during the 2004 season, whale shark sightings were down to one to two whale sharks per dive from a historical high of eight to nine whale sharks per dive (Jones 2004). The decreasing likelihood of whale shark sightings in Gladden Spit should make evident to stakeholders the need for impact monitoring. Whale sharks, a long-lived, K-selected species,<sup>8</sup> may be the type of animal that does not immediately exhibit negative effects of disturbance. Tourism at both sites is not older than ten years, while a whale shark can live up to eighty years (Norman 2000). Therefore, negative effects of tourism may not be seen until more years have passed. Given the lack of scientific knowledge about this species, employing the precautionary principle is a prudent long-term plan.

Integrating monitoring into the management plans of Gladden Spit and Donsol would improve the current band-aid approach to whale shark conservation at these sites, where management does not mitigate adverse impacts with adequate foresight. Monitoring would help the two sites move toward true ecotourism principles, by indicating which activities most adversely affect the whale sharks and informing managers to minimize those impacts.

## Conclusion

The community-based “eco-tourism” projects in Donsol and Placencia have the potential

to be model enterprise strategies that will lead to conservation. A successful long-term approach is contingent on several factors: impacts to the whale sharks and the environment must be properly managed, conflicts among stakeholders must be relieved through better management practices, benefits must be spread more equitably for all participants, and the two sites must continue to receive active NGO and government support. Institutionalizing ecotourism at both sites – through implementing strategies that respond and adjust to changes, properly financing tourism management, and monitoring tourism impacts – will move Donsol and Placencia closer to sustainability.

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Aguirre, Vicky Zayco, Rolly Magpayo, Jef Buscar, Chino Villanueva, Christine Edullantes, Vera Horigue, and Elson Aca.

### Endnotes

<sup>1</sup> Ecotourism is defined as a “low-impact, environmentally-sound and community-participatory tourism activity...that yields socio-economic benefits to the concerned community” (Libosada 1998).

<sup>2</sup> Personal communication with Maria Ravanilla, Department of Tourism, Philippines, Director of Bicol Region on March 22, 2005.

<sup>3</sup> Logistic regression analyses were used to model whale shark avoidance behavior.

<sup>4</sup> *Butanding* is whale shark in Bicolano.

<sup>5</sup> Personal communication with Tito Arevalo, former Tourism Officer of Donsol’s Tourism Office, May 2004.

<sup>6</sup> Personal communication with Karina Escudero, March 11, 2004.

<sup>7</sup> Personal communication with Will Jones, Development Director of Friends of Nature, October 1, 2004.

<sup>8</sup> K-selected species have more or less stable populations at or near carrying capacity in relatively stable habitats.

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# Integrating Forest Biodiversity Conservation and Poverty Alleviation in Local Forest-Based Enterprises: A Case Study of the Woodcarving Industry, Ghana

by Dora Nsuwa Cudjoe, MEM 2005

## Introduction

Woodcarving is one of the informal employment sectors in the forested areas in Southern Ghana, notably in the Ashanti, Central, Western, Eastern and Volta regions. An otherwise part-time lean season activity, however, is being nurtured into a full-fledged trade as a result of regulatory and policy framework support for the tourism industry, which provides the main local market for carved products (Addo and Marshall 2000). Ghanaian woodcarvings are gaining increased recognition both locally and internationally, presently contributing approximately \$500,000 annually to the Ghanaian economy and providing employment to about 20,000-30,000 people (Okrah 2002). The producers, individuals and cooperatives, rely almost solely on the natural forest for wood. Wood inputs usually tend to be a few specified hard wood species, some of which, like African mahogany (*Khaya ivorensis*), have been extracted almost to the brink of extinction. Woodcarving is therefore perceived as a source of forest biodiversity loss in Ghana (Dei 1990).

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Since woodcarving is an industry important to two vital aspects of human social welfare – rural economy and forest biodiversity conservation – it becomes imperative to find alternative wood sources that are more environmentally benign. In this study, I describe the woodcarving industry of Ehwiaa, the largest woodcarving center in the Ashanti region. Ehwiaa, a tourist town located five miles from the regional capital, Kumasi, has gained local and international recognition for its carvings. I investigate the industry's structure, discuss ways in which its production could be spurred, and evaluate the potential for using byproducts from the timber industry to provide a sustainable source of wood for artisanal woodcarving. I draw inferences from a similar woodcarving enterprise, the 'Ecocraft', which uses strictly byproducts from the timber industry rather than directly from the forest. Finally, I address plausible conclusions and recommendations towards sustaining the woodcarving industry.

## Methodology

### *Research design*

I conducted field surveys; a method through which I could extract substantial amounts of data at relatively low cost within the limited time available for this research (Babbie 1989). I targeted woodcarvers from Ehwiaa after preliminary interviews with retailers in New York revealed that over 60% of woodcarvings sourced from Ghana come from

this town. Interviews in Ghana confirmed Ehwiaa's suitability as the study site: of the 150 woodcarving export companies in Ghana, "almost all source their products from Ehwiaa."<sup>1</sup>

I surveyed the following actors: one-man (individual) carvers who form about 70% of total woodcarvers; association woodcarvers who constitute about 30% of the town's woodcarving population; industrial carvers (Ecocraft project); and finally government and non-government institutions such as the Forestry Commission, Ghana Export Promotion Council, Aid to Artisans-Ghana, and the Director of UNDP-GEF, by virtue of their influence on the industry. One hundred woodcarvers were targeted, but only 20 carvers could be interviewed.<sup>2</sup> Nonetheless, I obtained a representative number of people from the various categories within the woodcarving sector (carvers, retailers, and exporters). Questions were directed at eliciting information on the social background of woodcarvers, the production chain from sourcing of wood to retailing both locally and by export, and the factors that account for changing trends in production.<sup>3</sup>

## Results and Discussion

### *Current status of Ehwiaa woodcarving*

The backbone of the town's economy and an embodiment of the rich Ashanti cultural legacy, Ehwiaa woodcarvings date back to the 19th century.<sup>4</sup> Back then, the art of carving wood was seasonal, done during the lean agricultural seasons. Two main tree species, *Khaya ivorensis* (African mahogany) and *Holarrhea wifsbergii* (sese), were used.

Woodcarving in Ehwiaa has since evolved from serving a strictly local market to being an almost entirely export-based activity. Currently the export market to Europe and the US accounts for 65% of all products made in the town, while the remaining local market includes

tourist travel to Ghana. The quality of labor force (as producers and exporters), tree species used, and product lines have changed over the years in response to economic policies (such as redundant labor from the formal sector), availability of required tree species, and market forces.

*we used to source wood from the town's vicinity but residential facilities are reducing at a fast pace the availability of wood. We have to travel for about 60 miles into the forest in search of the required species...<sup>5</sup>*

According to Okrah (2002), the retrenchment of workers from the formal sectors as part of the World Bank's Structural Adjustment Program led to more and more people resorting to informal sectors of the economy, such as woodcarving. Over 60% of Ehwiaa's population was woodcarvers about three decades ago, until receding access to the required tree species resulted in a shrinking number of carvers. Woodcarvers presently make up 10% of the town's population of 20,000 (Table 1).

Constituting over 60% of wood volume used now, *Cedrella odorata* (gyenygyene) is said to have replaced African mahogany as the most popular carving tree species. *Cedrella odorata*, in addition to having a similar coloration as the African mahogany, has the prized forestry value of a fast regenerative capacity. Logs from this species located at the research site came from 8-10 year old trees with diameter at breast height ranging between 0.4 and 0.8 meters.<sup>6</sup>

Interviews revealed that although forest plantations could serve as an alternative wood input, lack of access to land limits this source's potential. Since Ehwiaa is only five miles from the region's capital and has comparatively cheaper land prices, home owners and estate developers are increasingly buying lands that could otherwise have been used for tree plantations. Moreover, the Forestry Commission of the Ashanti Region allocates an annual quota of only 40 trees from production forests to all woodcarvers in the region, enough to supply

**Table 1.** Categories of Woodcarvers in Ehwiaa

| <b>Association</b>                | <b>Description</b>                                       | <b>Number of active carvers</b> |
|-----------------------------------|--|---------------------------------|
| Unity Carvers                     | Basically carve the Unity design                         | 120                             |
| Ehwiaa Woodcarvers<br>Woodcarvers | who own retail stores                                    | 40                              |
| Non-associational<br>woodcarvers  | Do not belong to<br>any of the associations              | 1,500                           |
| Woodcarving Export<br>Association | Network with local and<br>International wholesale buyers | 10                              |

only one-fiftieth of the approximately 2,000 Ehwiaa woodcarvers for a month.<sup>7</sup>

### ***Production and marketing***

Analysis of the rate of production revealed that, generally, an individual woodcarver utilizes about six m<sup>3</sup> of wood annually, creating a cumulative total of 12,000m<sup>3</sup> for the whole carving community in Ehwiaa. According to the carvers, this volume of wood is sourced mainly from farmlands since informal price negotiations with farmland owners for trees are far cheaper than via permits from the Forestry Commission. Previously, a Legislative Instrument, LI 1518, granted permits to carvers, but this has been repealed on the grounds that carvers frequently abused these permits.<sup>8</sup> As dwindling access to off-reserve sources therefore loom, illegal sourcing from the natural forest becomes the last resort. Woodcarvers clearly stated that they have taken to carving products at felling sites or in remote villages to evade security checks by the Forestry Commission Task Force for illegally harvested timber. Woodcarvers employ very simple locally made hand tools, which include the hammer, knife, and axe. This limits the diversity of wood species they can use, the quality of finish, and the intricacy of designs.

On entering Ehwiaa Township, a visitor is welcomed by a stream of woodcarving retail stores that lines both sides of the main road. Retailers carry the same set of items, the only differences

being in sizes and colors. Products were mostly for decorative purposes – animal and human figurines – with no little household use. Observational studies revealed that cultural artifacts which served dual purposes, such as flower vases, book-stops, cutlery, lamp stands, fruit bowls, and furniture, had greater market value. This was confirmed by Bob Hewes, Manager in charge of product sourcing nationwide for Pier 1 Imports.<sup>9</sup> Commenting on carved products from Ghana, he suggested that woodcarvers exploit avenues for more utilitarian products since “the interest among our customers for traditionally based ethnic wood carvings is not as strong as it was.”

### ***The framework within which the woodcarving industry operates***

Although a fairly small and informal sector of the Ghanaian economy, the woodcarving trade interlinks with a host of formal governmental and nongovernmental institutions (Figure 1). These linkages undoubtedly are centered on the production, financing, and market extension at levels that are, however, not involved enough to optimize the potential of the industry. There is not enough attention given to sustaining the wood resource base, an effort that will demand the regulatory and policy support from the Forestry Commission and environmental NGOs. Aid to Artisans, Ghana (ATAG), an NGO, has embarked on a forest plantation program that is geared towards establishing



1,500 ha in forest plantations. One hundred and forty-four hectares of this has already been planted. Educational institutions like colleges and vocational schools could be a source of logistical support in production and business skills training, as well as research.

### ***The 'Ecocraft' project***

A new model has emerged to address the growing gap between the dwindling supply of trees and the growing demand for wood to carve. Since a substantial quantity of products are currently being carved from smaller diameter trees,<sup>10</sup> wood waste from timber companies may support the shrinking supplies from off reserve forests such as farmlands. The Samartex Timber and Plywood Company, which has stated "the need to utilize all raw materials," has established a woodcarving unit called Ecocraft that follows this model.<sup>11</sup>

Samartex Timber and Plywood Company is a privately-owned German company located in the Western Region of Ghana, which has a well-developed woodcarving industry like that of the Ashanti Region. Samartex is situated about 240 kilometers from the Western Regional Capital, Takoradi.

Ecocraft was initiated three years ago as part of Samartex Timber and Plywood's quest to maximally utilize all their industrial waste. The concepts behind this project are (i) to add value to harvested trees; (ii) to increase recovery from the timber industry waste; and (iii) to create jobs and increase awareness about the various valuable uses to which non-conforming wood could be put.<sup>12</sup>

By channeling all industry waste (non-conforming timber forms,<sup>13</sup> round core, unwanted veneer) to the Ecocraft woodcarving unit, Samartex is able to maintain its electricity and heat generation and also increase earnings from recovered waste wood. By giving added value to waste wood, sometimes values higher than that obtained from equivalent timber volume, woodcarving is serving as an added source

of income without direct pressure on the natural forest for virgin timber.<sup>14</sup>

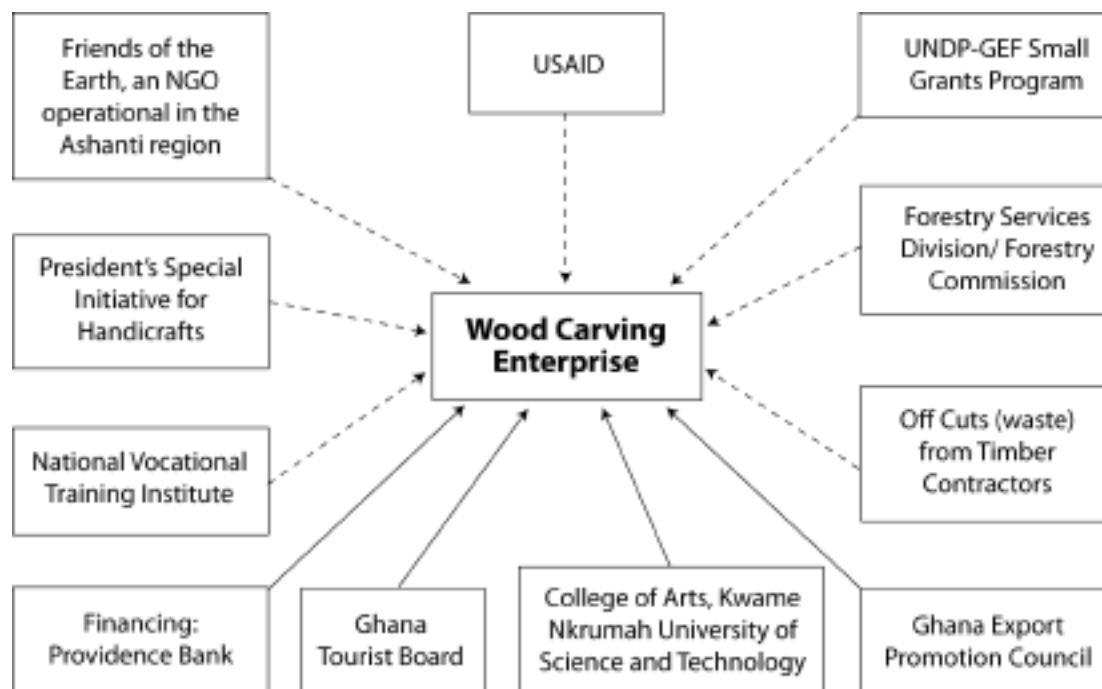
The company produces lumber, veneer plywood, and tongue and groove boards mainly for export from 25 tree species, 14 of which are utilized by the woodcarving unit. Eighty percent of products are for the international market. Of this, 60% goes to Europe, 30% to USA, and 10% to the Far East and other destinations.

The saw mill, veneer mill, plywood mill, and molding departments demand a monthly wood volume of 9,500 m<sup>3</sup>. Forty-two percent of this volume is made of species that cannot be carved. Of the 5,500m<sup>3</sup> carveable tree species, 2,750 m<sup>3</sup> – a startling 50% – is generated as off-cuts, or byproducts. Of this volume, 1,000m<sup>3</sup>, a monthly supply of carveable wood is made available to the carving unit. The rest, which is composed of cracks, slabs, heartwood, and sawdust, goes to feed the cogeneration plant. Samartex also ensures that timber harvest meets the soil nutrient replenishment and forest landscape restoration standards set by the Forestry Services Division.

It is interesting to note that the volume of wood generated from industrial waste to feed Ecocraft per annum is the same as that required by the carvers in Ehwiaa (approximately 12,000m<sup>3</sup> annually).

### ***Product comparison***

Products made by Ecocraft and by woodcarvers from Ehwiaa differed substantially in terms of product diversity and quality of finish. Samartex products are diverse and cross-cutting: both useful household items, such as furniture and house wares (bowls and cutlery), and purely decorative pieces like human and animal figurines. Ehwiaa products, conversely, focus largely on the decorative pieces. Samartex is also able to utilize 14 species of wood,<sup>15</sup> as compared to the two main species used in Ehwiaa. Although these two production lines have characteristics peculiar to them and thus cannot be directly compared, artistic creativity and available technology appear to be the main factors that account

**Figure 1.** Perceived Stakeholders Partnerships and Relationships

*The links represent the various existing or proposed linkages between the stakeholders in woodcarving. Solid lines represents existing working relations; dotted lines represents no or very weak relations. Taking a cue from India and Kenya, the UNDP-GEF Small Grants Program is targeted as the main source of donor support for this industry. The Friends of the Earth may also act as a medium between woodcarvers and the donor.*

for differences in product diversity and quality of finish. Samartex employs design service support from German-trained nationals and the Ghana National Vocational Training Institute, and adopts the use of simple but efficient carving and finishing tools such as the hand-held sand paper machine, the circular saw, and the bend saw. Woodcarvers from Ehwiaa, meanwhile, still use less-efficient indigenous handmade tools. Carvers in Ehwiaa are also slow in adapting their cultural designs into products preferred by customers.

### Conclusions and Recommendations

Woodcarving, as an informal employment sector, contributes to strengthening the Ghanaian economy. Having been given a facelift by the

tourism industry and its supporting policy regulations, woodcarving is continually expanding its market both locally and internationally. Expansion is, however, at the expense of the biodiversity of the natural forest via illegal harvesting. It is posited that this effect is partly due to lack of support from the governmental and non-governmental institutions in sustaining the input material base; as such, woodcarvers are forced to thrive on illegal harvesting.

Ecocraft therefore provides an important example of an alternate wood source, demonstrating the possibility of an industrial ecology relationship between woodcarvers and timber concessionaires, if given the necessary logistical and financial support by the Forestry Commission and donor organizations such as the UNDP-GEF.

I do not suggest that this relationship could serve to provide all the wood material needs for the woodcarving industry, but it could effectively meet at least 10-15% of annual inputs. It must be recognized, of course, that some concessions may not be close enough to woodcarvers to be economically viable to feed byproducts into carving. The Ashanti region has enough timber concessions to substantially support woodcarving with industry waste. Samartex is not supplying its wastes to other carvers in the Western region since the Ecocraft unit absorbs it all.

This relationship undoubtedly will require a “medium of transfer” such as an environmental NGO (ENGO).<sup>16</sup> The ENGO could provide the production policy framework needed to raise and sustain funding for the industry in the areas of education, skills and technology, marketing strategy, and forest plantations. If a linkage like this is successful, eventually Ghanaian woodcarvings may be able to compete with ecologically friendly products being promoted in Kenya and India (WWF 2003; Sudipto et al. 2003).

### Acknowledgements

I owe a debt of gratitude to the Compton Foundation and the Tropical Resources Institute, Yale University, for sponsoring my research. I also owe my greatest appreciation to Professors Chad Oliver and Florencia Montagnini of the Yale School of Forestry and Environmental Studies, for their supervision and support. I thank Dr. Stephen Duah-Yentumi, the Sustainable Development Advisor of UNDP, Ghana, the staff of Kumasi Forestry Commission, the woodcarvers in Ehwiaa, Ms. Emma Ampofo and all the management and staff of Samartex Timber and Plywood Company, Sameraboi. I thank my parents, my siblings and my fiancée for their undying support. Finally, I thank my God for being the lifter of my head.

### Endnotes

<sup>1</sup> Interview with Isaac Okyere, exporter, July 2004.

<sup>2</sup> In order to evade routine checks by the

Forestry task force, woodcarvers have taken to carving on felling sites and transporting the semi-finished products to Ehwiaa.

<sup>3</sup> I could not obtain a copy of the Development Plan for the Kwabre District (referred to as the “Bible” by the District Development Officer). There has not been any prior study of the woodcarving industry in Ehwiaa and so, without the Development Plan, research was based mostly on oral data.

<sup>4</sup> The original designs are the queen-mother stool (*asesedwa*) and the fertility doll (*akuaba*).

<sup>5</sup> Interview with Kwadwo Dwomoh 2004.

<sup>6</sup> Interviews with Samuel Opoku, Woodcarver and Treasurer of Ehwiaa Woodcarving Association, June-July 2004.

<sup>7</sup> This is based on the estimate that an average carver uses a volume of six m<sup>3</sup> of wood annually.

<sup>8</sup> Interview with George Atta-Wusu, Regional Director, Forestry Commission, Ashanti Region, 2004.

<sup>9</sup> Pier 1 Imports, AMC Mar/Maxx, Cost Plus, and TARGET are all USA stores that source products from Ehwiaa.

<sup>10</sup> Unity woodcarving designs use logs of diameters between 40 cm and 60 cm.

<sup>11</sup> Interview with Al-Helou Raymond, General Manager, Samartex, Smarerobio, West Region, Ghana, 2004.

<sup>12</sup> It is also worth noting that Samartex co-generates electricity and heat from wood residues mostly saw dust from its log yard, sawmill, plywood mill, and veneer mill. Electric power and heat generated from such waste is used to run the company’s 24-hour operation schedule and to supply energy to company’s residential facilities as well as the Sameraboi Township

<sup>13</sup> Tree boles that are buttressed are not straight enough or have scars or ring shakes.

<sup>14</sup> Interview with Richard Nsenkyire, Production Manager, 2004

<sup>15</sup> Note, however, that not all 14 species have been proven to be very viable for carving.

<sup>16</sup> Friends of the Earth is already operational in the Ashanti Region. This middle link will mitigate

the mistrust that has been mentioned as a problem in past relations between the Forestry Commission and the carving community.

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# Modeling Soil Erosion Risk in Los Maribos Volcanic Chain, Nicaragua

by Richard Chávez, MF 2003

## Introduction

Nicaragua is a country heavily affected by natural disasters, many of which are linked to land degradation and anthropogenic pressure on its natural resources, especially forests. On the Pacific side of Nicaragua, land transformation in rural areas is most prevalent where the expansion of agriculture practices is contributing to an unprecedented rate of land use change. Conversion of land from forest to agriculture has created both on and off site problems for rural people living in these watersheds. One of the most visible problems is soil erosion (Landa et al. 1997). Deforestation and land transformation have exposed soils to water erosion, increasing their susceptibility to natural disasters such as the landslides caused by Hurricane Mitch in 1998.

Land transformation, deforestation, and lack of soil conservation practices have made the Los Maribios volcanic chain one of the most degraded landscapes in the country; agribusinesses, subsistence farming, and cattle ranching have contributed to the increased soil erosion risk.

This research aimed to develop a tool that can be used to both model and monitor the effect of land use on soil erosion potential,

given the physical conditions within the Los Maribios volcanic chain. The applied model is based upon the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) and is integrated with GIS.

The objectives for this study were: (1) to analyze existing rainfall data to generate a soil erosivity map; (2) to collect and analyze existing geographic information to develop a soil erodibility map; (3) to assess land cover and land use through both field visits (ground truthing) and satellite imagery analysis, in order to develop a land cover map; and (4) to analyze collected and processed information to identify areas of soil erosion risk.

## Study Site

Research took place in four micro watersheds: Casitas, Cristo Rey, Las Marias, and Las Quemadas in the Volcanic Chain of Los Maribios. Most of the soils of this region are of volcanic origin and have textures varying from very sandy to sandy loam, with depths from superficial to greater than 90 cm (MAGFOR 1971).

Land use and land cover patterns in this region are the result of both natural and socio-economic factors. In general, the top organic layer of these soils has been eroded, resulting in low productivity levels (Sharma 1990). Most families who inhabit the area rely on subsistence agriculture. The lack of available low elevation lands forces subsistence and marginal farmers to move to higher altitudes on the slopes of Los Maribios; this, in turn, results in further soil degradation.

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Agriculture in lowlands and highlands. Cordillera Los Maribios, Nicaragua. Photograph by R. Chávez

## Methods

### Data sources

This research integrates the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) with the Arc Geographic Information System (GIS) to model soil erosion risk within the Los Maribios Volcanic Chain. The data used was obtained from weather stations, vegetation surveys, and topographic maps. GIS files were created for each factor of the USLE – precipitation, soil type, landcover, and slope – and combined by cell-grid modeling procedures in ArcGIS to predict soil erosion risk. Resolution was set to 30 meters by 30 meters.

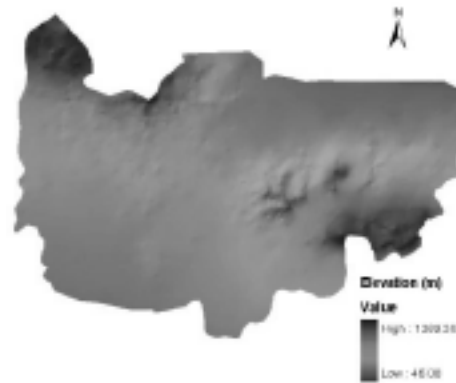
### Digital Elevation Model (DEM)

In many developing countries, spatial information data is limited or non-existent. It is therefore necessary to create digital spatial information, such as elevation models (DEM), by digitizing contour lines from topographic maps.

The DEM for this research was developed from vector contour lines using a topographic map scale 1:50,000 with Wise Image Pro5 software package. Interpolation of the elevation

points to create the DEM was achieved using ArcGIS v8.2.; the interpolation method used was Kriging (Figure 1).

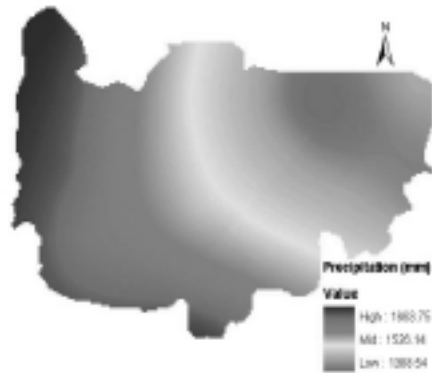
**Figure 1.** The Digital Elevation Model (DEM)



### Rainfall

The precipitation surface was obtained by interpolating average rainfall during a 10-year period for twelve observation points within the study area. The interpolation method used was Kriging (Figure 2).

**Figure 2.** Precipitation surface (mean annual precipitation in mm)



**Soil**

Soil data was digitized from a map with scale 1:50,000 produced by MAGFOR (1987).

**Figure 3.** Soil type



Some of the soil types shown in the soil classification map (Figure 3) have not yet been classified using the USDA system. A nomenclature was therefore developed based on their physical characteristics (Catastro e Inventario de Recursos Naturales 1971). For instance:

1. Qe (Lands with moderately steep slopes) includes soils with slopes between 15–30% that have not been classified in a specific class because they lack uniformity in their profile. However, these soils' type has been characterized based on deepness, texture, and gravel content.

2. Qeu (Lands with moderately steep slopes, very shallow soils, and slopes between 15–30%) are soils that vary in their textural

characteristics, are very permeable, and have very low organic matter content. The soil profile is not well defined.

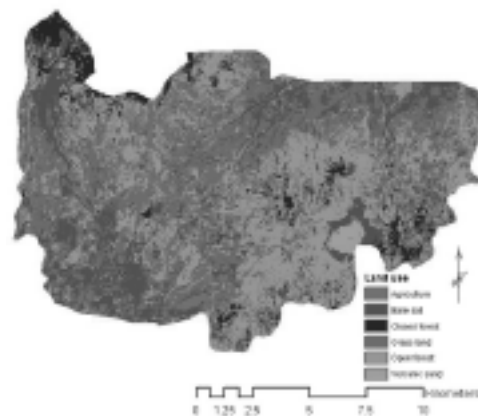
3. Qf (Steepest slopes) includes soils with slopes between 30–75% that have not been formally classified.

4. Qg are very shallow soils located in very steep slopes (greater than 75%).

**Land cover**

The land cover data used was derived from satellite imagery (Landsat-7 Thematic Mapper (TM) image, Path 017 Row 51, July 15th 2001) and classified using a supervised classification with the ERMMapper software package. First, six different land use types were defined: (i) agriculture, (ii) open forest, (iii) closed forest, (iv) grass land, (v) bare soil, and (vi) volcanic sand. The training regions were defined using ground truth data collected during the summer of 2002 as well as other ground truth data, such as aerial photo land use classifications (MAGFOR 1999). An aerial photo of land use was used to assess the accuracy of the classifications (Figure 4).

**Figure 4.** Land cover



**The Model**

The four data layers and the subsequent derivation of the LS-, R-, K-, C-, and P-factors from these layers were created using the following technique (Figure 5):

**Figure 5.** GIS procedure for creating coverage for each USLE factor



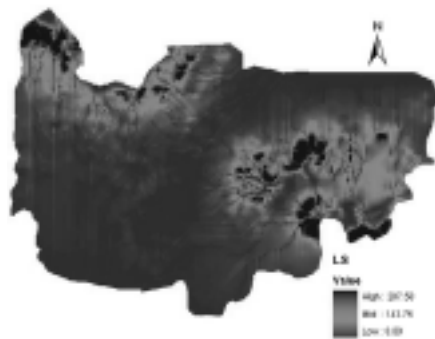
**Slope length and Steepness factor (LS)**

Calculating slope length presents the largest problem when using USLE as a model to predict soil loss within GIS. Schmidt (2001) created an extension for Arc-View 3x to calculate the slope length factor. The S factor was calculated using the DEM and Nearing's equation (1997) (Figure 6).

$$S = -1.5 + \frac{17}{1 + \exp(2.3 - 6.1 \sin \theta)}$$

where  $\theta$  is the slope angle in degrees. Nearing's equation (1997)

**Figure 6.** Slope Length and Steepness factor (LS)



**Soil erodibility factor (K)**

The soil erodibility factor (K) is the soil's resistance to erosion by water in units of ton MJ<sup>-1</sup>mm<sup>-1</sup>hr. A digital map of ecological regions developed by MAGFOR (not pub-

lished) was used to identify the soil series in the study area.

K-factor values were estimated using the soil-erodibility nomograph (Wischmeier and Smith 1978). Since soil samples were not taken, the K values presented in this paper are estimations based on the physical characteristics of the soils described in the internal 1971 MAGFOR document (Figure 7).

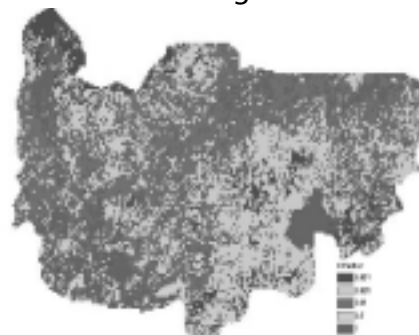
**Figure 7.** Soil erodibility ton MJ<sup>-1</sup> mm<sup>-1</sup> hr



**Cover-management factor (C)**

The C-factor models the effect of cropping and management practices on erosion rates. C factor values were applied to five cover types identified in the study area. The USLE's cover and management factors (C-factors) corresponding to each land cover condition were estimated from the USLE guide tables (Morgan 1995; Wischmeier and Smith 1978). These values were used to reclassify the land cover map to obtain the C-factor map of the study area.

**Figure 8.** Cover Management Factor





### Rainfall and runoff factor (R)

The rainfall and runoff factor (R) represents the energy available to erode land in units of MJ mm ha<sup>-1</sup>h<sup>-1</sup>y<sup>-1</sup> (Wishmeier and Smith 1978).

The rainfall erosivity factor was determined by calculating storm erosivity indices using data from three weather stations (Leon, Chinandega, and Posoltega) [INETER 2002] over a four-year period. The index was calculated for the winter season only (May to November). The sum of monthly EI<sub>30</sub> is the annual R-factor (Dissmeyer and Foster 1980; Renard and Freimund 1993; Yu et al. 2001).

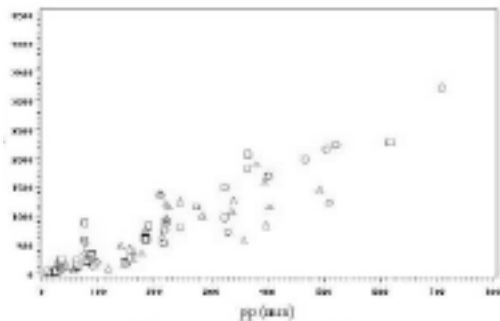
$$R = \sum EI_{30}$$

Where:

R is the Erosivity factor

EI<sub>30</sub> is the Erosion index

**Figure 9.** Linear relationship between monthly precipitation and the monthly erosion index



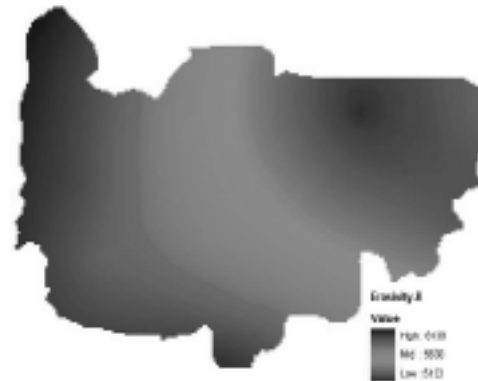
The regression equation to predict monthly EI<sub>30</sub>, given monthly precipitation in millimeters, is:

$$EI_{30} = 3.88pp - 37.23 \quad R^2 = 0.802$$

### Support practice factor (P)

Because no information in regard to the P-factor is available for this area, a value of 1 was assigned to the model presented in this study. A P-factor value of 1.00 represents no land-use influence.

**Figure 10.** Soil Erosivity factor map MJ ha<sup>-1</sup> mm h<sup>-1</sup> yr<sup>-1</sup>



## Results and Discussion

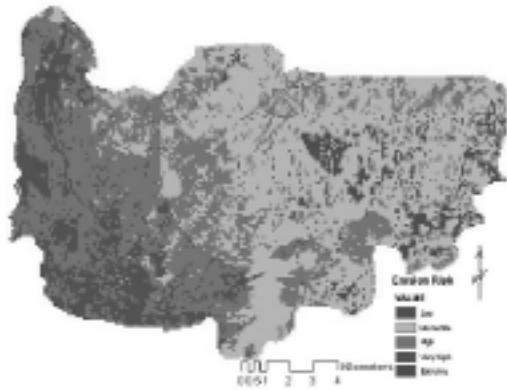
Soil erosion risk was modeled within Los Maribios volcanic chain, integrating the Universal Soil Loss Equation (USLE) with GIS. The quantitative data of predicted soil loss in each map (LS, R, K, C) was reclassified into qualitative data to identify areas that are the most susceptible to soil erosion within the study area.

The model included only LS, R, K, and C factors. More research is necessary to characterize the effect of contouring and tillage practice as well as other soil conservation practices needed to develop a P-index.

Figure 11 shows erosion hazard in the upper and lower parts of the study area, which is expressed in five classes, ranging from low risk to extreme erosion risk.

Bare soils with clay contents ranging from moderate to high were estimated to have extreme to very high erosion. They showed higher values in slope-length and steepness. Some areas of lower elevation showed high erosion risk. This is because there is bare soil, high erosivity values, and high indices of erodibility. These areas of high risk in lower elevations are frequently cultivated areas.

More than 50% of the study area was considered to be at high to extreme risk of erosion (Table 1). Most of these lands were situated in the casitas site and were used extensively for

**Figure 11.** Soil erosion risk map

cultivated agriculture. In contrast, the moderate to low erosion risk areas were generally covered by grass, shrubs, and open forest.

**Table 1.** Area and Percentage Erosion Hazard

| Erosion Risk | Area (ha) | Percent (%) |
|--------------|-----------|-------------|
| Low          | 1116.54   | 5.73        |
| Moderate     | 8210.79   | 42.0        |
| High         | 7766.64   | 39.74       |
| Very High    | 2412.45   | 12.34       |
| Extreme      | 39.51     | 0.20        |

Some of the maps used in this model might lack accuracy due to the insufficient information used in the interpolation. Accuracy of the precipitation surface would have improved if more data points were used in the interpolation.

Figure 11, depicting erosion risk is a qualitative description of erosion potential in the study area. Because the USLE/RUSLE requires a series of complex algorithms, the model makes it difficult to quantitatively characterize the area in terms of erosion risk while using GIS.

The characterization of the erosion risk map demonstrated the utility of the model as a conservation management tool where the relative comparison among land areas is more important than the absolute soil loss in any single cell.

## Conclusions

This project developed and applied a simple methodology to predict a qualitative estimate of soil erosion risk in a format that can be understood and interpreted by any land manager.

This study further demonstrated the compatibility of integrating GIS with USLE to predict soil erosion risk. Although it was not possible to quantify soil loss in the study area, the classification of soil erosion risk used in the final map can help identify where alternative soil conservation practices would be best applied.

There were limitations in determining the P-factor when using USLE in this model. There were limitations in this study due to the lack of information on the P-factor in the USLE model. Further research is necessary to determine the appropriate P-factor for local soil conservation practices.

## Acknowledgements

This work would not have been possible without the help of the following people and institutions: Professors Dana Tomlin and Timothy Gregoire, Abraham Parrish for his guidance, the Compton Fellowship Program, Latin American Association of Yale, the National University of Nicaragua-Leon, the Ministry of Agriculture and Forestry of Nicaragua, and the Tropical Resource Institute at the Yale School of Forestry and Environmental Studies.

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# Colonial Maize and Climate: Limits of Agricultural Development for Adaptation in Rift Valley, Kenya

William Collier, MEdSc 2010

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## Introduction

Concerns about global climate change have brought heightened attention to the potentially dangerous impacts of climate variability on farming systems in Sub-Saharan Africa. Increased variability in rainfall, resulting in more drought and flood events, will have drastic impacts on agricultural production throughout Sub-Saharan Africa (Boko et al. 2007; Schlenker and Lobell 2010). In Kenya, the Ministry of Agriculture anticipates that increases in rainfall variability and temperature in the Rift Valley will negatively impact the production, availability, and accessibility of cereal crops nationwide (Waigwa 2009). The consequences of these predictions will be most acute in terms of famine and food shortages.

Climate variability and drought, however, have been reoccurring characteristics of Kenya's climate for hundreds, if not thousands, of years. Famine and food shortages have been intimately woven into the lives of the Kenyan people. These events are not only linked to climatic activity; they are also deeply historical and political.

In this article, I examine the recent history of agricultural development in Kenya through a case study of Uasin Gishu District in Rift Valley Province. I discuss several historical adaptations to climate variability embedded within the broader political economy of Kenya. In doing so, I bring to question the orthodox views driving agricultural development

in Kenya while exploring alternative avenues for future development and climate adaptation.

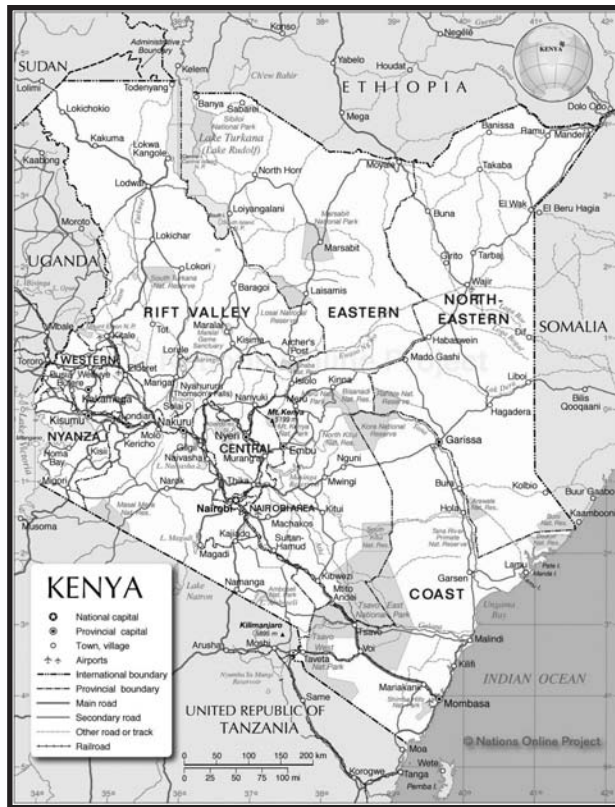
Local populations in the Rift Valley have adapted to variable climatic conditions over hundreds of years. A variety of indigenous farming techniques and cultural practices helped to manage risk in times of climatic uncertainty. Colonial expansion in Kenya replaced many of these historical coping mechanisms with much riskier monoculture maize and cash crop systems. Today, many smallholder farmers in Kenya are highly vulnerable to climatic shocks that disrupt maize cultivation. During these times, farmers turn their attention, and labor, to small gardens beside their homes. These homegardens resemble the indigenous systems that flourished before colonial encroachment, and they may provide an avenue to adapt to future changes in climate that has been largely overlooked by national policies and research objectives.

## Study Site

Kenya has a total geographic area of approximately 580,000 sq km, containing a diversity of agro-ecological zones including humid and semi-humid plateaus, highland steppes, semi-arid zones, and arid lands (Fig 1). Within each zone exists a similarly diverse suite of livelihood strategies that coincide with local cultures and environmental conditions, ranging from sedentary agriculture to nomadic pastoralism. Over 70% of the land in Kenya is considered arid or semi-arid, restricting crop agriculture to the coastal, central, and western regions of the country. Agriculture is the single-most important sector in the Kenyan economy, accounting for more than 50% of economic product and more than 80% of employment (Bates 2005). The major staple crop producing regions in the country are found mainly

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**Figure 1.** Political map of Kenya. Fieldwork was conducted in Moiben Division, Rift Valley Province, located northeast of Eldoret. Map courtesy of Nations Online Project.

in the Western Province and the Rift Valley Province, the latter of which is the location of my field site.

Uasin Gishu is located in the Rift Valley, commonly known as the breadbasket of the country, and provides an exceptional laboratory to analyze agricultural development in Kenya. In the modern Kenyan economy, more than 70% of the staple cereal crops of maize, wheat, sorghum, and millet come from the region. The fertile Rift Valley contains a variety of agro-ecological zones, consisting mainly of an upper-highland wheat and barley zone and a lower-highland maize, pyrethrum, and sunflower zone. Uasin Gishu lies approximately 400 km northwest of Nairobi.

Interviews with small, medium, and large-scale farmers as well as political officials, environmental professionals, and government employees form the basis of the study. Interview data are contextualized with archival documents and missionary memoirs pertaining to agriculture and climate. In corresponding research, I employ agricultural and meteorological statistical analyses to elucidate broader historical trends of agricultural development in the Rift Valley.

## Agricultural Development in Uasin Gishu

### *Pre-colonial agrarian history*

The diverse agro-ecological zones in the Rift Valley have provided fertile soils and favorable climatic conditions to farmers for thousands of years. The Nandi are believed to be one of the earliest dominant ethnic groups in the Rift Valley, at least since the mid-sixteenth century (Kipkorir 1978). Nandi were primarily agriculturalists that grew tremendous varieties of millets and tubers, a stark contrast to their famous nomadic contemporaries, the pastoral Maasai. Nandi farmers grew mainly eleusine, also known as finger millet, and raised small livestock such as goats and sheep (Kipkorir 1978).

While in-depth information concerning cultivation practices is sparse, it is clear that Nandi grew a variety of grains for food, beer, and trade (Kipkorir 1978). There is also evidence that trade in foodstuffs between different tribes in the Rift Valley was a common practice, especially during times of heightened climate variability. Along with traditional crops and agricultural techniques, trade and storage of grain were highly specialized forms of risk aversion during times of

environmental hazard or uncertainty for Nandi.

### ***Colonial rule and New World crops***

Western exploration and expansion in Africa had a profound influence on agricultural and economic development. Perhaps one of the longest-lasting relics of this encroachment was the establishment and proliferation of Western cereals and cash crops. Maize (*Zea mays*), a New World cereal crop, first appeared in East Africa following mercantilism and formal colonialism in the sixteenth century, when Portuguese settlers grew it along the Swahili coast (Fig 2) (McCann 2005). It slowly became a staple of the local diet, and by the mid-nineteenth century, maize was well-established as a principle crop in Swahili trade caravans and agricultural systems throughout the region (McCann 2005). Early maize agriculture in Kenya was characterized by highly localized variation in breeding and cultivation. Maize was originally incorporated into traditional mixed plots and swidden systems (Kipkorir 1978).

In the early part of the twentieth century, British settlers started growing maize in larger quantities, and colonial landowners used maize, a cheap food source, as the main form of sustenance

for their African farm laborers. During the period from 1900-25, maize gradually became a staple food in the Kenyan diet, which was previously dominated by the millets, tubers, legumes, and kales commonly found in traditional farming systems (Republic of Kenya 1966). During this time, maize cultivation shifted to increased uniformity and standardization. Small farms with highly localized variability were replaced with large monoculture plantations. Maize and wheat became substitutes for the traditional varieties of sorghum and millet. This evolution from local variation to homogenization is a defining characteristic of both maize production and agricultural development in colonial Sub-Saharan Africa (McCann 2005).

### ***Policies for monoculture cash crops***

Droughts, and the resultant disputes over food policy, have played a fundamental role in contemporary Kenyan politics and agricultural development (Bates 2005). One of the earliest colonial agricultural policies influencing maize development occurred as a result of a severe drought and widespread food shortage in 1918-21. In 1921, the colonial government undertook measures to increase food supply, developing policies to stimulate agricultural production. The government “unhesitatingly recommended that farmers should

**Figure 2.** Desiccated maize field, Moiben Division, Rift Valley, Kenya. A field of maize intercropped with beans is withering due to insufficient rains. Photo by William Collier.



concentrate on the growing of maize" (Republic of Kenya 1966,6). The area under maize production increased to a record high by 1928, and for the first time in the agrarian history of Kenya, a dominant system of maize production emerged (Fig 3) (Republic of Kenya 1966). Fifteen years later, maize development was, again, catalyzed as the result of a near-famine that occurred in 1943-44. This time, however, the colonial government questioned the policies created several years earlier. The Director of Agriculture stated "the correct policy would be to return at the earliest possible moment to a reduced production of cereals and an increase in leguminous and other crops" (Republic of Kenya 1966, 10). But due to the urgency of the situation and the resources available, the government concluded that there was "no alternative to giving all possible encouragement to the production of maize and other cereals" (Republic of Kenya 1966, 10). Thus, although the government recognized the limitations to mono-cropping cereal crops, and although it was suggested to develop other avenues of agricultural development, the colonial government concluded that the only practical option was to develop a system of increased dependency upon maize.

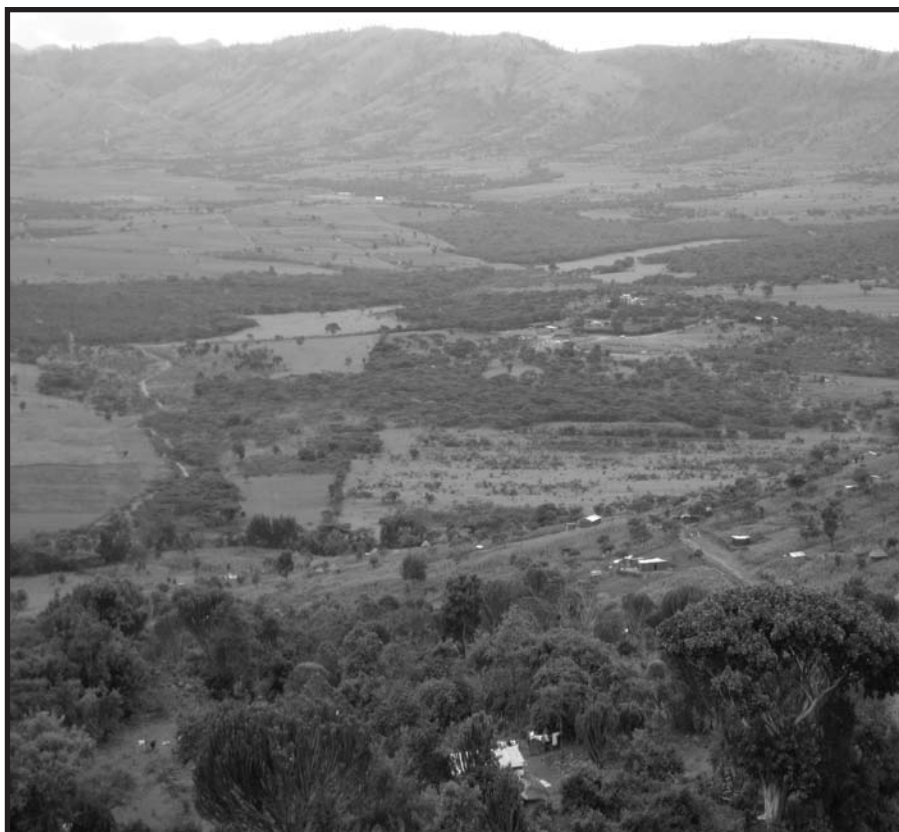
In 1966, just four years after independence in Kenya, a government commission was established to

inquire into the status of maize in the country (Republic of Kenya 1966). The commission concerned with the future of agricultural production and development in independent Kenya, quickly criticized the previous colonial regime, stating, "The unwisdom of the policy of monoculture agriculture had not become apparent as of yet" (Republic of Kenya 1966, 12). The newly formed independent government recognized that the previous agricultural development path was unwise. But now, after more than four decades of independence, policies promoting monoculture cereals and cash crops still dominate agricultural development in the Rift Valley and throughout Kenya.

## Future Climate Adaptation

### *Homegardens and climate variability*

Farmers in the Rift Valley commonly keep several small gardens beside their homes. These gardens contain a variety of kales, legumes, and tubers, the crops that dominated Kenyan farming systems before establishment of cash crop agriculture. These vegetables are intercropped and grown in a variety of small plots around the homestead, increasing the nutritional base and diversifying the risk of crop failure across multiple plots and configurations. Beyond the



**Figure 3.** Agriculture-forest mosaic in Moiben Division, Rift Valley, Kenya. The agricultural landscape is dominated by large tracts of maize and wheat. A relic of a colonial plantation is located in the center of the valley. Photo by William Collier.

**Figure 4.** Home garden in Moiben Division, Rift Valley, Kenya. This small home garden -- containing pumpkin, kales, cassava, maize, and bananas -- provides a diverse source of subsistence for smallholder farmers during drought and climate variability. Photo by William Collier.



small, green mosaic of vegetables, these homegardens also provide a window into the broader history of agriculture in Kenya. Well-adapted to the climatic and environmental conditions, these crops exhibit a variety of characteristics advantageous for farmers. Above all, they are hearty, quick growing, and resistant to drought.

When weather conditions are unfavorable, farmers throughout the Rift Valley shift their daily labor schedules to spend significantly more time working in these small gardens, leaving the larger, less manageable fields of maize and wheat to wilt for fodder. These gardens not only represent the current success and survival, but also the indigenous environmental knowledge passed down from previous generations. These agricultural systems flourished for thousands of years in Kenya prior to colonial encroachment, and the knowledge, skills, and techniques developed to make them successful are a testament to their heritage.

Agroforestry techniques and systems, such as homegardens, can provide a wide range of nutritional and economic benefits to Kenyan farmers. Historically, home gardens have proven advantageous for spreading risk, diversifying the economic base, and providing increased sources of nutrition to Kenyan families (Fig 4). Similar to smallholder farmers in

Indonesia, homegardens in Kenya provide an avenue for farmers to rely on and develop their own resources despite the transformations of the colonial experience (Dove 1990).

### ***Implications for adaptation***

As the impacts of climate change are anticipated to exacerbate food insecurity, there will be a need to balance short-term measures for hunger relief with long-term strategies for adaptation and resilience. It is important to recognize the complex economic, environmental, social, and political contexts of agricultural development and food security in Kenya. Understanding the historical roots of traditional agriculture and the contemporary consequences of a monoculture agricultural system may provide insights on how to adapt to future climate threats, while revolutionizing agriculture to increase food security in Kenya.

In the past two decades, agricultural scientists and policy planners have heralded the rapid advancement of maize as a major food crop in Africa. Agricultural economists have viewed the dominance of maize in East Africa as a miracle of the free market (McCann 2005). Even Nobel Laureate Norman Borlaug, father of Asia's wheat-and-rice-



based agricultural Green Revolution of the 1970s, argues “the technologies and new crop varieties to launch Africa’s own Green Revolution, with maize adoption as its most visible expression, are already in existence” (McCann 2005, 11). But climate change adaptation initiatives that focus exclusively on new varieties of maize and increases in national crop productivity will not solve current and future food crises. They may very well continue to perpetuate a system that increases the vulnerability of poor smallholder farmers.

In Kenya, historically, concerns about food supplies have been manipulated to consolidate political power (Bates 2005). But over the last century, there have been voices warning of problems with colonial and contemporary agricultural policies, urging officials and policy-makers to move beyond unwise and vulnerable policies and investments. There have also been voices describing the daily struggles that emerge from a system of continued dependencies. Yet these are merely whispers from a far-off village, a message inaudible on the bustling paved streets of downtown Nairobi.

Current rainfall shortages in the Rift Valley have strained food supplies throughout the country, affecting more than 10 million people, one quarter of the total population. Food security is not expected to improve with the anticipated impacts of climate change. But the urgency of the situation and the need to act should not cloud our understanding of the historical, political, and economic circumstances in which 10 million people are hungry and 20 million people are trapped in a sea of maize.

## Acknowledgement

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# Saltwater Hydroponics Atop Shrimp Farms: Exploring a New Method of Reducing Environmental Impacts from Shrimp Aquaculture in Tropical Developing Countries

Hui Cheng, MEd 2010

## Introduction

A few days ago on Facebook, the popular online social network, one of my former co-workers set his status as, "Well tonight was the final night for all-you-can-eat shrimp, so of course I took advantage. Even after a [Caesar] salad and a bread roll I still beat my record. 113 SHRIMP BABY!!!!!!" Jacob was referring to the annual "Endless Shrimp Fest" at Red Lobster.

For the past few years, Jacob has had 85, 96 and 105 shrimp in one sitting at his neighborhood Red Lobster. Seeing this Facebook status of his, I could not help but return a comment, for I have extensively studied both the societal and environmental impacts that result from shrimp farming. I wanted to get my point across in as few words as possible, hoped not to be condemnatory and wrote, "Farmed shrimp is destroying coastal habitats in the tropics. The US imports more than US\$3 billion of it yearly (COP 2004). The largest shrimp farm is in Indonesia; it is the size of Hong Kong (Murphy 2000)."

The sad thing is not that Jacob replied, "To Hui, I think they should build more farms, the loss of coastal habitat is worth the tastiness that is in my belly." The sad thing is that Jacob and I were fisheries observers in the Bering Sea. He is a certified SCUBA diver and majored in marine biology in Australia. Despite all his knowledge and experience with coastal and marine natural resources, he does not seem to show concern about how his everyday actions could influence environmental integrity of coastal areas in

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*Hui Cheng holds BS Biology from University of North Carolina at Chapel Hill and worked as a fisheries observer in the Bering Sea and Central Pacific. Hui's environmental interests are coastal communities and coastal and marine ecosystems. Hui intends to work for the government on coastal and marine resources issues.*

foreign lands. His apparent lack of accountability is unfortunately widespread among people today, yet it is understandable. The intricate connectedness of our global resource flow blurs the linkages between our daily actions and the ultimate end result.

## Impacts of Shrimp Farming

First, let's consider shrimp farming itself. Saltwater shrimp farming requires coastal land in the tropics. Shrimp is cultivated in earthen ponds filled with a mix of freshwater and seawater. The creation of these earthen ponds usually involves conversion from traditional agriculture land or native habitats such as mangrove forests and salt marshes (Fig. 1). The impact of land conversion is multidimensional. First, the power dynamics of the local community are altered along with the change in land use (EJF 2004). Social stability is undermined. In Bangladesh, locals who oppose shrimp farms have been raped, murdered, or endured harassment and intimidation (EJF 2004). Second, the ability for local food production is reduced and/or threatened, as local resources are geared toward commodity production (van Mulekom et al. 2006, Sarwar and Khan 2007, Stonich and Bailey 2000). Third, the ecosystem services that the destroyed native habitats provide are compromised (Primavera 2006). For example, without the natural vegetative barrier between land and sea, the vulnerability of coastal communities to tropical storms is increased (Barbier et al. 2008).

The shrimp pond water quality is maintained by constant water exchange with the surrounding environment. Freshwater is often used for this purpose, as shrimp is usually raised at salinity lower than that of seawater, which is 35 ppt (parts per thousand). The impact of constant water exchange is also multidimensional. Social conflicts can arise over competition for freshwater between shrimp farmers and other water users, such as traditional agriculturalists. Additionally, in locations where freshwater is drawn from underground



**Figure 1.** An aerial photo of a large-scale shrimp farm in Indonesia. Smaller canals crisscross the entire aquaculture operation and lead to larger waterways that exchange water directly with the ocean beyond the strip of mangroves in the background. Photo obtained from <http://dinos.anesc.u-tokyo.ac.jp/Small/reference/R0010shrim-s.jpg>.

aquifers, extensive withdrawals for shrimp farming have caused land to cave in (Páez-Osuna 2001).

The released saline water turns the surrounding soils and freshwater resources salty (Primavera 2006). Salinization of the soils reduces local biodiversity and renders the land unsuitable for traditional agriculture (EJF 2004, Haque 2006, Islam 2004). Salty freshwater sources further reduce the availability of resources to other users (Primavera 2006). Moreover, the released water is overloaded with suspended solids, treatment chemicals and excess nutrients from shrimp waste and leftover shrimp feed (ibid). The assimilation of this heavily polluted saline water into the surrounding ecosystems alters ecology and biodiversity (EJF 2004). The polluted water also causes eutrophication, the condition of water bodies receiving excess nutrient runoff that leads to reduced animal life, in coastal waters (Páez-Osuna 2001, Primavera 2006). Because many marine animals spend their early lives in coastal waters, the negative effects of eutrophication are eventually felt in marine ecosystems.

Shrimp farming is undoubtedly one of the most environmentally damaging food production methods, and the social impacts are not any less dramatic. Essentially, by consuming farmed shrimp from foreign lands, we import the tastiness that is in our bellies and export all the societal and environmental impacts to the low-income tropical countries that produce them.

## Unabated Demand

Shrimp has been promoted by FAO (United Nations Food and Agriculture Organization) and similar organizations as a way to replace protein lost from the depletion of global fisheries (FAO et al 2006, Roheim 2004). This resulting increase in global shrimp demand in high-income countries coupled with diminishing wild shrimp stocks, in turn, resulted in the explosive expansion of shrimp farms in supplier countries. The enormous demand-and-supply is illustrated by US shrimp imports, which exceed US\$3 billion of shrimp annually (Fig. 2) (COP 2004). Because the product is sold to consumers in high-income countries, shrimp farming is a lucrative



**Figure 2.** Breakdown of the United States annual seafood trade deficit. Source: COP, 2004. The most valuable imported seafood item in the US is shrimp, at over US\$3 billion. Shrimp is followed by salmon, which is imported at less than US\$1 billion.

foreign exchange earner in low-income countries of the tropics where technology is limited and environmental laws are lax (Stonich and Bailey 2000, van Mulekom 2006). As of 2001, it is estimated that one to one and a half million ha of land worldwide are under shrimp aquaculture (Páez-Osuna 2001).

Shrimp farming as an industry began in Asia, under the auspices of Asian Development Bank and the World Bank (Béné 2005). The industry has gradually made its way to Latin America and Africa. The major producers currently are China, Thailand, Vietnam, Indonesia, India, Brazil, Mexico, and Ecuador (Boyd 2008). Shrimp farming is, by this point, an unstoppable enterprise. Unless the demand for shrimp decreases, the producer countries will keep on supplying the commodity. Thanks to the marketing strategies of Red Lobster and others, such as Jacob's favorite "Endless Shrimp Fest," the demand is not likely to decrease.

So, what can be done? According to Seafood Watch of Monterey Bay Aquarium, the consumer can "make ocean-friendly seafood choices today" (2009). The Seafood Watch ranks seafood items:

"Best Choice", "Good alternative", or "Avoid". Imported farmed shrimp, considering our previous examination, is, predictably, on the Avoid list. But given that 80% of shrimp consumed in the US occurs in restaurants (Mangrove Action Project 2008), how are we to know where our shrimp is from in order to make ocean-friendly seafood choices?

## Research Premise

My research is based on the following premise: Shrimp farming in tropical countries cannot be stopped due to enormous demand from the West and complex political economies. The numerous pervasive environmental impacts are caused by the need to maintain shrimp pond water. Thus, by improving the quality of the effluent, the discharged water, the impacts of shrimp farming would hopefully be reduced. In a nutshell, if we cannot stop it, how can we make it less environmentally damaging?

The most up-to-date Better Management Practices (BMP) for shrimp pond effluents are: "(1) comply with applicable effluent standards; (2) reduce

water exchange;(3) recirculate water on the farm during shrimp grow-out; (4) reuse water discharged when ponds are drained; (5) use settling basins to remove organic particles from draining effluents; (6) use mangrove wetlands to treat effluents; and (7) monitor off-site water quality” (Boyd 2008).

Of all the Better Management Practices, only BMP #6 actually removes chemicals and nutrients from the discharged effluent. However, the shortcoming of this BMP is that the absorptive capacity of the surrounding mangroves to clean the polluted effluent is greatly exceeded due to the diminishing wetlands and the increasing shrimp pond hectareage. In addition, the shrimp-producing low-income countries cannot technologically or economically implement many of these BMPs.

### Experimental Concept

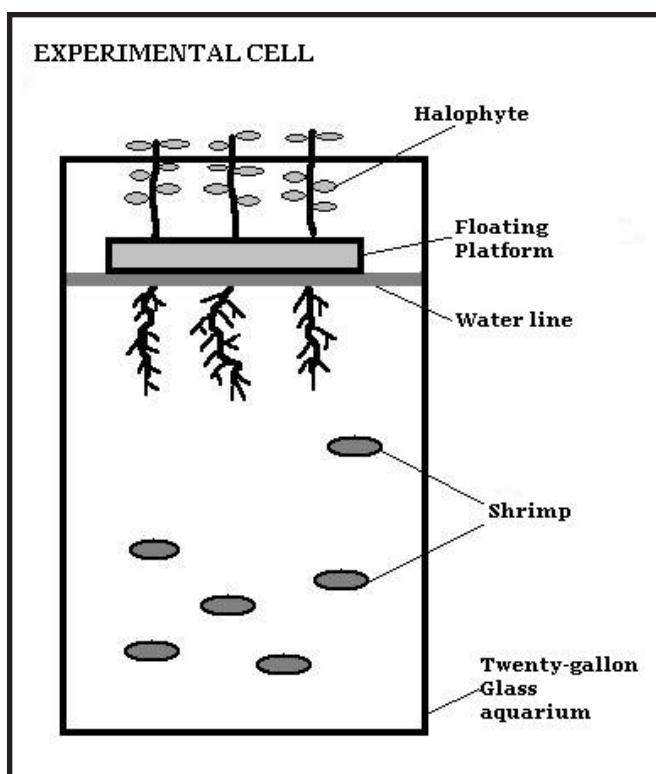
The concept of my experimental design is based on three questions: How can implementing a mitigation measure also be a direct economic incentive for the shrimp farmers? What will be low-tech enough for realistic implementation in these low-income countries? What will use the least amount of land? The third question stems from the

hypothesis that if shrimp farmers had access to more land, they would convert it to more ponds rather than a mitigation measure, such as a settling basin.

Addressing these three questions, I explored the principles of aquaponics, the cultivation of plants and aquatic animals in a recirculating system. The only nutrient input in aquaponics is fish feed. The recirculating system incessantly circulates the nutrient-rich water from the fish compartment to the hydroponic plant compartment and back. The plants remove the nutrient from fish waste and leftover fish feed from the water, and the cleaned water is returned to the fish compartment. Aquaponics can reduce water demand of aquaculture and produce a second crop of food (Diver 2000, McMurtry 1997). As shrimp aquaculture is saline, halophytes, saltwater plants, would be utilized. In fact, halophytes grown in soil and irrigated with saltwater aquaculture effluent have been shown to remove significant amounts of nitrogen from the water (Brown and Glenn 1999, Brown et al. 1999).

### Experimental Design

To provide direct economic incentives for shrimp farmers, I identified halophytes that are edible to humans. I selected the halophyte *Atriplex*



**Figure 3.** Cultivating saltwater plants and shrimp in the same space. Plants were grown in a floating platform that sits on top of the water. Roots were allowed to extend into the water. The only nutrient input to the system was shrimp feed.

*hortensis*, commonly called orache or mountain spinach. The plant is leafy and is regularly eaten in central Europe today. To devise something relatively low-tech and also save land, I eliminated the recirculating component of aquaponics and grew plants and shrimp in the same space. My resulting experimental design was that halophytes were grown hydroponically in a floating platform directly above the shrimp (Fig. 3). The experiment was conducted at University of Hawai'i at Hilo to simulate the tropical climatic conditions of actual shrimp farms. I tested five plant coverages: none (Control), Very Low, Low, Medium and High. I used complete block design and had six blocks with each treatment represented once per block for a total of 30 experimental cells (Fig. 4). Twenty-gallon glass aquaria were used as the experimental cells. Each aquarium was stocked with 18 seventeen-day old shrimp (*Litopenaeus vannamei*) post-larvae, matching the stocking density of 100 animals per squared meter in intensive shrimp culture. All aquaria were filled with the same mixture of seawater and county water to obtain a salinity of 20 ppt. The daily input of shrimp feed was the same for all aquaria. Over the course of eight weeks, I measured the concentrations of three forms of organic nitrogen in each system: nitrate, nitrite and ammonia.

I hypothesized that 1) nitrogen concentration in treatments with plants would decrease to a greater degree compared to control; and 2) nitrogen concentration in treatments of higher plant coverage would decrease to a greater degree than treatments of lower plant coverage.

## Results and Discussion

The changes in concentration of nitrate were most interesting compared to the changes in concentrations of nitrite and ammonia. Nitrate concentration in treatments with plants decreased at a rate of at least 70% faster than that of Control (Table 1), which is in support of the first hypothesis. The nitrate concentration that showed the greatest rate of decrease was that of High plant coverage, at a rate of 118% faster than that of Control. Though High plant coverage had the greatest rate of decrease and Control had the lowest rate of decrease, the second hypothesis that nitrogen concentration in treatments of higher plant coverage would decrease at a greater degree than treatments of lower plant coverage was not supported. This, however, does not mean that higher plant coverage would not reduce nitrate concentration at a greater rate, as the plant coverage



**Figure 4.** A block in the actual experiment. Each block consisted of a 300-gallon tank that held five glass aquaria for temperature control. Each of the five treatments was represented once per block.

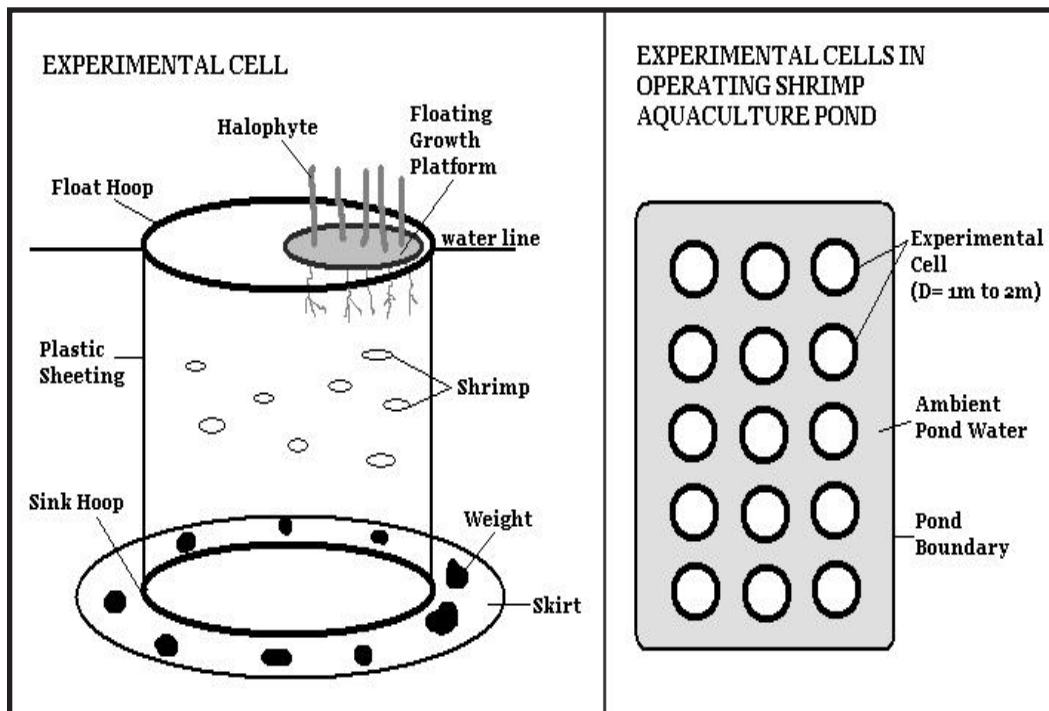
| Treatment | Slope of nitrate changes over time | Slope of treatment/Slope of Control |
|-----------|------------------------------------|-------------------------------------|
| Control   | -0.0049                            | 1                                   |
| Very Low  | -0.0087                            | 1.78                                |
| Low       | -0.0084                            | 1.71                                |
| Medium    | -0.0089                            | 1.82                                |
| High      | -0.0107                            | 2.18                                |

**Table 1.** Rate of nitrate decrease (slope of nitrate changes over time) was the least for Control and the highest for High plant coverage. Very Low, Low, and Medium plant coverage had similar rate of nitrate decrease.

Very Low, Low, and Medium were similar, all under 3%. have influenced their ability to uptake nitrogen.

Though nitrate concentrations in treatments with plants significantly decreased at a faster rate than that of Control, the actual amount of decrease was minimal. This could be attributed to a few reasons. One possible reason is that the experimental system was too small. Each glass aquarium had 18 shrimp, which did not allow much nutrient input in the first place. Additionally, the small amount of nutrient might not have been enough to sustain the proper development of the plants, which may

Second, glass aquaria do not have the earthen component of actual shrimp ponds. This could have led to a greater amount of suspended solids that affected the growth of the plants by smothering the roots because the solids did not have other attachable surfaces. Finally, the plants did not respond well to the hydroponic system. This could be partly due to the previous two concerns and/or the 20 ppt salinity. High salt concentration has the same effect as low water availability. Many



**Figure 5.** Hypothetical experimental set-up of halophyte hydroponics in a commercial shrimp pond.

plants developed leaves that resemble succulent plants, which are adapted to arid environments.

## Conclusion

Despite the shortcomings in my experimental design that negatively influenced the growth and development of the plants, nitrate still decreased at a faster rate in treatments with plants. This suggests that halophyte hydroponics is capable of removing nitrate from shrimp aquaculture water.

It would be of value to utilize the concept of this experiment on a larger system, such as an actual shrimp pond (Fig. 5). I was not able to pursue the larger scale experiment due to logistical constraints unrelated to the experimental design. It is possible that *Atriplex hortensis* could respond more favorably to the conditions in an actual shrimp pond, as commercial ponds typically have salinities from 5ppt to 10ppt, which translates into more water available for plant uptake for growth. Also, different species of halophytes could be explored. Given that shrimp farming is wreaking havoc both socially and environmentally in tropical countries, as responsible consumers, we must find a feasible method to reduce its impacts.

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# Farming the Fouta Djallon: The Effects of Climate on Agrobiodiversity and Household Economies

by Stephen Wood, MESC 2011

## Abstract

The Fouta Djallon is a region of northern Guinea and southern Senegal that contains a dramatic topographically-driven climate gradient over a relatively small land area. Despite this variation in climate, the region is inhabited by a single dominant ethnic group whose agricultural and land use practices are fairly common across the area. The natural climatic variation in the Fouta Djallon paired with fairly uniform agricultural and natural resource use creates a natural experiment in which to explore the effects of differences in climate—which vary across the region—on agriculture and household economies. In this paper I use an original data set to study the effects of a variation in climate on agricultural biodiversity and household economies.

## Introduction

Research in the climate sciences shows, almost unequivocally, a change in global climate by 2100. Though the precise pattern of this change is not certain, some warming is expected (IPCC 2001, IPCC 2007). Given this likelihood, it is important to ask what the effects will be on humanity's well-being and the ecosystems on which we depend.

Poor communities are particularly vulnerable to climate change, given their sparse economic resources available to invest in adaptation. These communities, especially in developing countries, are often engaged in economic activities that are directly affected by changes in climate. More than any continent, Africa's population is at risk from climate change

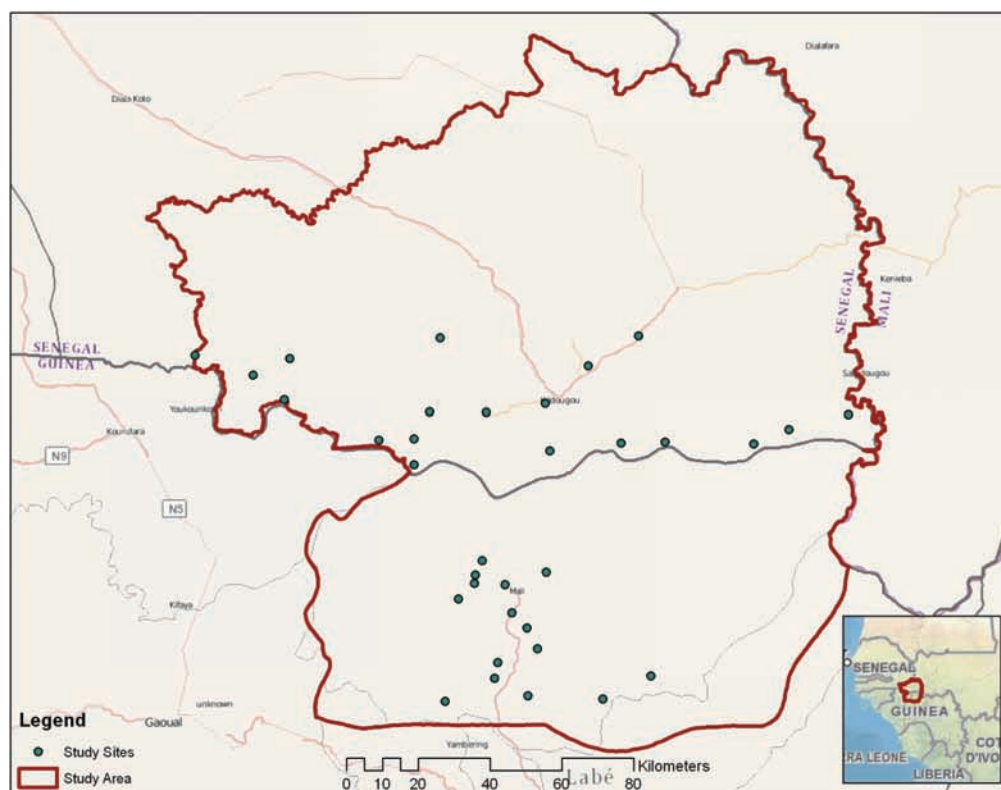
due to dependence on vulnerable economic sectors; much of the continent's population lives in rural areas and depends on agriculture (Jaeger 1991).

It is now apparent that changes in climate negatively affect African agriculture at the continental level (Kurukulasuriya et al. 2006, Schlenker and Lobell 2010). These results hold for high-resolution, national-level studies in South Africa and Cameroon (Deressa et al. 2005, Gbetibouo and Hassan 2005, Molua 2009), though the direct mechanism through which climate affects agricultural profitability is not clear. Though national level studies give insight into dynamics that continent-wide analyses might miss, analysis at the national level in Africa may miss important sub- and international factors, such as ethnicity. Countries tend to be bad proxies for cultural groups; the borders established in the colonial era reflect colonial economic interests more than real cultural, ethnic, or geographic divisions. Sub-national studies of the effect of climate on agriculture have not been conducted in Africa because the variation needed to conduct such a study generally occurs on a large spatial scale.

In this study, I use an original, sub-national

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**Figure 1.** Map of the study area.

data set for a region of northern Guinea and southern Senegal with a drastic climate gradient to examine a hypothesis for the mechanism of the effect of climate on household economies. I posit that climate negatively affects agricultural biodiversity, which positively determines household well-being (Cavatassi et al. 2011, Netting 1993:146-156) as well as providing public benefits, such as genetic resources for seed breeding or developing medicines (Heal et al. 2004, Oldfield 1989). The natural topographical and climatic variabilities within the study zone capture the effects of changes between climate zones on agricultural biodiversity while other important factors remain constant, such as ethnicity.

### Conceptual Model

Much prior research on the effect of climate on agricultural profitability in Africa has employed a Ricardian model. This Ricardian approach improves upon previous production

function models by allowing farmers to adjust their crop choices over time and in response to a difference in climate, thus maximizing revenue. The production function approach, because it ignored crop transitions, overvalued the damages to agriculture from climate change.

According to theory, each farmer will maximize net revenue given various exogenous constraints on his farm, such as climate and soils. The farmer will choose a particular crop and inputs that maximize net revenue for their land. This is given as:

$$\max R = \int P_{qi} Q_i(X_i, L_i, K_i, C, S, G) - \int P_x X_i - \int P_l L_i$$

where R is annual net revenue,  $P_{qi}$  is the market price for crop  $i$ ,  $Q_i$  is a production function for crop  $i$ , for which  $X_i$  is a vector of inputs, such as seed and fertilizer,  $L_i$  is a vector of labor (hired and owned),  $K_i$  is a vector of capital, such as plows, C is a vector of climate

variables,  $S$  is a vector of soil characteristics,  $G$  is a vector of socioeconomic variables,  $P_x$  is the price for inputs  $X$ , and  $P_l$  is the price for labor  $L$  (Mendelsohn et al. 1994, Seo and Mendelsohn 2008, Wang et al. 2009). The goal of the Ricardian technique is to look at changes in net revenue of land for agricultural land across climatic gradients, particularly variation in temperature and precipitation.

I use a similar hedonic-based approach to study the effects of climate on agrobiodiversity by substituting three measures of crop diversity: the number of crops grown, number of varieties known, and number of varieties grown, for net revenue. I apply similar control variables to the regressions for agrobiodiversity. I then regress net revenue on the three measures of agrobiodiversity to test the hypothesis that increased on-farm diversity is associated with higher household well-being (Cavatassi et al. 2011, Netting 1993).

### Data and Methodology

I used a spatially explicit data set of 127

farmers collected from 38 villages. Sixteen villages are from the prefecture of Mali in northern Guinea, four villages were from the region of Tambacounda in eastern Senegal, and the remaining 18 villages were from the region of Kedougou in Senegal (figure 1). The surveys were conducted between June and September 2010. Although this is the most difficult time of year to access villages and many farmers are busy working in their fields, we were able to collect data on all of the sales from previous harvests. Had we conducted the survey at the height of the dry season, we would not have had information on the large amount of goods sold to buy materials for planting early in the rainy season. The surveys were conducted by the author with the help of two research assistants, one based in the town of Kedougou, Senegal and the other based in Mali, Guinea.

The villages surveyed span a topographical, ecological, and climatic gradient, ranging in elevation from sea level to 1,300m, in mean annual temperature from 17°C to 30°C, and in precipitation from 400mm per year to

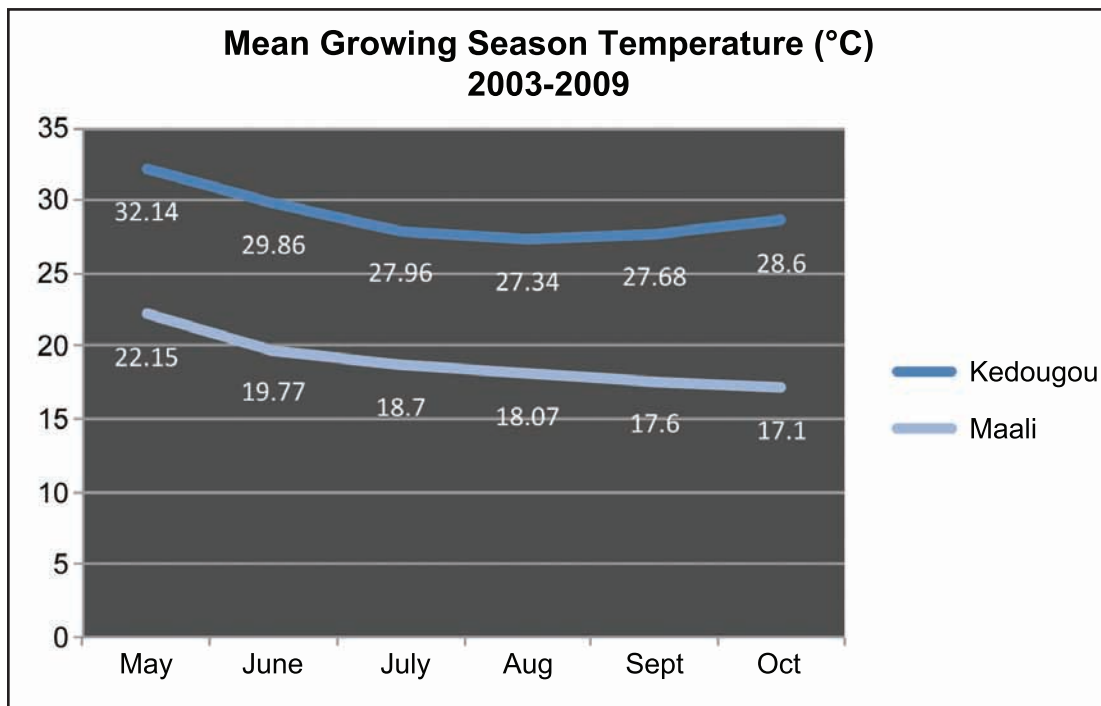
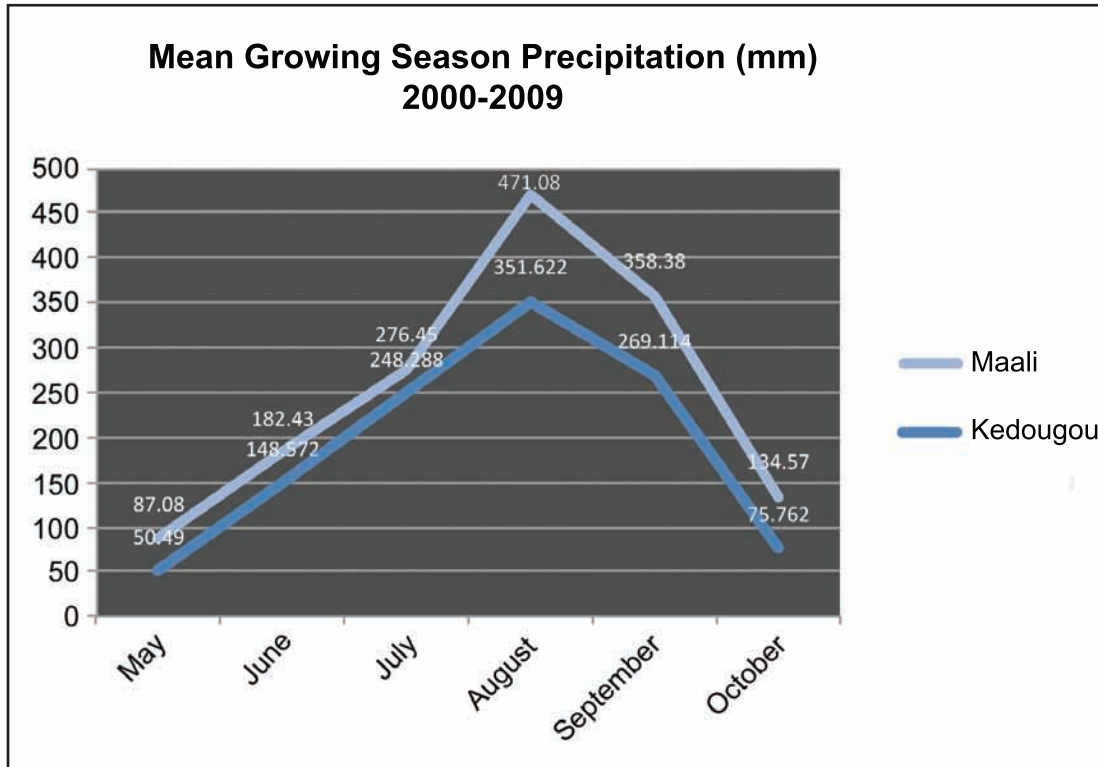


Figure 2. Monthly temperatures of the study sites.



**Figure 3.** Monthly precipitation at the study sites

2,000mm per year (figures 2 and 3). The study zone was stratified into three zones along this ecological gradient. Koussanar is the furthest north in Senegal and has a Sahelian climate and topography: it is flatter, hotter, and drier than the region of Kedougou in southern Senegal. Kedougou shares the border with Guinea, has a slightly higher elevation of about 300m and has higher precipitation than Koussanar, although temperature is similar. The prefecture of Mali in northern Guinea reaches an altitude of 1,300m. Precipitation in Mali is much higher than in Kedougou and temperatures are much lower (figures 2 and 3).

The surveyed villages were selected at random from regional village lists provided by local health workers and agricultural extension agents. These lists are more thorough and up-to-date than the existing government lists, which exclude smaller villages and seasonal farming communities.

In each community, the chief of the

village was asked to identify two large volume farmers and two small volume farmers as well as one average farmer to be surveyed. Farmers were surveyed as long as a minimum of three identified farmers were available. If the minimum number were not available, the surveyors returned later in the day or at another date. The survey included questions on production levels, inputs, demography, local infrastructure, soil, environmental change, wage rates, and other socio-economic variables.

Climate data were taken from weather stations throughout the study zone. These data, while fairly precise, are somewhat inconsistently recorded and span only a five year period. These data, therefore, are supplemented with temperature and precipitation data from the African Rainfall and Temperature Evaluation System (ARTES) (World Bank 2003).

Previous studies have divided climate data according to the four seasons that are familiar in the northeast United States. In this study

zone, however, there are three seasons, only two of which are arguably relevant: the rainy season and the dry season. Climate data were categorized according to these seasons, since the climate data generally exhibit collinearity between months (Mendelsohn et al. 1994). Previous climate studies in Africa have faced the challenge of trying to compare seasons across the equator (Kurukulasuriya et al. 2006). This relative seasonal simplicity is an advantage of this study.

The analysis of climate in these data was based solely on temperature. Precipitation has an obvious effect on agriculture, but was excluded from the analysis because of correlation with temperature. This correlation is due to the fact that the climate difference between southern Senegal and northern Guinea is driven exclusively by a topographical gradient.

## Results

Using three separate measures of agrobiodiversity—number of crops grown, total varieties known, and total varieties grown—I

find that climate has a strongly significant impact on the level of biodiversity on a farm in the study area.

For the number of crops grown, I find that a ten degree increase in temperature is associated with an increase in one and a half crops, controlling for the number of children in school—a proxy for household well-being – and whether or not the farm is on a hill—a proxy for the quality of the land (table 1). For the number of total varieties known, I find that a ten degree increase in temperature is associated with an increase in 4.1 varieties known, using the same control variables (table 1). For the number of varieties grown, I find that an increase in ten degrees is associated with an increase in 1.3 total varieties grown (table 1), using the same control. Although the effect of temperature on crop diversity is highly significant, the effect of precipitation is not. This is shown in the regression tables.

Also, consistent with some of the anthropological literature on crop diversity, I find that higher crop diversity is clearly and

| VARIABLES         | (1)<br>numberCropsGrown         | (2)<br>totalVarsKnown          | (3)<br>totalVarsGrown           |
|-------------------|---------------------------------|--------------------------------|---------------------------------|
| meanStationTemp   | <b>0.154</b><br><b>(0.0296)</b> | <b>0.410</b><br><b>(0.115)</b> | <b>0.130</b><br><b>(0.0671)</b> |
| meanStationPrecip | 0.00107<br>(0.000555)           | 0.00293<br>(0.00224)           | -9.63e-05<br>(0.00107)          |
| kidsInSchool      | 0.0889<br>(0.0344)              | 0.278<br>(0.176)               | 0.307<br>(0.1000)               |
| farmOnHill        | 0.830<br>(0.188)                | 1.364<br>(0.723)               | 1.157<br>(0.525)                |
| Constant          | -2.443<br>(1.354)               | -7.453<br>(5.225)              | -0.0128<br>(2.752)              |
| Observations      | 127                             | 116                            | 89                              |
| R-squared         | 0.357                           | 0.187                          | 0.196                           |

Robust standard errors reported in parentheses  
Key covariates in bold

**Table 1.** Effects of climate on agrobiodiversity. The table shows the effect of a unit increase in the independent variables in the first column on three dependent variables (columns 2-4), each of which is a different measure of agrobiodiversity. Results in bold indicate key results of the effect of temperature on agrobiodiversity.

**Table 2.** Effects of agrobiodiversity on net revenue, reported in the West African CFA franc. The table shows the effect of a unit increase in the independent variables in the first column on net agricultural revenue. Columns 2-4 each represent a different model specification, each with a different measure of agrobiodiversity. Results in bold indicate key results of the effect of agrobiodiversity on net revenue.

| VARIABLES             | (1)<br>Net Revenue               | (2)<br>Net Revenue              | (3)<br>Net Revenue               |
|-----------------------|----------------------------------|---------------------------------|----------------------------------|
| numberCropsGrown      | <b>54,562</b><br><b>(25,574)</b> |                                 |                                  |
| Guinea                | 133,674<br>(47,289)              | 152,753<br>(50,612)             | 92,812<br>(63,702)               |
| householdsInCommunity | 1,630<br>(750.7)                 | 1,656<br>(794.4)                | 1,875<br>(1,087)                 |
| timeToClosestMarket   | 1,078<br>(456.4)                 | 1,396<br>(474.7)                | 1,046<br>(553.5)                 |
| agWorkersInHH         | 28,683<br>(8,813)                | 25,791<br>(8,115)               | 24,461<br>(12,269)               |
| totalVarsKnown        |                                  | <b>23,580</b><br><b>(7,397)</b> |                                  |
| totalVarsGrown        |                                  |                                 | <b>26,832</b><br><b>(12,969)</b> |
| Constant              | -355,773<br>(126,506)            | -380,219<br>(125,875)           | -247,651<br>(115,426)            |
| Observations          | 96                               | 87                              | 68                               |
| R-squared             | 0.329                            | 0.358                           | 0.302                            |

Robust standard errors reported in parentheses  
Key covariates in bold

significantly associated with higher incomes. For an increase in one crop grown, there is an associated increase in annual net revenue of \$100 US (table 2). An increase in one variety known about is associated with an increase in annual net revenue of \$50 US (table 2). And an increase in one variety grown is associated with an increase in annual net revenue of \$50 US (table 2). All of these analyses control for country, village size, the time required to travel to the nearest market, and household labor supply.

## Discussion

The primary finding that higher mean temperature is associated with greater agrobiodiversity may seem to be counterintuitive. One might think that more temperate climates would be able to support a

wider range of crops and, thus, have higher crop diversity. These results show, however, that in warmer climates a wider range of crops are grown and, less significantly, a wider range of varieties. Why might a warmer climate support a wider range of crops? One possible explanation is that very few farmers in northern Guinea grow millet and sorghum varieties because it is too cool and dry. Also, the wide variety of agroecological zones in northern Guinea—within the same climate zone—mean that although there is a wide variety of crops grown in northern Guinea, any given farmer is quite specialized in the crops that are within his agroecological zone. Another possible explanation is that farmers in southern Senegal could be growing more crops in order to buffer against shock—in a warmer region, seasonal temperature increases might be more likely to negatively affect some crops, in



**Photograph 1.** A farmer in his carrot and parsnip garden in Medina, Senegal.

which case it would be advantageous to have a wider variety of crops. More research in the social and natural sciences needs to be done to determine the precise explanation of the direct effect of climate on agrobiodiversity.

The observed effect of climate on agrobiodiversity could also be an indirect effect, due to unobserved factors that co-vary with climate. For instance, Senegal is warmer than Guinea, but it also happens to be more economically developed. Because Senegal has more developed market infrastructure, there is a greater number of crops with higher economic value. Farmers therefore choose more diversity on their farm in order to maximize their net revenue. I controlled for this effect, to some extent, by including a measure of household well-being: the number of children in school. There is likely, however, a still-unobserved effect of economic development on agrobiodiversity that is independent of the number of children in school.

Although there is a clear and significant relationship between climate and temperature, it is not clear to what extent the relationship is driven by climate *per se* or by factors that co-vary with

climate, such as economic development. After controlling for some of the differences in economic development, there is strong reason to think that climate does play a role, in and of itself, on agricultural diversity. However, it is likely that there is an as-of-yet unobserved effect of climate covariates on agrobiodiversity. Future research in economics and ecology needs to be done in order to tease out more precisely the relative effects of climate *per se* and economic development on agrobiodiversity.

The effect of agrobiodiversity on household economies, however, is clear and significantly positive. Depending on the measure of crop diversity, an increase in one more crop or crop variety is associated with an annual increase in net revenue of between \$50 and \$100 USD. By contrast, the negative effect of climate on net revenue is predicted to be around \$28 USD per annum (Kurukulasuriya et al. 2006). Increasing on-farm diversity, therefore, could be an effective tool for climate adaptation.

## Conclusion

If a change in global and local climates is expected in the future, decision makers



need to think carefully about how to protect the most vulnerable populations to these changes. For small-scale West African farmers, climate adaptation programs have focused on diversifying revenue developing agricultural practices and inputs that are less sensitive to climate variability than traditional practices. The results from this paper show that increasing on-farm diversity could be an effective strategy for adapting to climate change. It is unlikely, however, that species richness itself matters as much as increasing the number of crops that play important functional roles, such as nitrogen fixation or drought resistance. More research is needed in both the natural and social sciences to determine what the important functional roles are in this agroecosystem, how local communities value them, and how they are likely to change with climate.

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