UNIVERSIDAD DE PUERTO RICO EN CAYEY
INSTITUTO DE INVESTIGACIONES INTERDISCIPLINARIAS

INFORMACIÓN DEL PROYECTO:

TÍTULO DE LA PROPUESTA:	HOW SOCIAL AND ECOLOGICAL CHANGES HAVE AFFECTED THE ECOSYSTEM SERVICES IN THE GUAVATE WATERSHED
INVESTIGADOR PRINCIPAL:	DR. JAVIER ARCE NAZARIO
DEPARTAMENTO:	BIOLOGÍA INSTITUTO DE INVESTIGACIONES INTERDISCIPLINARIAS
VIGENCIA DEL PROYECTO:	ENERO 2010 – 15 DE AGOSTO 2011

Title: How social and ecological changes have affected the ecosystem services in the Guavate watershed

Principal Investigator: Dr. Javier A. Arce Nazario, UPR Cayey

Overview:

The primary purpose of this project is to identify the ecosystem services of the Guavate watershed and to understand how these services have been altered by social and biophysical changes within the region. Understanding the interaction of social and ecological processes in the Guavate watershed is of particular scientific interest because this area has undergone multiple environmental changes in the past, and is presently undergoing environmental change as result of urban sprawl and local tourism. While interdisciplinary watershed studies in temperate areas are now common, this type of study is needed in the tropics.

To perform this study, three main methodologies are required: (1) remote sensing, (2) water quality analysis, and (3) ethnographic methods. The remote sensing task consists of reconstructing the landscape change of the region and developing land cover change maps using remote sensing images, while the water quality analysis entails sampling the quality of different streams, and the ethnographic study involves in-depth interviews with expert community members. The fieldwork and data gathered through this year-long project will significantly strengthen the competitiveness of related proposals I will submit to the NSF and a subproject I will submit to the NIH's Research Infrastructure in Minority Institutions (RIMI) grant, and the results and synthesis of the methodologies in this project will be disseminated in an Institute of Interdisciplinary Research (III) publication as well as in oral presentations. The project will also engage students at UPR Cayey in fieldwork in the vicinity, exposing them to new educational opportunities and to the neighboring community.

Introduction:

Ecosystem services are the benefits that humans obtain directly from an ecosystem, such as clean water, timber, recreational space and food (Costanza et al. 1998, Daily 1997). Many of these services are essential to human livelihood, and so there is a pressing need to understand the ecological and social processes that can safeguard these services. The diversity and quality of services an ecosystem can provide are a result of both changing environmental and social factors. Understanding the interdependence of services provided by a system and how human activities can be sustained without negatively affecting other ecosystem services is an important theoretical and practical question in conservation research.

The environmental and social composition of Puerto Rico has dramatically changed in the last two centuries, and so the ecosystem services have also changed. Forest cover island-wide exceeded 80% until the beginning of the 19th century (Birdsey & Weaver 1982, Grau et al. 2003), when the population of Puerto Rico was less than 200,000 individuals. At that moment in Puerto Rican history forests provided ecosystem services that are less apparent today. Forests served as construction material and as fuel for cooking (Dominguez-Cristobal 2000). As the population grew to approximately 1,000,000 individuals by the early 20th century, and to over 2,000,000 by 1950, forest cover declined steadily to less than 20% (Helmer 2004, Helmer et al. 2008). A typical Puerto Rican landscape was one of nearly complete deforestation except for small patches of forest along steep mountains and kitchen gardens grown under a canopy of leguminous trees (Zimmerman et al. 2007). Primary forest was limited to the Luquillo Mountains in northeastern Puerto Rico and to the highest portions of the Cordillera Central, including the Carite Forest Reserve (Pascarella et al. 2000). After the 1950's Puerto Rico shifted from an agricultural to an industrial economy, which

resulted in the natural reforestation of abandoned agricultural lands into secondary forests (Aide & Grau 2004). In the past 20 years, deforestation rates have again increased, because urban sprawl and development threaten the secondary forests (Crk et al. 2008, Helmer 2004, Lopez et al. 2001).

This recent history of landscape change has been measured by interpreting air photographs and satellite imagery at coarse (30 m) resolutions, with a focus on terrestrial rather than aquatic features. Such methods of reconstructing a landscape allow for a relatively fast analysis of change at a national scale, but they have three major flaws. First, a scale of 30 meter pixels is too coarse to observe important social transformations such as the increase in low density urbanization (Martinuzzi et al. 2007). Second, the focus on forest cover and other terrestrial features does not represent the history of aquatic spaces (Figure 1). Finally, the dependence on remote sensing information alone results in a "snapshot" reconstruction of landscape history which can miss important biophysical transitions as well as a serious humanistic viewpoint (Arce 2007, Klepeis and Turner 2001).

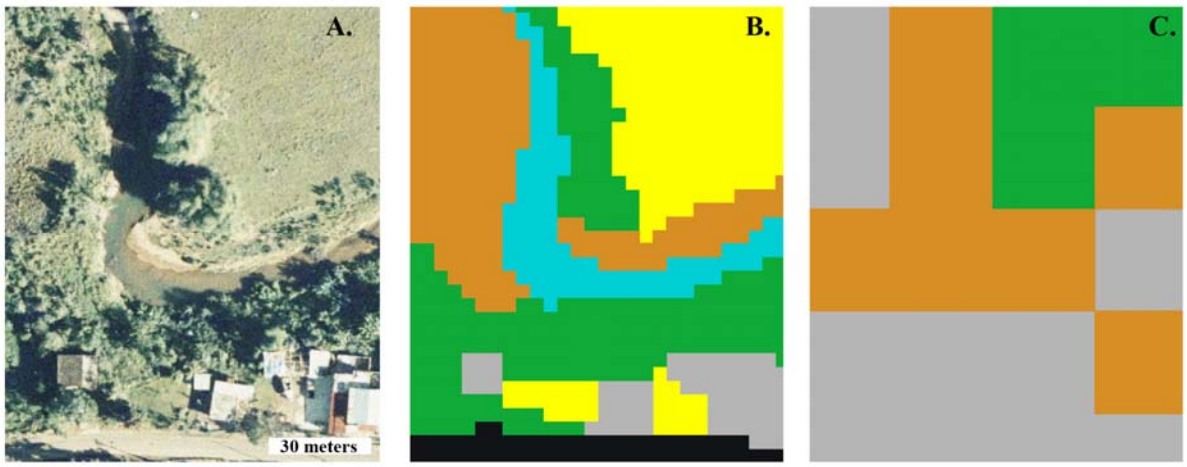

FIGURE 1: Comparison of an original aerial photography image from 2004 (A), a 4m resolution land cover classification (B), and a 30m resolution land cover classification from Helmer 2004 (C). Certain urban and aquatic features visible in the original image are not detected at a 30m scale of analysis, resulting in lost information that can have social and ecological significance. In the classified images, black represents roads, gray is low-density urban, green is forest, orange is abandoned pastures, blue is water, and yellow is grass.

To address these shortcomings of existing landscape change analysis in the Guavate region, I will perform a study of social and biophysical changes of the Guavate watershed using fine-scale remote sensing methods, measurements of aquatic components, and incorporation of human perspectives. By analyzing the landscape changes through an interdisciplinary lens I plan to evaluate how ecosystems services of the Guavate watershed have been altered by these changes, and how the ecosystem services can be conserved.

Study Area:

The study will be performed in the Guavate watershed, a 1,840ha area which is located within the Cayey *Municipio*. The Guavate watershed can be divided into sub-watersheds which are distinctive because each of these sub-watersheds has a different degree of deforestation. Two of the streams are from within sub-watersheds that are entirely forested and can serve as a control, while other sub-watersheds have different degrees of forest and urban land cover (Figure 2). This diversity of sub-watershed land cover allows comparisons among sub-watersheds which can determine the effects of land cover change on the ecosystem and, ultimately, the water quality provided.

Other biophysical and social characteristics make the Guavate watershed an excellent study site for analyzing the impact of landscape changes on ecosystems services. The Guavate watershed is populated by a broad spectrum of social classes, it has topographic diversity including mountains and valleys, and it has forested, farmed and urbanized regions. The Guavate watershed is an important destination for domestic and international tourists. In a sense, this watershed is a microcosm of Puerto Rico. Furthermore, within the Guavate watershed I have identified three communities that depend on stream water. These communities drink the stream water with little or

no treatment, therefore the communities´ health is at risk if the sub-watershed from which they obtain water is contaminated. This condition makes the findings of this study one of direct benefit to the community. Finally, the Guavate watershed is just 10 minutes away from UPR Cayey, making it an ideal field site for student participation since students often have schedule constraints which compromise their ability to participate in field work.

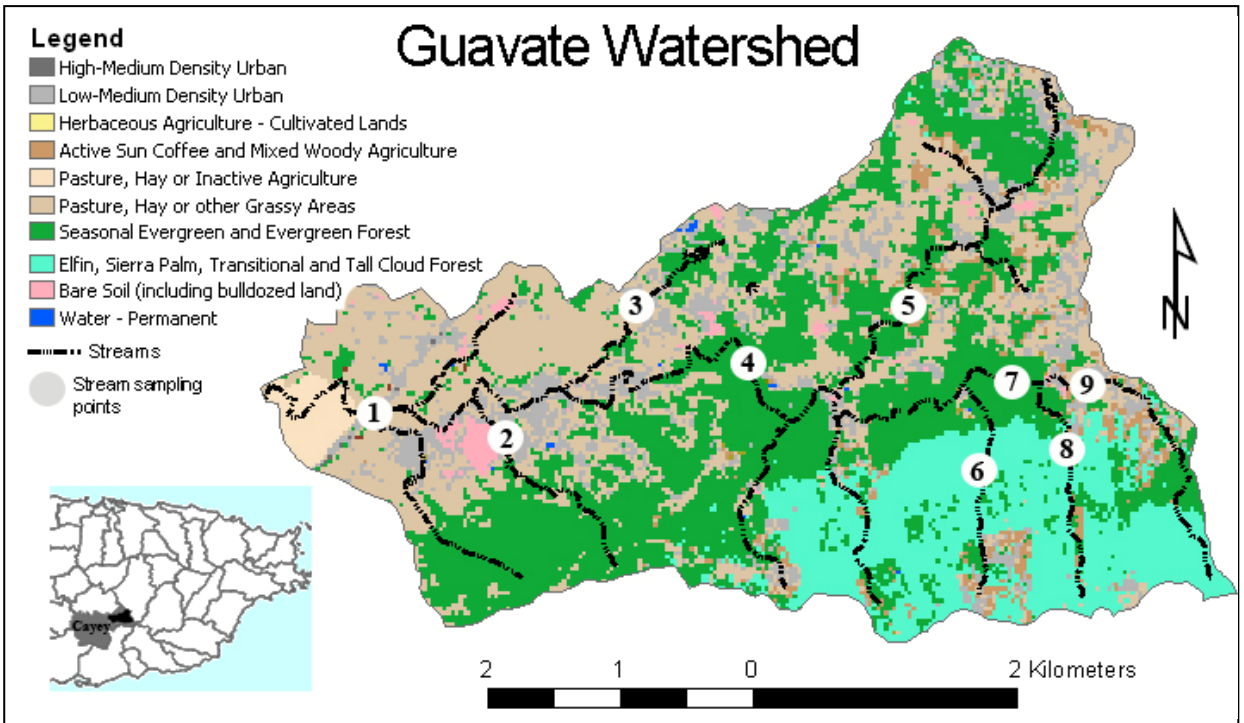

Figure 2: Map of the 1840 ha Guavate watershed region, displaying land cover (Helmer 2004), major streams, and the 9 stream sampling points. The sampling points were chosen based on accessibility and their potential to represent the water quality of different sub-watersheds.

Objectives & Methods:

The following are a set of objectives and associated methods for this research program:

Objective 1: Reconstruct the land cover change of the Guavate watershed from 1959 to the present at a fine (4m) scale of spatial analysis.

I have already obtained digital scans of aerial photographs of the watershed from 1959, 1968, 1977, 1987, 1995 and 2004 from the United States Geological Service (USGS). The first step will be to orthorectify these images, with the exception of the 2004 and 1995 images which have already been orthorectified by the USGS and a private company. These images will then be classified using stereophotogrammetric techniques and texture analysis. I will use similar classes to those used by the GAP Analysis Project (Gould et al. 2007), to allow future comparisons and use by other researchers. The result of this activity will be land cover maps for each of the six imaged years. Using these maps I can carry out landscape change analysis, reconstructing how landscape change progressed during intervals of approximately 9 years. The information obtained from the landscape change analysis will serve to correlate social and biophysical elements to landscape change processes. For example, through GIS modeling I can assess the degree to which road construction has promoted deforestation, or how physical characteristics of the landscape such as topography have affected deforestation patterns.

The land cover maps will be compared to existent land cover maps from 1977, 1991 and 2000 which are the result of coarse-scale analysis and are set at longer temporal periods. This will allow me to further analyze how spatial and temporal scales in remote sensing may affect our understanding of landscape transitions. The question of how scale affects our understanding of landscape dynamics is currently a pressing topic in landscape ecology, so this objective addresses

important issues in landscape ecology, and will result in maps useful to the development of the second and third objectives of this project as well as to other scientific work.

Objective 2: Determine how land use history, biophysical, and social factors affect the water quality of the watershed and its sub-watersheds

I will measure water quality at different points within the watershed (Figure 2) using a multimeter instrument that measures dissolved oxygen, pH, conductivity, temperature and nitrates. I will also obtain water samples to quantify coliforms, and E.coli using the IDEXX Quanti-Tray/2000 system. One day a week I will gather the water quality information at 9 collection points (Figure 2), both using the multimeter and obtaining water samples to measure microbial activity using IDEXX Quanti-Tray/2000 system. The information gathered for each stream will then be correlated to the present and past land cover. Although it seems obvious that water quality is correlated to present land cover, previous land cover can also affect the present water conditions (Harding et al. 1998). Using GIS modeling techniques and incorporating data from USGS rain gauges, I will evaluate how water quality is correlated to land cover. This study is of particular interest since in the tropics there are very few studies that analyze the effect of land cover on water quality. Furthermore the communities that depend on these waters will benefit from measurements of the quality of their water and from learning which landscape elements can sustain healthy water.

Objective 3: Determine what other ecosystem services the watershed provides and how landscape change has influenced these services

The Guavate Watershed provides other services besides water. I will conduct oral histories and participant observation of local experts to evaluate which services are provided and how they have changed through time. A community leader, an elder or a local historian would be considered a local expert, and they will be identified through preliminary interviews and visits to the community. The in-depth oral history interviews will be focused on the Guavate environment in the past, and on how it has changed. Particular attention will be given to anecdotes that pertain to obtaining services from the watershed. A minimum of 10 in-depth oral histories will be recorded and transcribed.

The methodology of gathering oral histories serves to better inform this study about the landscape changes and ecosystem services. Preliminary interviews with community members from Guavate have shown that the nearby forests serve the community for multiple services, such as drinking water, fishing and hunting grounds, and areas for swimming and other recreational activities. Interviewees have also mentioned that certain creeks are no longer potable, and that other creeks do not drain as much water as they once did. This fine-scale information about landscape transformations is not observable by remote sensing analysis, which makes an oral history component to this project imperative. Interviewing community members also promotes the exchange of ideas between the local community and academics. This type of interaction will promote stronger relationships between the University and its surrounding communities.

Expected Outcomes:

The study should result in several sets of data: new land cover maps for the Guavate Watershed for multiple years, oral history interviews, and water quality data. It will also lead to the development of new remote sensing methodologies. These outcomes should benefit my external funding proposals. Institutions such as the NSF place significant value on strong preliminary data when evaluating proposals. I intend to submit grant proposals to two NSF programs between July 2010 and January 2011 (See Appendix 1), and design a subproject for the RIMI proposal that will be submitted by the III in the spring semester.

The information from this study will also be disseminated through the publication of an Institute of Interdisciplinary Research manuscript and through local seminars. The data will serve in the preparation of a manuscript for peer review. Furthermore, the project will result in the training of students through their participation in field research. My plan is to integrate students from the Biology department through a BIOL4990 course, as well as RISE students and students from other departments that would like to be involved in social-ecological research.

Timeline:

Month	Activity
January/February 2010	Equipment Purchase and Preliminary Interviews
March	Orthorectification of Images / Water Data Collection / Preliminary Interviews
April	Classification of Images / Water Data Collection / Oral History Interviews
May	Classification of Images / Water Data Collection / Oral History Interviews

June	Preliminary Landscape Change Analysis / NSF Proposal Preparation / Water Data Collection
July	NSF CAREER Proposal Submission / Water Data Collection
August	In depth analysis of collected data / Water Data Collection
September	GIS Modeling / Water Data Collection / Oral History Interviews
October	GIS Modeling / Water Data Collection / Oral History Interviews
November	Final Manuscript Preparation / Water Data Collection
December	NSF Proposal Preparation / Final Manuscript Preparation
January 2011	NSF Geography Proposal Submission

Summary:

I propose to start an innovative and interdisciplinary project in the Guavate Watershed which evaluates current ecological paradigms and addresses recent scientific questions. This project will elaborate fine-scale land cover maps for multiple years to understand the watershed's landscape transitions. Water quality data will be obtained from multiple creeks, and this data will be correlated to the information obtained from the land cover analysis. To integrate the human perception of and response to landscape change, the project includes interviews that will allow me to interact with the community and to learn the fine-scale social process of the region. Because of the proximity of the Guavate Watershed, this project will allow UPR Cayey students to easily be involved in field research. The interdisciplinary and practical nature of this project will allow the community to be participants in the project and to benefit from the results. The expected outcomes of this project are the development of stronger grant proposals that will mean better resources for

the academic development of students and faculty at UPR Cayey, and the creation of stronger relationships with the surrounding community.

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