PAYMENTS FOR ENVIRONMENTAL SERVICES IN COSTA RICA: CONSERVATION AND PRODUCTION DECISIONS WITHIN THE SAN JUAN – LA SELVA BIOLOGICAL CORRIDOR

A Dissertation

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by

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AUTHORIZATION TO SUBMIT DISSERTATION

This dissertation of Wayde Cameron Morse submitted for the degree of Doctor of Philosophy with a major in Natural Resources and titled "Payments for Environmental Services in Costa Rica: Conservation and Production Decisions within the San Juan – La Selva Biological Corridor", has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies at the University of Idaho (UI), and to the Postgraduate School at Centro Agronómico Tropical de Investigatión y Enseñaza (CATIE) for approval.

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ABSTRACT

Understanding the dynamic nature of human-environment interactions is critical for mitigating the impacts of human induced environmental change. Current research on environmental change has focused on the deterioration of environmental services that ecosystems provide and the subsequent impact on human well-being. The linkages between the influences of land use change and the provision of environmental services is not thoroughly developed. This dissertation develops a model linking social and ecological theories to explain this interaction. This model is applied to Costa Rica's program of payments for environmental service (PES) as a case example. The model has potential for application to land use change studies in general and evaluation of PES programs specifically.

Several issues critical to understanding the efficiency of PES include additionality, baseline conditions, leakage, and equity. These topics have been relatively unexplored with empirical data. Participants and non-participants (N=207) in Costa Rica's PES program within the San Juan-La Selva portion of the Mesoamerican Biological Corridor were compared to assess these critical issues. Results indicate that PES for forest protection contributed to a reduction in the deforestation rate and incentives for reforestation have been effective at increasing forest cover. Positive development impacts are due to hiring local labor for PES projects. Recommendations are offered on how to adjust the program to increase ecological and economic efficiency.

In addition to the above research, I was part of an interdisciplinary team of researchers that examined Costa Rica's PES to determine its influence on landowner decisions, carbon services, and forest connectivity in a biological corridor. Landsat images were used to compare landcover changes before and after 1996, and these data were linked to landowner surveys investigating land use decisions. Carbon services provided by secondary forests were examined both above- and belowground. Forest change observations were explained by landowner survey data, indicating that PES positively influenced forest retention and recruitment. Secondary forest carbon storage approached values found in primary forest after 25-30 years of succession, though few landowners retained natural forest regeneration. The Costa Rican experience provides evidence that PES have been effective at providing environmental services within this particular socioeconomic context.

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I thank all the faculty of the Department of Conservation Social Sciences for their camaraderie, inspiration, and for sharing their knowledge over the years. I would like to convey my appreciation to Steve Hollenhorst for taking a chance on me and letting me develop and co-teach a new graduate level course and for providing encouragement throughout my time at the University of Idaho. Lena Le deserves special mention for statistical guidance and her constant support. I wish to recognize Troy Hall for her advice on theory and for providing interesting research and funding opportunities, lessons on organization, and the occasional pot-luck. Friendship and advice from Nick Sanyal, Ed Krumpe, Chuck Harris, Debbie McLaughlin and fellow graduate students Kim Skyelander, Erik Nielsen, Pablo Gomez, Sandra de Urioste Stone, Christine Jakobsen, and Heidi Bigler Cole was greatly appreciated and made the process a whole lot more fun. I thank Lilly Steinhorst for her consistently sound advice and for helping me navigate all of the bureaucracy. Furthermore, I wish to thank Gary Machlis for opportunities to conduct research with him as part of the Human Ecosystems Study Group, for bringing me on as a consultant for a series of workshops for the United Nations University Institute of Advanced Studies, and for his ‘real world’ mentorship and advice.

Steve Sesnie, Jessica Schedlbauer and I designed an interdisciplinary project to explore how Costa Rica's policy of payments for environmental services influenced landowner land-use decisions and how those decisions translated into the provision of forest cover and ecosystem processes. Their patience and dedication to this challenging integrated project and their willingness to share their knowledge deserves special consideration. I would also like to thank Bryan Finegan, Celia Harvey, and J. D. Wulfhorst for their extensive reviews and recommendations on the team project.

Special thanks go to Stacy Sesnie for her exceptional work as a field assistant, transcriber, and friend. Stacy and Steve provided much appreciated friendship and support through Marisol's sleepless early months. I am indebted to my other field assistants Edwin Peirera, Isabel Venegas, and Sandra Candela for their professional and tireless work and their good humor. Erika Barrientes deserves mention for her work transcribing my interviews.

This research was also made possible through cooperation from national organizations and individuals willing to assist myself and fellow integrated team members. Germán Obando, Andres Sanchún from the Fundacion para el Dessarollo Sostenible de la Cordillera Volcánica Central (FUNDECOR), and Jhonny Mendez and Oscar Quirós from the Comisión de Dessarollo Forestal San Carlos (CODEFORSA) provided information and logistical support that were essential to disciplinary and interdisciplinary aspects of this dissertation. I wish to extend my gratitude to all of the land owners in the Sarapiquí and San Carlos region who welcomed me into their homes and provided candid and thoughtful answers to my litany of questions.

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DEDICATION

Desde el fondo de mi corazón, quiero agradecer a mi esposa Jennifer, y a mis hijos Marisol y Forrest por todo su apoyo, comprensión y amor durante esta etapa de nuestra vida.

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CHAPTER 1

Introduction

Longstanding concerns regarding environmental change have included deforestation, fragmentation and land use change in the tropics and consequent impact on biodiversity and sustainable livelihoods (such as Angelsen & Kaimowitz, 1999; Brandon, Redford, & Sanderson, 1998; Kramer, Schaik, & Johnson, 1997; Rudel & Roper, 1997). More recently, the focus has shifted to environmental services that ecosystems can provide (including biodiversity habitat, carbon sequestration, watershed values, etc.) and how those changes impact human well-being (Lambin, Geist, & Lepers, 2003; Millennium Ecosystem Assessment, 2003; Pagiola, Arcenas, & Platais, 2005; Smith & Scherr, 2003; Wunder, 2007).

Discussion of environmental services has evolved from identification of their importance and value to both human and natural systems (Costanza et al., 1997; Daily, 1997) toward more nuanced efforts of classification and understanding of the ecological processes providing services (de Groot, Wilson, & Boumans, 2002; Farber, Costanza, & Wilson, 2002; Kremen, 2005; Millennium Ecosystem Assessment, 2003; Norberg, 1999), attempts to define, identify and calculate values of environmental services from ecological, economic and integrated perspectives (Boyd & Banzhaf, 2006; Heal, 2005; National Research Council, 2005; Pagiola, von Ritter, & Bishop, 2004; Turner et al., 2003; Winkler, 2006), and emergent markets and public schemes used to promote/conserve land uses that provide environmental services (Ferraro & Kiss, 2002; Grieg-Gran, Porras, & Wunder, 2005; Landell-Mills & Prorras, 2002; Pagiola, Bishop, & Landell-Mills, 2002; Wunder, 2005, 2007). However, the links between the influences of land use change and the provision of environmental services is yet to be as thoroughly developed. This introduction serves as a road map for the dissertation. Three chapters have been written in the form of manuscripts and are outlined below.

A landscape can be viewed as the result of complex adaptive systems where multiple household production decisions about land use are made within a particular social and environmental context over time (Lambin, Geist, & Lepers, 2003). Within a regional context, individual farmers pursue a variety of livelihood strategies with direct implications for the biophysical landscape (Chambers, 1997; Scherr & Current, 1997). Livelihood strategies are the activities and choices that people pursue about making a living and meeting their own goals and objectives (de Haan & Zoomers, 2005; Scoones, 1998). Individual farm households tend to vary in terms of livelihood assets, production goals, skills and knowledge, resource endowments (Chambers & Conway, 1992). Furthermore, landowner decisions about land use are made in an increasingly interconnected, complex, and dynamic world. Recognition of this complexity has led to a shift in analysis in land use change studies to 'people in places' where detailed social and environmental histories are used to provide information about how unique and dynamic social contexts have influenced land use choices of landowners over time (Batterbury & Bebbington, 1999; Leach, Mearns, & Scoones, 1999; Scoones, 1999). However, as indicated in Lambin et al. (2003):

> What has been lacking so far is the development of an integrative framework that would provide a unifying theory for these insights and pathways to land use change and a more process oriented understanding of how multiple macro-structural variables interact to affect micro agency with respect to land. (p. 217).

Understanding the dynamic nature of human-environment interactions is critical for mitigating the impacts of human induced environmental change on the things that we value as humans (Stern, 1993). In chapter two, a model for analyzing linked human-environment systems was developed for analyzing Costa Rica's program of payments for environmental services (PES). The PES provides direct payments to landowners for reforestation, sustainable forest management, and natural forest protection. The payments are made in exchange for the provision of four environmental services including carbon sequestration, watershed, biodiversity habitat, and aesthetics. The first half of chapter two is dedicated to the presentation of a theoretical model that outlines linked micro-macro processes of both social and ecological systems: a Social Ecological Structuration Model (SEStM). The model was developed for investigating the impact of Costa Rica's PES program on land use decisions and how those decisions have influenced the provision of environmental services. The second half of chapter two presents a case study using a component of the model to assess the dynamic social context for implementation of Costa Rica's PES program for landowners within the La Selva – San Juan portion of the Mesoamerican Biological Corridor.

Ecosystems provide a variety of essential services critical to the well being of all species (Daily, 1997; de Groot, Wilson, & Boumans, 2002). The ability of ecosystems to provide these services are in decline at the same time as our need for them grows

(Millennium Ecosystem Assessment, 2003). Based on a need to increase the efficiency of conservation efforts, a new era of conservation programs are using payments for environmental services (PES) as a direct approach to involving landowners in the conservation of the environmental services their lands provide (Ferraro & Kiss, 2002; Wunder, 2007). Several issues critical to understanding the efficiency of PES include, additionality, baseline conditions, leakage, and equity (Wunder, 2005). These topics have been relatively unexplored with empirical data. Chapter three examines each of these issues by comparing participants and non-participants in Costa Rica's PES program (N=207). Participants and non-participants were randomly sampled within the San Juan-La Selva portion of the Mesoamerican Biological Corridor. Results indicate that PES for forest protection has helped to reduce the deforestation rate and that the incentives for reforestation have been effective at increasing forest cover. Both protection and reforestation can be shown to contribute to rural development, but in indirect ways.

This research was funded by a Fellowship through the National Science Foundation (NSF) Integrated Graduate Education and Research Traineeship (IGERT). The IGERT program was designed to foster interdisciplinary research and education (NSF, 2004). The grant was awarded to the University of Idaho for a program start date in the spring of 2002. CATIE (Tropical Agricultural Research and Higher Education Center) is a partner institution for the project. The focus of the grant is "achieving biodiversity conservation and sustainable production in anthropogenically fragmented landscape" (Bosque-Perez et al., 2001). As required by the program, each student was required to be part of an interdisciplinary team. Each team defined a common research problem, developed integrated proposals, conducted collaborative research, and wrote a joint chapter from our research. Chapter three was co-authored by two other doctoral students, Steve Sesnie and Jessica Schedlbauer. This jointly written chapter was required as part of the program and is included in teammate dissertations as well.

As one of the first developing countries to develop a PES program, Costa Rica presents a compelling case study for analysis. The objectives of 1996 Forestry Law and PES are to provide environmental services through forest stewardship; however their impacts on carbon storage, forest structure, and connectivity in fragmented landscapes are unclear. Further, the relative influence of forest policies and programs on landowner decisions to maintain or increase forest cover remains poorly understood. Chapter four discusses an integrated research approach that was used to determine the extent to which the 1996 Forestry Law and PES incentives for landowners influenced their decision making and if those decisions provided additional environmental services. Landsat images were used to compare landcover changes before and after 1996, and these data were linked to landowner surveys investigating land use decisions. Carbon services provided by secondary forests were examined both above and below ground. Evaluation of the survey data provided insights into the observed land cover changes, and the effects of environmental service payments on forest retention and recruitment following implementation of the 1996 Forestry Law. Forest cover and connectivity increased through tree plantations and secondary forest recruitment. Secondary forest carbon storage approached values found in primary forest after 25-30 years of succession, though few landowners retained natural regeneration. The Costa Rican experience provides evidence that environmental service payments can be effective in retaining natural forest and recruiting tree cover. Chapter five presents a brief conclusion to this research project.

Six appendices are included in this dissertation. Appendix one is a list of acronyms used in this research. Appendix two is a detailed description of the methods used in this research. Appendix three is a brief analysis of the potential ‘conservation multiplier’ effects of the PES program. Multiplier effects could be considered if participation in the PES program influenced the management of other tree resources on the farm. The fourth appendix is a presentation of the results of a livelihood asset analysis developed from the survey presented in Chapter three. These results were used for the team paper in Chapter four and will be used for a future manuscript on the methodology for livelihoods analysis. Appendix five is based on a midterm project evaluation on interdisciplinary research within our IGERT program was conducted by the lead author and another doctoral student in the program, Max Nielsen-Pincus and two faculty members from the UI-CATIE NSF IGERT program, Dr. Jo Ellen Force and Dr. J.D. Wulfhorst. As lead author, an extended version of the article is included in this dissertation. Appendix six is the Human Assurances Form granting approval for this research project.

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CHAPTER 2

Social Ecological Structuration: Developing a Linked Human-Environment Model with a Case Example of Costa Rica's Program of Payments for Environmental Services

Abstract

The environment is both a setting for and a product of human interactions. Understanding the dynamic nature of human-environment interactions is critical for mitigating the impacts of human induced environmental change. Current research on environmental change has focused on the reduction in the ability of many ecosystems to provide environmental services and the subsequent impact on human well-being. To frame these interactions, a theoretical model or framework is necessary. This paper presents a model based upon linking structuration theory from the social science with a theory of patch dynamics from landscape ecology. To operationalize the model for empirical analysis, variables from a meta-analysis on tropical deforestation and from the livelihoods framework are then added and discussed in terms of multiple landscape and social scales. This model then guides an agent context analysis using Costa Rica's program of payments for environmental service as a case example. Findings suggest the model has potential for understanding land use change and evaluation of environmental service payment programs.

Introduction

A landscape is both a setting for and a product of human interactions (Scoones, 1999). Understanding the dynamic nature of human-environment interactions is critical for mitigating the impacts of human induced environmental change on the ecological services that that we, as humans, value (Stern, 1993). Research on the causes and consequences of environmental change is necessarily an integrated endeavor and has spawned a cross-fertilization of ideas among numerous disciplines (Grimm, Grove, Pickett, & Redman, 2000; Grove & Burch, 1997; Gunderson & Holling, 2002; Klein, 2004; Millennium Ecosystem Assessment, 2003; Scoones, 1999). A longstanding conceptualization of the reasons for environmental change has focused on deforestation, fragmentation and land use change in the tropics and consequent impact on biodiversity and sustainable livelihoods (such as Angelsen & Kaimowitz, 1999; Brandon, Redford, & Sanderson, 1998; Kramer, Schaik, & Johnson, 1997; Rudel & Roper, 1997). More recently, the focus of research on deforestation and land use change has shifted to environmental services that ecosystems can provide (including biodiversity habitat, carbon sequestration, watershed values, etc.), as well as how those impact human well-being (Lambin, Geist, & Lepers, 2003; Millennium Ecosystem Assessment, 2003; Pagiola, Arcenas, & Platais, 2005; Smith & Scherr, 2003; Wunder, 2007).

Discussion of environmental services has evolved from identification of their importance and value to both human and natural systems (Costanza et al., 1997; Daily, 1997) toward more nuanced efforts of classification and understanding of the ecological processes providing services (de Groot, Wilson, & Boumans, 2002; Farber, Costanza, & Wilson, 2002; Kremen, 2005; Millennium Ecosystem Assessment, 2003; Norberg, 1999). There has also been attempts to define, identify and calculate values of environmental services from ecological, economic and integrated perspectives (Boyd & Banzhaf, 2006; Heal, 2005; National Research Council, 2005; Pagiola, von Ritter, & Bishop, 2004; Turner et al., 2003; Winkler, 2006). Furthermore, a growing body of literature discusses emergent markets and public schemes used to promote/conserve land uses that provide environmental services (Ferraro & Kiss, 2002; Grieg-Gran, Porras, & Wunder, 2005; Landell-Mills & Prorras, 2002; Pagiola, Bishop, & Landell-Mills, 2002; Wunder, 2007). However, making the links between the influences of land use change and the provision of environmental services is not thoroughly developed. To date, this area has relied on integrated studies of land use change.

A recent meta-analysis of land use change case studies of deforestation in the tropics concludes that change is influenced by multiple, multiscale, and synergistic factors such as economic markets, political policies, demographic changes and technological factors among others (Geist & Lambin, 2002). Land use change is rarely driven by single underlying factors such as population or poverty as is commonly perceived (Lambin et al., 2001). In accordance with this more dynamic perspective, a landscape can be viewed as the result of complex adaptive systems where multiple household production decisions resulting in land use allocations are made within a particular social and environmental context over time (Lambin, Geist, & Lepers, 2003). This has led to a shift in analysis to 'people in places', where detailed social and environmental histories are used to provide information about how unique and dynamic social contexts influence land use choices of households (agents) over time (Batterbury & Bebbington, 1999; Leach, Mearns, & Scoones, 1999; Scoones, 1999). However, as indicated in Lambin et al. (2003):

> What has been lacking so far is the development of an integrative framework that would provide a unifying theory for these insights and pathways to land use change and a more process oriented understanding of how multiple macro-structural variables interact to affect micro agency with respect to land. (p. 217)

The need for this type of integrative framework for human-environmental systems has also been identified by others and has led to the development of a number of conceptual models of linked human-environmental systems (such as Alberti et al., 2003; Bebbington, 1999; Grimm, Grove, Pickett, & Redman, 2000; Millennium Ecosystem Assessment, 2003; Pickett et al., 1997). However, none of the models to date explicitly identify variables and relationships or adequately use social and ecological theories that account for both agent – structure interactions of social systems let alone the linked biophysical patterns and processes.

This research was part of a larger interdisciplinary study that explored the consequences of Costa Rica's program of payments for environmental services (PES) on influencing landowners' decisions regarding land use and the subsequent provision of environmental services. As such, a model that could be used to explore policy, landowner decision making and their linkage to the provision of environmental services was postulated. The first part of this paper is dedicated to the presentation of the theoretical model, which links micro-macro social and ecological process; a Social Ecological Structuration Model (SEStM). The model was developed for investigating the impact of Costa Rica's PES program on land use decisions and how those decisions have influenced the provision of targeted environmental services.

The second part presents a case study using the model to explore the dynamic social context for implementation of Costa Rica's PES program for landowners within the La Selva – San Juan portion of the Mesoamerican Biological Corridor. The objective of this portion of the paper was to identify the social factors that have influenced land use change in the region since 1969. The year 1969 was selected because it was the first formal Forestry Law. Specifically, the following four research questions were asked: 1) What are the social systems that have influenced land use decision since 1969?; 2) How have the identified social systems influenced land use decision since 1969?; 3) What are the Forestry Laws and policies that have influenced land use decision since 1969?; and 4) How have the identified Forestry Laws and policies influenced land use decision since 1969?

Social Ecological Structuration Model (SEStM)

To understand the impacts of Costa Rica's policy on land use decisions, an approach encompassing how structural factors (policy) influence agents' (landowners) decision making was used. Additionally, the framework incorporated aspects of land use choices and their relationships to changes in environmental services. Elements of structuration theory from the social sciences (Giddens, 1984; Stones, 2005) and the theory of patch dynamics from the ecological sciences (Pickett & White, 1985; Wu & Loucks, 1995) were used to provide the heuristic framework for this study. The following sections will present the integrated theoretical components of this social ecological structuration model (SEStM). Next, the use of the model to conduct an actor-context analysis (Stones, 2005) specific to understanding Costa Rica's PES program is described.

Land Use and Land Cover

Land cover is the link between social and ecological systems and the key element for understanding the effect of policy and landowner livelihoods and on the alteration of landscape patterns ultimately resulting in environmental services. Quoting Leach et al. (1999):

> People's actions and practices, preformed within certain institutional contexts, may serve to conserve or reproduce existing ecological features or processes (e.g., maintain a regular cycle of fallow growth or protect the existing state of a watershed and its hydrological functions). But people may also act as agents who transform environments (e.g., shorten the fallow, altering soils and vegetation, or plant trees in a watershed). (p. 239)

Pickett et al. (1997), Grimm et al. (2000) and Redman et al. (2004) have also argued that land use and land cover should be the central focal point of linked human-environmental systems in the study of urban ecosystems...

Two separate theoretical frameworks interact and mirror each other in the model. However, since the mechanisms of ecological and social structuration function differently, they were modeled as opposite sides of the same process. For example, humans act with foresight, intent, reflexivity and can communicate these ideas into the future, which ecological systems do not (Holling, Gunderson, & Peterson, 2002; Walker et al., 2006). Further differences that have been identified are the ability of humans to abstract from a situation in time and space, the ability to be reflexive and evaluative, the ability to generate expectations, the ability to create technology, and the scale of influence that humans have, all of which warrant using a theoretical framework that can differentiate the systems processes (Westley, Carpenter, Brock, Holling, & Gunderson, 2002). The theoretical frameworks mirror each other in that they together represent linked complex adaptive systems that are both the medium and outcome of interactions recursively organized across time and space (Giddens, 1984; Gunderson & Holling, 2002; Scoones, 1999).

Structuration Theory

Structuration theory (Giddens, 1984; Stones, 2005) is a promising social theory for linking social and ecological systems (Bebbington, 1999; Gunderson & Holling, 2002; Leach, Mearns, & Scoones, 1999; Scoones, 1999). Structuration theory combines "the notion of emergent processes with the notion of enduring institutions" (Scheffer, Westley, Brock, & Holmgren, 2002). It postulates "the interaction of structure and agency across scales [that] must be the centerpiece of a dynamic understanding of people-environment interaction" (Scoones, 1999, p. 493). A number of studies have argued that structuration theory can help to: 1) move beyond static structural explanations (Leach, Mearns, & Scoones, 1999); 2) frame rural livelihoods analysis (Bebbington, 1999); 3) integrate human-environmental systems across scales (Warren, 2005); and 4) provide an explanation of the similarities and differences in social and ecological systems (Scheffer, Westley, Brock, & Holmgren, 2002; Westley, Carpenter, Brock, Holling, & Gunderson, 2002). Giddens' structuration theory as presented by himself and others (Giddens, 1984; Kaspersen, 1995; Kondrat, 2002; Munch, 1994; Ritzer & Goodman, 2004), but particularly as modified by Stones (2005) forms the basis of this study's model.

Social Structuration

Structuration theory avoids an overly objective structural approach and an exaggerated emphasis of subjectivist, agent-based approaches by focusing on their interaction as socially situated practice (Stones, 2005). Human action is viewed as a continuous flow of practice (Giddens, 1984). Based on this procession of human social conduct, Giddens identifies a concept termed duality of structure. It is a duality because agents and structure are not considered independent of one another (Ritzer & Goodman, 2004). Structure is seen as both "the medium and outcome of the conduct it recursively organizes; the structural properties of social systems do not exist outside of action but are chronically implicated in its production and reproduction" (Giddens, 1984, p. 374). Structure enters into the constitution of the agent as a medium (internal structure) and from there into the practices that the agent produces as an outcome (external structure) (Stones, 2005). Structures that are the outcome of one period of practices (actions, activities, praxis) become the medium for the next round of agents' practices (Stones, 2005). Through recursive social practice, structures influence the activity of individuals, who in turn, produce, transform, or otherwise reaffirm those same structures constantly producing and reproducing society (Kaspersen, 1995; Kondrat, 2002). According to Munch (1994),

> This means that structures are not predetermined once and for all, but made in social praxis. All social praxis starts with a given structure that has emerged from previous praxis and provides an instantiation of that structure in social actions, and results in contributing to the continuation or transformation of the structure. (p. 191)

Therefore, the process of structuration can be defined as the "structuring of social relations across time and space" due to the recursive nature of social practice (Giddens, 1984).

Social Systems

Social systems can be thought of as the *patterns* of social relations, or regularized social practices that stretch across time and space produced by the process of structuration (Kaspersen, 1995). They are the "complex, entrenched, and powerful networks of relationships, behaviors, beliefs, interactions, rules, and resources" and are both temporally and spatially contingent (Kondrat, 2002, p. 446). Furthermore, they are integrated with other social systems hierarchically and across space and over time; "all societies both are social systems and at the same time are constituted by the intersection of multiple social systems" (Giddens, 1984, p. 164). However, if one of the social systems involved is based a long way away from the actor spatially (e.g. global markets) or temporary (e.g. the constitution), the more resistant to change the social systems become (Giddens, 1984).

Agency

That said, actors (households owning land) are perceived to always have agency, to be able to 'act otherwise,' 'make a difference' or otherwise intervene in the world (Giddens, 1984). This means that an actor has the power to make things change, and that whenever an actor acts; it is an assertion of that power (Munch, 1994). An actor's agency/capabilities in this regard also emanate from their ability to harness elements of structure (Bebbington, 1999; Stones, 2005). Structures are considered to be both enabling and constraining of agents actions (Giddens, 1984). Structure can be further broken down into 'rules and resources' that are recursively involved in the reproduction of social systems (Giddens, 1984). Rules are "techniques or generalizable procedures applied in the enactment/reproduction of social practices" (Giddens, 1984, p. 21). These are the formula or procedures to action that tell us 'how to get on' in the world (Kaspersen, 1995). Rules can be codified and formal, such as laws and regulations or informal such as how close one should stand when talking (Kondrat, 2002). The term *rules* is considered by some to be an overly rigid interpretation of social structure, so the term *cultural schemas* (or schemas) has been offered as a replacement (Sewell, 1992; Stones, 2005). Resources, on the other hand, refer to the 'structures of domination' and include both allocative and authoritative resources (Giddens, 1984). Allocative resources are the "material resources involved in the generation of power, including the natural environment and physical artifacts" (Giddens, 1984, p. 373). Authoritative resources involve domination or control over people and their activities (Giddens, 1984). Having control over either of these types of resources can increase an agent’s power and transformative capabilities (Sewell, 1992). However, all actors are not situated equally in their capabilities, or knowledge of schemas and access to resources as indicated by Kondrat (2002):

> Actors may be located at varying positions along structuring dimensions of social life such as class, status, gender, and cultural or religious marginality. An individual’s social location influences access to resources (including technological resources), power, opportunity, and information, all of which enter into the determination of what one knows, does not know, or is prevented from knowing (Giddens, 1984, Kondrat, 1999). (p. 441)

Additionally, an actors knowledge of and access to structural resources is likely to be geographically and historically contingent (Kondrat, 2002). Agency can also be limited by other actors who have sanctioning power. Therefore agency should be seen on a continuum where all actors have some degree of agency, but no actor has completely unconstrained agency (Ritzer & Goodman, 2004). Power, then, is the medium through which agency operates and can be “defined pragmatically in terms of the allocation of rules and resources in a given situation” (Kondrat, 2002, p. 438).

Giddens views actors as both powerful and knowledgeable; “all social actors know a great deal about the conditions and consequences of what they do in their day to day lives” (Giddens, 1984, p. 281). A key to understanding the capability of actors to use structural resources is the conception of the agent in structuration including: 1) motivation to action; 2) knowledgability and the rationalization of action; and 3) reflexive monitoring of action (Giddens, 1984). Motivation to action includes the wants and desires that prompt individuals to engage in social practice. Motivations can be intense and directed but are usually mundane with no motivation identifiable for most daily actions (Stones, 2005). Rationalization of action includes knowledgability of social structures and how to do things best to obtain one’s goals (Munch, 1994). Reflexive monitoring of action includes the intentional and purposive part of action (Kaspersen, 1995). While agents are seen as knowledgeable it is not a perfect knowledge, “the agent’s knowledgability is always limited by the unacknowledged conditions of and the unintended consequences of action” (Kaspersen, 1995, p. 40).

Visualizing Social Structuration

Building on this framework and the critiques of numerous authors (Archer, 1995; Mouzelis, 2000; Sewell, 1992 and others as cited in Stones, 2005), Stones (2005) outlined a quadripartite formulation of structuration. As the four stages are outlined, they will be represented on a diagram (Figure 1). To maintain the mutually constitutive formulation of the duality of structure and to heed cautions about using too simplistic and sequential pattern of causality (Stones, 2005, p. 20), we have adopted a cyclic model to present the four stages of structuration as a process. The model is similar to and adopted from Gunderson and Holling's (2002) adaptive cycles used to represent their "heuristic theory of change" (Holling & Gunderson, 2002, p. 49). However, for the purposes of this paper, the model depicts the process of structuration specifically and does not apply it to the four phase cycle representing exploitation, conservation, release and reorganization of social and ecological systems of Panarchy theory (though the sequence of these phases is entirely possible within the structuration framework as presented herein).

Stones (2005) presents the duality of structure in four separate but dependent components. The diagram presents the process of structuration as a linked figure eight showing structure as both the medium and the outcome of actors' actions (Figure 1). The arrows represent the flow of time, but also to demonstrate the continual interaction of the structure and agency. The three aspects describing the process of agency happen instantaneously through action and the outcomes (both internal and external) are created for the next period. This flow of structuration is outlined with a hypothetical example of a landowner's (the actor) decision to change land use (Figure 1). The larger and thicker circle representing external structures is to be indicative of the time space distanciation of social structures, they are generally slower to change and last longer than agents (Giddens, 1984).

External social structure (1S- Figure 1).

The first (though there is no correct order as the process is cyclic) aspect is external structures as conditions of action. This is the in situ 'action horizon' structural context faced by the landowner at time 1 (T1) (Stones, 2005) and is diagramed as the top of the structure circle flowing into the landowner. External structures feature existing social systems such as the economic markets for goods and services, the politics and policies regulating trade, and the cultural norms related to marketing a product that are present at time one and currently exogenous to the landowner.

Internal structure (2S).

External structures or social systems are diagramed to flow into the internal structures of landowner livelihood strategies. Examples of a landowner's internal structures include their worldview and general understanding of the norms and procedures of how a market system operates (schemas) and their specific understanding of their place within those systems. Internal structures would include landowner's knowledge of the resources at their disposal and how to apply those resources to accomplish their goals. A landowner can look at price trends and supply and demand and consider their own costs and benefits and make a decision about whether to clear land or to plant a crop. They can also make use of their social assets and talk to their neighbors and extension agents to learn about what they have to say about the market conditions.

Unacknowledged conditions (dashed line).

The dashed line above the internal structures represents the unacknowledged conditions at time one (T1). This aspect of the model recognizes that knowledge of the external structures such as markets and policies is often incomplete, such that actors lack perfect information at any given time. Current investment in the same crop in another country is an example of a possible unacknowledged condition that might affect price at harvest time.

Action (3S).

The third aspect of the duality of structure is that of active agency where the landowner uses the internal structures for action. This is the moment of structuration. This is where a landowner makes a decision applying their knowledge of the social systems and their capabilities and control over resources such as financial assets for investment and their farm conditions and takes an action that impacts land cover. For example, a landowner may clear a patch of forest or change a pasture into a crop. This is the 'proximate' cause outlined in the land use change literature and is the result of the landowners action.

Outcomes (4S & 5S).

The final phase is that of outcomes as "external and internal structures and as events" (Stones, 2005, p. 85). In this way there are multiple simultaneous outcomes of the action, internal and external outcomes. Results of the action may have pleased or frustrated the landowner changing or reinforcing internal structure as part of the whole structuration process (Stones, 2005). The planting of a crop may have been more difficult or costly than expected or the labor may have been unreliable all of which the landowner has learned and will consider in any subsequent land use decision as part of their internal structure. Additionally, the external social structure could be elaborated, reproduced or preserved by the outcome of the event. In the action of planting a crop, the landowner bought seeds from a local distributor and hired employees from local labor force, reinforcing or contributing to the social systems that support the industry surrounding that crop.

Unintended consequence (dashed line).

The dashed line below the internal structures as outcomes represents the unintended consequences of the action that is both an input to external structures and internal structures for the next period. A landowner may not have expected that their own land use decision to influence migration patterns, but the hiring of employees may have contributed to local demand for labor and immigration to the area.

Theory of Patch Dynamics

Patch dynamics theory is used in this model to present the ecological 'side' of the complex adaptive systems (Pickett & White, 1985). Additionally, hierarchical patch dynamics (Wu & David, 2002; Wu & Loucks, 1995) is incorporated because it focuses on both the structural and functional properties of patches. This theory was selected because of its prevalence in landscape ecology and conservation biology (Franklin, 2005). Patch dynamics are also effectively and commonly applied to land use change studies with remote sensing and GIS technologies because of its landscape, or horizontal perspective (Turner, Gardner, & O'Neill, 2001). Because of these properties, the framework also lends itself to framing ecological processes across a variety of scales useful for assessing environmental services. Using a human ecosystem model, both patch dynamics and hierarchical patch dynamics have been used to explain ecological and social processes in urban ecosystems (Grimm, Grove, Pickett, & Redman, 2000; Grove & Burch, 1997; Machlis, Force, & Burch, 1997; Pickett et al., 1997; Wu & David, 2002).

Ecological Structuration

Modern ecological understanding of environments is that they are non-linear, hierarchically organized, have multiple equilibrium, and function as complex adaptive systems (Gunderson & Holling, 2002; Levin, 1999; Peterson, 2000; Scoones, 1999; Wu &

David, 2002). Quoting Levin (1999) (as cited in Gunderson and Holling 2002, p. 89), “The combined weight of multiple small scale processes can accumulate to help shape other patterns of interaction, and hence the structure and function of ecosystems, from small scales to the biosphere.” This concept of dynamic interaction of small and fast variables with large and slow variables is also a fundamental concept for the adaptive cycle in Panarchy (Gunderson & Holling, 2002). Along this same line, Scoones (1999) describes ecological processes using the key notion of recursiveness as used in structuration theory; “environments are dynamically and recursively created in a nonlinear, nondeterministic, and contingent fashion” (Scoones, 1999, p. 492). When this recursive process of ecological ‘structuration’ is viewed with the explicit interaction of linked social and ecological systems, it has been termed “structuration of the environment” (Leach, Mearns, & Scoones, 1999, p. 238). For this model, we use patch dynamics as an ecological theoretical framework within a recursive structuration process that structures ecological relations across time and space.

Patches

Patches are defined as a discrete spatial pattern or homogeneous unit relative to an ecological system that can be characterized by their size, shape, content, structure, function or complexity (Wu & Loucks, 1995). Patches are scale independent and the research question of interest drives patch definition (Pickett, Wu, & Cadenasso, 1999). Hierarchy theory was integrated with patch dynamics to extend the ability of the theory to address multi-scale issues with a ‘vertical’ perspective (Wu & Loucks, 1995). Controlling for complexity by using the idea of ‘enveloping’ from hierarchy theory, or the exploration of the scale below the focal scale to understand mechanism while examining the scale above to understand context, provides a practical framework for analyzing patch dynamics (Allen & Hoekstra, 1992; O'Niell & King, 1998; Wu & David, 2002). As described in this model, the focal level is the patch with the impacts of disturbance on the patch’s internal dynamics as the scale below and the impact of those changes on the larger patch mosaic as the scale above. In this way, it is possible to consider hierarchies of nested patch mosaics where at each level a patch is composed of its own dynamic patch mosaic (Wu & Loucks, 1995). This is an important feature for use in this model because it recognizes the internal structure of an individual patch. As with the internal structure of the actors in structuration theory who have various livelihood assets, the individual patch will have its own unique heterogeneity, function, and relationship to the external patch mosaic.

Patch Dynamics

The theory of patch dynamics defines ecological systems as dynamic patch mosaics and "studies the structure, function and dynamics of patchy systems with an emphasis on their emergent properties that arise from interactions at the patch level" (Wu & David, 2002, p. 11). It emphasizes change and heterogeneity which are driven by natural variation and disturbance (Turner, Gardner, & O'Neill, 2001). Disturbances are discrete events that change patches and are classified by size, shape, frequency, and intensity (Turner, Gardner, & O'Neill, 2001). Disturbances can be either naturally occurring such as a lightning fire or due to human intervention such as land use change. Multiple patches form a landscape or patch mosaic. A dynamic patch mosaic refers to the change in the mosaic over time including changes in structure and function (Pickett, Wu, & Cadenasso, 1999). We can therefore view a duality of patch dynamics where the external structure of the patch mosaic is both the medium and the outcome of recursive disturbances at the patch level. Disturbance corresponds to the actors' actions in structuration theory. Action and disturbance become synonymous when the action is one of land use change.

Visualizing Ecological Structuration

Figure 2 presents the process of ecological structuration as a linked figure eight designed to show how structure (both internal patch and external patch mosaics) is both the medium and the outcome of disturbance events. The flow is meant to show the progress of time, but also to demonstrate the continual interaction of the patch with the patch mosaic. It is suggested that this model represents the hierarchical patch dynamics model in terms of flows; "Thus, the dynamics of ecological systems are composed of the dynamics and interactions of constituent patches on different scales; this is an emergent property in that it is not simply the sum of the individual patch dynamics." (Wu & Loucks, 1995, p. 451). The three aspects describing the process at the patch level happen instantaneously as the outcomes (both internal and external) are created for the next period. The larger and thicker circle representing structures is to be indicative of the time/space distanciation of ecological structures; they are generally slower to change and last longer than individual patches.

External structure (1E - Figure 3).

The first (though there is no correct order as the process is cyclic) aspect is the patch mosaic as the existing condition at time one (T1) (external structure) and is diagramed as the top of the patch mosaic circle and flowing into the internal patch structure. This is the initial condition or template “for the subsequent structural development and dynamic interactions of the system” (White & Brown, 2005, p. 31). A landscape composed of a patch mosaic of forest and agricultural lands with all the attendant ecological functions and processes such as soil erosion rates into streams is an example of the external structure at time one.

Internal patch structure (2E).

The internal structure of the patch prior to a disturbance is included to represent the internal patch mosaic of any given patch within the hierarchical patch mosaic at time1. The patch in this case might be a forest that a landowner is considering clearing to plant crops. The patch of forest has certain characteristics of its own such as riparian areas and fallen tree gaps signifying its own internal patch mosaic.

Disturbance (3E).

The third aspect of the model represents the disturbance event on the patch. Disturbance (like action in the social system), is the catalyst of structuration of the ecological system, where the disturbance has the potential to transform, reproduce or maintain the structure and function of the patch and the patch mosaic. The disturbance could be caused by a farmer clearing part of the patch to plant a crop or could be a fire that runs through the patch of forest.

Outcomes (4E & 5E).

A disturbance will impact both the internal structure of the patch, but also, and simultaneously, be an input to alter the dynamics in the patch mosaic. A disturbance may have impacts on some aspects of the internal patch mosaic, but not others. For example, clearing a forest for a crop may leave a buffer around riparian areas, or a fire may never reach the crown of a forest. Therefore, *how* the patch has been impacted by the disturbance (disturbance to structure at the internal patch level, or the internal patch mosaic) will impact how it will in turn influence the larger patch mosaic. The structure of the patch mosaic could be changed, reproduced or preserved by the outcome of the disturbance. The example of forest clearing may significantly alter landscape connectivity and impact biodiversity at the landscape level, however, a ground fire may reinforce the patterns of vegetation that are dependent on fire.

Social Knowledge of Ecological Systems

The combination of the two models requires further explanation (Figure 3). In structuration theory there is a distinction made between actions and intentions (Ritzer & Goodman, 2004). The distinction is made because of the limited nature of human knowledgability and the likelihood of unacknowledged conditions and unintended consequences of human action (Giddens, 1984). These conditions have already been addressed in relation to social structures, however, when combined with ecological systems; two new instances need to be added to the model.

Actor's knowledge of ecosystems (1SE).

This process is labeled with the social element first, because it represents an interaction element of the social and ecological systems. This is the landowner's knowledge of 'ecology in general' of the larger patch mosaic (Figure 3). It includes a landowner's general knowledge of the larger environment, about conditions, processes, feedbacks, and thresholds. For example, a landowner may have a general understanding about greenhouse gases and global warming and how carbon from the atmosphere could be sequestered in their forest.

Actor's knowledge regarding knowledge about their land (2SE).

This is the specific knowledge that a landowner has about the ecological conditions specific to the action they are considering such as land use change on their farm. This 'local knowledge' may be different than their general ecological knowledge due to direct interaction and feedbacks that they may have experienced and learned on their land. A landowner may be aware of variations of soil types across their land and how crops have fared in the past.

Actor's unacknowledged conditions of ecosystems (dashed line).

As noted regarding ecosystems, "knowledge of the system we deal with is always incomplete. Surprise is inevitable. Not only is the science incomplete, the system itself is a moving target" (Holling, 1993, p. 553 as cited in Scoones, 1999). There may be unacknowledged conditions about both general ecosystems and the landowners own land. Both of these unacknowledged conditions are indicated by the dashed line beginning in the patch mosaic at time one (T1) and entering into land use and cover change action/disturbance of the agent.

Unintended consequences (dashed line).

The land use decision by a landowner results in an action/disturbance that may be either intended or unintended. Either way, the physical result is represented in 4E as the internal patch outcome. The remaining dashed line under 4E is to indicate unintended ecological consequences of the landowner's action. An example of this is if the crop the landowner planted had led to the spread of a disease across the landscape.

Open systems.

The final elements on Figure 3 are the flows to and from other social and ecological systems. These are done in recognition that both social and ecological systems are open systems (Gunderson & Holling, 2002). Both systems represented are hierarchical across both space and time and therefore require acknowledgement of flows to and from other systems (Giddens, 1984).

Methodological Bracketing

The SEStM depicts the multiple scales of analysis that are necessary to analyze land use change at the regional level. It frames the individual decisions farmers make on their land in terms of agency, and the contextual external structures in terms of social structures. Methodological bracketing is a method designed to focus the researcher on certain aspects or dimensions of the structuration process (Giddens, 1984). Stones (2005) reformulated Giddens' brackets to include agents' conduct analysis and agent context analysis. The conduct analysis is focused on the knowledgability, motivations, reflexive monitoring, and desires of the agent (Stones, 2005). Context analysis is intended to be "used to analyze the terrain that faces an actor, the terrain that constitutes the range of possibilities and limits the possible" by focusing on social systems (Stones, 2005, p. 122). The two bracketed methods are intended to provide an outside-looking-in and inside-looking-out analysis of the process of structuration in social systems. A similar type of bracketing that helps reduce complexity can be found in the use of hierarchy theory for ecological systems (O'Neill, Johnson, & King, 1989).

Empirical Analysis

For empirical analysis, however, the model needs additional specificity and identifiable variables. As recommended by Stones (2005) and McKee et al. (2000), combining research frameworks with insight into a particular issue can "produce more powerful critical frameworks" (Stones, 2005, p. 119). Therefore, a meta-analysis of the proximate and underlying causes of tropical deforestation (Geist & Lambin, 2001; Lambin, Geist, & Lepers, 2003) was used to provide variables for the social systems for a context analysis. Variables identified for analysis of livelihood strategies were added to specify the actors' capabilities to exert power for the agent conduct analysis (Bebbington, 1999). A summary of the two frameworks follows.

Agency to Livelihood Strategies

Livelihood strategies are the activities and choices that actors (in this case, landowners) make about the different ways of combining their livelihood assets to meet their own goals and objectives that can vary within geographic areas, across sectors, and even within households over time (Chambers & Conway, 1992). Livelihood assets include: 1) human; 2) social; 3) financial; 4) physical; and 5) natural capital (DFID, 2003). Individual farm households are different in terms of livelihood assets in that they have varied production goals, skills and knowledge, resource endowments, and incorporate different combinations of factors of production in their livelihood strategy (Leach, Mearns, & Scoones, 1999). As indicated in the discussion of agency, power is associated with proximate control over, or the capability to access and use rules and resources (Giddens, 1984). Because different actors begin with different initial endowments of livelihood assets, agent capabilities may be measured in terms of livelihood assets as detailed in Bebbington (1999). We will follow their insights for this model, and use the five livelihood assets as a measure of an agent's capability to exert power (DFID, 2003). Both social and human assets were used to identify authoritative resources to measure access to and integration of social structures into agents' internal structures. The livelihood assets identified as financial, physical, and natural were used to assess the allocative resources and the 'material levers' that landowners can combine with their social and human assets to perform an action and exert power. However, landowners are also nested within a regional and global context where socio-cultural, economic, and policy forces are constantly changing. The context of these social systems that an individual faces influences decisions regarding different livelihood strategies.

Structure to Social Systems

A meta-analysis of case studies of tropical deforestation provided a detailed account of the social systems associated with deforestation and land use change (Geist & Lambin, 2002; Lambin, Geist, & Lepers, 2003). In their analysis (Lambin, Geist & Lepers 2003), land use change can be seen as a process akin to structuration:

> Human-environmental systems are complex adaptive systems in which properties, such as land use, emerge from the interactions among various components of the entire system, which themselves feed back to influence the subsequent development of interactions. (p. 227)

Drivers of land use have been framed as proximate and underlying causes (Geist & Lambin, 2002). Proximate factors are the human actions that have directly led to land use change while the underlying factors are described as the indirect social factors causing the proximate changes. “Underlying causes are formed by a complex of ….variables that constitute initial conditions in the human-environment relations and are structural (or systemic) in nature” (Lambin, Geist, & Lepers, 2003, p. 203). The underlying factors identified in Geist & Lambin (2002) include: 1) demographic factors; 2) economic factors; 3) technological factors; 4) policy and institutional factors; and 5) cultural factors while predisposing environmental factors (e.g. soil quality); biophysical drivers (e.g. drought) and social trigger events (e.g. war) were lumped into an ‘other’ category within their framework. Two modifications to the model they presented were made including the inclusion of: 6) natural factors; and 7) infrastructure as a main bins or categories of social systems. As a key focus of this model is land use change, it was determined that the environmental factors (natural factors) were a critical element for evaluation. Additionally, although the category ‘infrastructure’ is presented as a proximate cause of land use change (a road takes up space) in the Geist and Lambin (2002) model, it made more sense to include infrastructure as a social system within this model where the proximate causes are directly resultant from landowner actions. Therefore, infrastructure in this model is presented as a social system that enables or constrains landowner decisions. Similar variables reported to drive land use change were found in frameworks for long term ecological research programs (Redman, Grove, & Kuby, 2004) and for the evaluation of the impact of loss of environmental services on human well being (Millennium Ecosystem Assessment, 2003). Table 1 and Figure 4 present how variables from the two frameworks were combined within the SEStM for empirical analysis.

Methodology

This research was part of a larger interdisciplinary study that explored the consequences of Costa Rica's program of payments for environmental services. This portion of the study explores the influence of social systems on conservation and production decisions about land use in the La Selva – San Juan portion of the Mesoamerican Biological Corridor in Costa Rica from 1969 until 2003. The conceptual model previously explained guided the data collection and analysis. The agent context analysis is presented in this paper as an example application of that component of the model.

Agent Context Analysis

To conduct the agent context analysis a single case study approach was used (Yin, 1994). A case is a phenomenon bounded in time and space (Miles & Huberman, 1994). The case presented here is the influence of social systems on farmer conservation and production decisions. The spatial boundary of the case is the San Juan-La Selva portion of the Mesoamerican Biological Corridor where Costa Rica heavily targets its PES payments. The temporal boundary of the case was selected on the basis of the signing of Costa Rica's first forestry law in 1969 with emphasis on land use changes since the mid-1980s until 2004 and used for the interdisciplinary study. Two sources of evidence were used: expert interviews and document evidence. These provided both a form of data triangulation and methodological triangulation "aimed at corroborating the same fact or phenomenon" (Yin, 1994, p. 92).

Data Collection and Participant Selection

Qualitative data were collected through semi-structured interviews with local land use experts (Table 2). Qualitative data were collected to provide richness and to explore the meaning, or salience, people place on the events and structures in their lives (Miles and Huberman 1994). Experts were defined as individuals that had influenced or had special regional insights to landowner land use decisions. The experts lived and/or worked in the region at local offices on a daily basis often working directly with landowners. These experts were members of conservation and production NGOs, government agencies, local companies, tourism operators or non-affiliated individuals. Eighteen semi-structured interviews were conducted in the fall of 2003. Interviews lasted approximately 1 ½ hour and were led by the lead author and one assistant. Four interviews were conducted with individuals and the rest with small groups. Small groups were interviewed to allow for discussion and synergistic effects that can develop in group interviews. After each interview, names of other 'experts' in the region who could provide insight into the study were solicited. This was a form of snowball sampling and used to identify additional participants to interview (Tashakkori & Teddlie, 1998). These groups of experts were important for both their intimate knowledge of the land use in the region and for their ability to provide access to local farmers in the region. Interviews were conducted until the amount of new information obtained at each interview declined dramatically and the suggestions for additional 'experts' no longer provided new contacts.

Expert Interviews

The small group semi-structured interviews with land use experts had two main components: 1) a land use – social system analysis using a matrix to guide the interview and 2) a land use transition tree. The expert group interview was used to explore how the regional social systems influenced landowner conservation and production decisions about land use. This grounded but regional perspective was considered key to understanding the local influence of social systems and provides a narrative perspective (Butterfield, 1994).

The first section of the interview allowed the experts to generate lists of current and historical local land uses (e.g. pineapple, forestry, pasture) that have existed in the region. They were instructed to discuss each land use from the perspective of each social system variable from the conceptual model (Figure 4). Data from this discussion was used to develop a historical timeline of influences on land use change for the study area (Figure 5). The second part of the interview had the experts develop a land use transition tree to identify and restrictions or land use legacy issues or restrictions. Participants were asked to describe the process of land use change from forest to the land uses that they identified in the previous part of the interview. For example, if they identified a change from forest to pasture this would be drawn as the first branch on a tree. If pasture was reported to change to perennial crops or reforestation, these were drawn as a second branch coming from pasture (Figure 6).

Data Analysis

Interviews were transcribed and entered into NVIVO (N6) textual analysis software (QSR, 2002) to organize the textual data for analysis through coding and data display. Coding is part of data reduction and conclusion drawing (Miles and Huberman 1994). Data analysis was ongoing throughout the interview process in batches with 3-4 interviews conducted before each analytical phase. This was done to allow time for transcribing the interviews. The analysis of qualitative data used descriptive coding which utilizes basic categorical codes as descriptive devices to categorize data. In the case of this research the codes included the categories from the decision model developed in the SEStM model; economics and technology, politics, infrastructure, culture, demographics, and nature (Figure 4). Organizing interview data under these codes formed the first layer of data reduction and analysis (Miles and Huberman 1994). Matrix displays with land uses on one axis (pasture, forest, pineapple, etc.) and social systems on the other (economics, politics, etc.) were then developed from the coded data. In this way it was possible to compare land uses by each social system attributed to be a factor in the selection of that land use.

Document Evidence

Contextual analysis of documents was used to understand the evolution of social systems influencing land use change at the national and regional level for this specific case. The documents used included government agency reports, company/NGO reports, theses, and peer reviewed literature that directly addressed the case (Yin, 1994). Data from the expert interviews was used to target documents for the purpose of corroboration and augmentation of information revealed during the interviews (Yin, 1994). Over 100 documents specific to this case were identified and analyzed. Special emphasis was given to forest policy in the evaluation of land use change because the context of the environmental service payment program was the focus of the study. Document analysis provided a systemic perspective of the underlying factors or social systems associated with land use change (Lambin, Geist, & Lepers, 2003). This information provided the opportunity to track trends over time and ‘fill in’ the temporal aspect of a historical timeline in detail (Yin, 1994). The results of this contextual analysis are presented in the form of a historical timeline of major policy and other social systems that were documented to influence land use in the region (Figure 5).

Quality Assurance

Multiple sources of evidence including expert interviews and secondary data in the form of documents specifically relevant to the case were used to triangulate data and thus improve inference quality (Yin 1994). The interview data provided a local 'story' of which social systems were thought to be important to landowners from their grounded perspective. Documents were used to augment and corroborate the findings of the interviews (Yin, 1994). Another consideration in quality design of a study is the potential for researcher effects which occur when participants change, target, or otherwise behave differently then they normally would because they know they are being studied (Miles and Huberman 1994). To minimize this potential problem the purposes of the research, researcher affiliation, and how the research would be used were made clear to participants (Miles and Huberman 1994).

Two additional methods were used to ensure interpretative rigor, including member checks, and peer debriefing. A member check involves having a participant in the study check the categories, conclusions and interpretations made by the researcher. Four formal member checks were conducted with expert representatives at the end of the expert interview phase. The expert 'story' was reviewed with each expert to identify missing or misinterpreted information. Peer debriefing on coding was conducted to probe the analysis for any potential biases (Tashakkori and Teddlie 1998).

Study Site

This research was conducted in the San Juan - La Selva portion of the Mesoamerican Biological Corridor (MBC). The MBC is a multinational project designed to integrate the conservation of ecosystems and biodiversity with sustainable cultural, social, and economic development (Miller et al. 2001). The MBC is a network of core protected areas and buffer zones linked together by proposed corridors throughout Central America. The San Juan-La Selva portion of the corridor connects the central volcanic mountain range of Costa Rica and the Indio Maiz protected area of southeastern Nicaragua. Costa Rica has established this area as a priority area for targeting PES payments.

Costa Rica's development policies have adjusted and been transformed by both national and global economic and political processes. Additionally, forest policy in Costa Rica has been evolving and adapting to changes in national forest conditions within the country and with the evolving understanding of conservation and the environment at the national and global level. It is therefore necessary to understand the historical contingencies and dynamic nature of these social processes if we desire to understand land-use and land-cover trends and to manage them toward desired ends. What follows is a historical timeline of the evolving forest policy and social context of the San Juan-La Selva corridor region in Costa Rica beginning with the passage of the first forestry law (Figure 6).

Results from Document Evidence Data Analysis

Social Context

1969-1979: Colonization and cattle expansion under policies of import substitution.

Two main factors influenced land use change in the region during this period including the expansion of banana plantations and colonization linked to several government policies. The government of Costa Rica offered incentives to banana companies in the mid-1960s to induce local companies to establish plantations (Montagnini, 1994). Moving up from the Atlantic lowlands, Standard Fruit Company established banana plantations in the region in 1967 (Pierce, 1992). In doing so they improved the road infrastructure and generated numerous employment opportunities drawing people to the region (Butterfield, 1994).

The study area is characterized by its relatively recent forest frontier status and colonization history (largely since the 60s) and for the large proportion of both spontaneous and government colonization projects (McDade, 1994; Montagnini, 1994). Government colonization was promoted and organized by the agrarian development institute (IDA, see Appendix 1 for a list of acronyms) which was formed in 1962 to take advantage of on unused public lands (Butterfield, 1994). IDA was created in response to problems with increasing landless individuals due to concentration of lands into fewer large landholdings in other areas of the country (Cruz, Meyer, Repetto, & Woodward, 1992), combined with increasing national population (Brockett, 1998), and difficult times for producers in the central valley in the mid 1960s (Bouman, Jansen, Schipper, Hengsdijk, & Nieuwenhuyse, 2000) which were pushing people to the frontiers in search of land.

In addition to government colonization, spontaneous colonization of the region was reportedly driven by a number of other factors including land titling laws, credit policies and an international boom in the cattle industry (Brockett & Gottfried, 2002; Butterfield, 1994). Legalized in 1941, land tenancy laws allowed individuals to develop rights to land through ‘improving’ forest land by converting it to pasture and agriculture (Brockett & Gottfried, 2002). At this time hard work was equated with how much land one cleared (Brockett & Gottfried, 2002). These titling policies combined with a cattle export boom throughout Central America to pull migrants to the region (Butterfield, 1994). During this period the government followed a program of import substitution with heavy government involvement in the economy (Bouman, Jansen, Schipper, Hengsdijk, & Nieuwenhuyse, 2000). Under this model, cattle production became a large part of Costa Rica's approach to generate foreign exchange (Sanchez-Azofeifa, 2000) into which the government pumped heavily subsidized federal and international credit (Schelhas, 1991) which greatly encouraged conversion of forest to pasture (Cruz, Meyer, Repetto, & Woodward, 1992; Lehmann, 1992; Lutz & Daly, 1991). The easy access and terms for credit meant that by 1974, 58% of all agricultural credits went for cattle (Watson et al., 1998). This combination of factors also led to substantial land speculation on the frontier where land was cheap. Squatters were reported to even start 'businesses' where they would clear lands not for their own colonization, but to sell them to larger ranchers who could then gain title to the land (Butterfield, 1994; Schelhas, 1996). Both farmers and policy makers had long considered forest areas as sites for future agricultural expansion and of rural development as synonymous with forest clearing (Roebeling & Ruben, 2001). Deforestation in Costa Rica had been reported to have some of the highest deforestation in the world during this period (Peuker, 1992; Sader & Joyce, 1988) and was due in part to the forest's status as an "open-access resource" (Harrison, 1991).

1979-1982: Economic crisis.

A history of foreign borrowing to support government programs when combined with oil price increases and a sharp decline in coffee prices caused a national economic crisis (Cattaneo, Hinojosa-Ojeda, & Robinson, 1999; Hansen-Kuhn, 1993). The government tried to borrow its way out (Montanye, Vargas, & Hall, 2000) and by the early 1980s had one of the world's highest levels of debt per capita (Hansen-Kuhn, 1993). With inflation exceeding 100% many invested in land as a hedge against declining monetary value (Watson et al., 1998) increasing land speculation in the region. With an external debt approaching US $3 billion in 1982, Costa Rica had no choice but to ask the World Bank, International Monetary Fund, and U. S. Agency for International Development for assistance (Montanye, Vargas, & Hall, 2000). This aid was tied to a series of structural adjustment loans which were to have direct and indirect ramifications for agricultural development and forest cover over the next few decades.

1982-1989: Non-traditional agriculture export production.

This period was dominated by government policies influenced greatly by international lending agencies primarily through non-traditional agriculture export promotion, weaning of support for the cattle industry, and U.S. geopolitical concerns. Funding for the recovery was tied to geopolitical concerns of the Reagan administration in the 1980s (Watson et al., 1998). Largely funded by USAID, "Costa Rica's programs to consolidate territorial and political control over the northern lowlands, border, and communities involved putting in roads, people and cattle leading to continued growth and deforestation well into the late 1980s" (Girot & Nietschmann, 1992, p. 58). Additionally, in 1986 the road was completed between San Jose and Limon which facilitated settlement and stimulated livestock production in the region (Ibrahim, Abarca, & Flores, 2000). Much of the regional development in the late 1980s was influenced by these governmental infrastructure and colonization initiatives and support of the non-traditional agricultural sector (Hall, Hall, & Aguilar, 2000).

Structural Adjustment Loans (SAL) were designed to lower inflation and help balance fiscal and external accounts by reforming state and fiscal sectors and stimulating exports with market liberalization policies (Bouman, Jansen, Schipper, Hengsdijk, & Nieuwenhuyse, 2000). Three SALs were introduced over the next decade and progressively required Costa Rica to reduce the size of government, lower tariffs, eliminate subsidized prices for agricultural products (corn, rice, beans), remove subsidized production credits (including for cattle), shift to non-traditional agricultural exports, and devalue their currency (Cattaneo, Hinojosa-Ojeda, & Robinson, 1999). Under a policy of 'Agriculture for Change' the resulting study area landscape included a shift from national food production crops such as beans and corn to non-traditional export crops such as heart of palm and pineapple and an increase in banana plantations (Kaimowitz & Segura, 1996; Lehmann, 1992).

Pasture continued to grow throughout the region into the mid 1980s even after the international beef price and subsequent exports levels dropped drastically (Read, Denslow, & Guzman, 2001). The distortions continued in part due to cattle subsidies (with real interest loans as low as -10%) and a debt forgiveness scheme that mostly benefited large cattle ranchers and stressed the banking system (de Camino, Segura, Arias, & Perez, 2000; Montanye, Vargas, & Hall, 2000; Watson et al., 1998). However, with subsidies eliminated in 1985, Costa Rican cattle herds reached their peak around 1988 (Ibrahim, Abarca, & Flores, 2000). National cattle loans dropped and both regionally and nationally abandoned pasture land increased as the cattle herd decreased in many parts of the country (Arroyo-Mora, Sanchez-Azofeifa, Rivard, Calvo, & Janzen, 2004; Ibrahim, Abarca, & Flores, 2000), but not in this region. However, cattle continued to be managed extensively with low stocking rates while the potential for greater returns were available from most other crops (Ibrahim, Abarca, & Flores, 2000). The logic of cattle of low labor, low input, proof of land utilization against squatters, and easy marketability meant that cattle remained a dominant use in the landscape and many landowners were investing in land and not trying to establish highly profitable farms (Schelhas, 1996). Using cattle production to show active use of the land remained important for the region as land invasions continued throughout the 1980s (Schelhas & Sanchez-Azofeifa, 2006).

1989-2002: Mixed development.

During this period Costa Rica continued with the structural adjustment program furthering trade liberalization, slowly downsizing the government, and diversifying agricultural exports while promoting both tourism and conservation. In 1989, the government developed a national strategy of sustainable development (ECODES) designed to negotiate the mix between agricultural development and strict conservation (Watson et al., 1998). By 1996, the administration declared its intent to turn the country into a laboratory for sustainable development (Brockett, 1998) by promoting environmental concerns along with social investment and a more participatory democracy (de Camino, Segura, Arias, & Perez, 2000).

As a region that has been heavily influenced by government policy, this era was no exception. These policies and a favorable market for bananas resulted in forest being cleared for bananas in the region in the early 1990s (Bouman, Jansen, Schipper, Hengsdijk, & Nieuwenhuyse, 2000). This led to an increase in population, employment, and business in the region, but displaced a number of farmers' whose lands were bought out even further into frontier regions (Bouman, Jansen, Schipper, Hengsdijk, & Nieuwenhuyse, 2000). With relatively low prices for cattle in 1994-6 the regional trend of pasture abandonment continued

(Bouman, Jansen, Schipper, Hengsdijk, & Nieuwenhuyse, 2000). Reforestation, plantations of pineapple, heart of palm, ornamental plants, and bananas, have all made the study region is one of the major contributors to the new agriculture export economy (Read, Denslow, & Guzman, 2001). Pineapple became the second leading agricultural export in 2002 passing coffee in earnings (FAO, 2006). There was increased growth and migration to the urban road corridor during this period as the region shifted toward a more wage and service oriented economy (Schelhas & Sanchez-Azofeifa, 2006).

Forest Policy

1969-1979: Park establishment.

Costa Rica's first Forestry Law of 1969 set the stage for many future land use trends in Costa Rica (Figure 5). The most important aspect of this law was that it established categories of national parks, the methods to create them and an administrative body to govern and manage them. The first parks were designed at protecting scenic, historic and cultural values, but soon shifted toward selections based on biological and scientific reasons (Watson et al., 1998). By the end of the 1970s, 13 National Parks had been established including those in the study area; Tortugero in 1975 and Brauilio Carrillo in 1978, and the private reserve La Selva biological research station by the OTS (Organization for Tropical Studies) in 1968 (Sanchez-Azofeifa, Daily, Pfaff, & Busch, 2003). The 1969 Forestry Law also prohibited squatting on public forest land, however, this was seldom enforced (Brockett & Gottfried, 2002).

1979-1990: Reforestation promotion and institution building.

Almost no reforestation occurred in Costa Rica before incentives were introduced in 1979 (de Camino, Segura, Arias, & Perez, 2000). Over then next decade an evolving set of incentives were implemented with the focus of meeting wood consumption needs while taking the pressure off of primary forests (Castro, Tattenbach, Gamez, & Olson, 2000). Though based on the Forestry Law of 1969, the first reforestation incentives were implemented in 1979 in the form of tax deductions which targeted the wealthy as poor landowners did not pay income taxes (de Camino, Segura, Arias, & Perez, 2000). In 1983, soft credits for reforestation were offered with low interest (8% compared to 28.5% for agriculture) loans with 10 year grace periods (Rojas & Aylward, 2003). A second Forestry Law in 1986 intended to 'democratize' the incentives and distribute them more evenly developed the CAF (Certificate of Payment for Forestry) which was a subsidy in the form of a tax-exempt tradable bond for the first five years and up to the cost of establishment (Miranda, Porras, & Moreno, 2004; Sierra & Russman, In press). These programs suffered from a number of problems including low success rates, corruption, and that perception that they benefited mostly wealthy landholders and companies (Brockett & Gottfried, 2002; Thacher, Lee, & Schelhas, 1997; Watson et al., 1998). It was also suggested that some areas were deforested to the plant trees with the subsidies (Brockett & Gottfried, 2002; Morell, 1997). In 1988, the CAFA (Certificate of Advanced Payment for Forestry) was introduced as a subsidy to be paid in advance for the development of forest plantations. It was specifically designed for small landholders who could not afford the up-front costs of establishing a plantation (de Camino, Segura, Arias, & Perez, 2000).

The study area was one of the most advanced regions in terms of the implementation of these programs and a strong civil society of organizations such as CODEFORSA (Forest Development Commission of San Carlos, created in 1983) have gained valuable experience and knowledge of reforestation through these incentives (Camacho Soto, Segura Bonilla, Reyes Garjens, & Miranda Quiros, 2002). While over 100,000 hectares were planted by 1995, a success rate of 50% of plantations reaching harvest is suspected (Arce Benavides & Barrantes Rodriguez, 2004; Watson et al., 1998). However, by the end of the decade there was an increase in private reforestation even without incentives (Watson et al., 1998).

During this same period, no tree was to be cut without a permit from the Forestry Department (DGF). The permit required a technical study of land suitability, a tax payment, and a management plan and was negatively perceived by landowners (Watson et al., 1998). Understaffed and largely unenforceable, this program has little oversight and impact (Brockett & Gottfried, 2002). In 1987, several government institutions were consolidated and MIRENEM (Ministry of Natural Resources, Energy and Mines) was created and to be the main organization responsible for managing natural resources. This same year Costa Rica banned the export of logs and unprocessed timber, and restricted new saw mills protecting the industry, which artificially lowered the value of trees and depressed income for sellers (Brockett & Gottfried, 2002; Kishor, Mani, & Constantino, 2003).

Deforestation rates slowed by the late 1980s and early 1990s (Read, Denslow, & Guzman, 2001; Sanchez-Azofeifa, 2000) and tourism and conservation efforts began to take hold. A strip between La Selva and Brauillo Carrillo was declared a protected zone in 1982 (enacted in 1986) completing an altitudinal tract from the lowland region up to the central valley (Read, Denslow, & Guzman, 2001). Additionally, in 1985 the Barra del Colorado Wildlife Refuge of 92,000 ha stretching along the Rio San Juan from southern Nicaragua to Tortugero was established (Butterfield, 1994). Strong private sector conservation initiatives were also developed during this period. One of the first Ecolodges in the world, Rara Avis, was initiated in 1986 (Honey, 2003) and several other private reserves including Selva Tica and Selva Verde have added to the base provided by the La Selva Biological Station. Though they offered little in the way of employment in the area (Butterfield, 1994), they were the beginning of an industry on the rise. During this period, Costa Rica at the national level benefited from a boom in tourism in part due to the country's national park system, its reputation as a peaceful nation and President Oscar Arias' winning of the Nobel peace prize in 1987, and to the global explosion of ecotourism (Honey, 2003).

1990-1995: Paradigm shift and institutional reorganization.

The economic benefits from environmental conservation were increasingly being compensated in debt for nature swaps, bioprospecting contracts, and ecotourism based (Lehmann, 1992; Rojas & Aylward, 2003). There was a growing recognition of the economic importance of conservation and a declining dependence on those industries that promoted deforestation (Kaimowitz & Segura, 1996). These trends were augmented with a series of international conferences including the Agenda 21 at the Rio Earth Summit in 1992, Convention on Climate Change, the Biodiversity Convention and the Central American Council for Forests and Protected Areas (Watson et al., 1998) which promoted sustainable development and the value of environmental services beyond what was protected within national parks (Rojas & Aylward, 2003). Beginning in the late 1980s tourism increased significantly and became the top national earner of foreign exchange by 1993 (Watson et al., 1998).

A new forestry law was required in 1990 when the Supreme Court of Costa Rica found the 1986 Forestry Law unconstitutional which initiated the 1990 Forestry Law which began the modern forest incentives era (Brockett & Gottfried, 2002, p. 21; Watson et al., 1998). In 1991, FONAFIFO (National Fund for Forest Financing) was created to distribute subsidies to the forestry sector. Two new incentive programs were initiated during this period. In 1994 the Certificate of Payment for Natural Forest Management (CAFMA) established credits for the development and implementation of forest management plans, and in 1995 the Certificate of Forest Protection (CPB) was developed as a subsidy to conserve forest on private lands.

Another important reorganization occurred in 1995 with the formation of the National System of Conservation Areas (SINAC) by combining the forestry department with the directorates of wildlife and the national parks. The intention was to consolidate the different agencies for efficiency and to distribute the offices to ten regions in the field to coordinate, democratize, and make the agencies more responsive to local needs and issues (Miranda, Porras, & Moreno, 2004). Costa Rica was an innovator in establishing the Office for Joint Implementation (OCIC) in July 1995 to be able to eventually sell credits in the carbon market as negotiated through the Kyoto Protocol. The process of agency consolidation and independent subsidy programs came to an end in the fall of 1995 when the Structural Adjustment Loan 3 required the elimination of subsidies, including forest subsidies. The current advances in environmental market opportunities and the recently developed payments for reforestation, management and protection combined with the need to eliminate forest subsidies culminated in Costa Rica’s Forestry Law of 1996 and their PES system (Rojas & Aylward, 2003).

1996-2002: Institutional strengthening and funding exploration.

The Forestry Law of 1996 instituted a number of changes including the establishment of a legal definition of forest, the prohibition of the conversion of natural forest to other uses on private and public land, and the creation of environmental service payment program (PES). PES is a public incentives system where the government raises funds, sets the payment levels and priorities, and then invites applications from landowners (Snider, Pattanayak, Sills, & Schuler, 2003, p. 20). Under the PES program four services are bundled together: watershed conservation, biodiversity habitat, carbon sequestration and aesthetic beauty (Pagiola, Bishop, & Landell-Mills, 2002). Two of the major changes to the previous subsidy system were the justification of payment for environmental services and a change in the funding mechanism from government subsidies to an earmarked gasoline tax following the polluter pay principal (Pagiola, Bishop, & Landell-Mills, 2002). FONAFIFO was incorporated into the scheme to distribute the funds from RECOPE (the government owned oil refinery), and the OCIC (Costa Rican Office for Joint Implementation - the organization designed to negotiate carbon sequestration contracts), and to investigate new funding sources (Rojas & Aylward, 2003). Further changes in the 1996 Forestry Law prohibited conversion of forest land to any other system (Snider, Pattanayak, Sills, & Schuler, 2003). Originally, one third of a tax on carbon fuels was earmarked to be used to fund the PES as part of a "polluter pays" principle. There were issues with the Ministry of Hacienda and the total amount of this payment was never paid (Camacho Soto, Segura Bonilla, Reyes Garjens, & Miranda Quiros, 2002), however, in 2001 the issue was resolved through political renegotiation and reduction of the amount dedicated to the PES program.

Within the study region, a number of alternative sources of funding have been found though negotiated contracts with hydroelectric (flow-over and dams) projects and a brewery, who contribute payment for PES programs within their watershed. Several of these agreements have been negotiated through the initiative of the NGO FUNDECOR (Foundation for the Development of the Central Volcanic Mountain Range). Additionally, Cost Rica initiated the Ecomarkets project in 2001 which included a grant and loan from GEF (Global Environmental Fund) and World Bank ($8 and $32 million respectively) to specifically target funding within the Mesoamerican Biological Corridor for protection (Pagiola, Bishop, & Landell-Mills, 2002). Additional funds for the region to support carbon sequestration have come from Germany through the KfW (Ortiz Malavasi, 2003). The PES program has had target areas that have focused on the study area through a focus on poorer provinces and corridor areas linking national parks (Ortiz Malavasi, 2003).

Programmatically, PES payments for sustainable forest management were suspended in 2001 due to arguments from environmentalists that opposed sustainable management in primary forests (Ortiz Malavasi, 2003; Watson et al., 1998). This decision significantly affected the study region as the majority of management projects occurred there (Camacho Soto, Segura Bonilla, Reyes Garjens, & Miranda Quiros, 2002). The forest management program was one of the institutional strengths of local organizations such as CODEFORSA and FUNDECOR, regional organizations that have greatly assisted in the development of PES (Arce Benavides & Barrantes Rodriguez, 2004). FUNDECOR, which began in 1991, has been a catalyst for developing innovative funding opportunities for the PES while simultaneously administering contracts, providing technical advice, and working with small landholders (Miranda, Porras, & Moreno, 2004).

Several programmatic issues such as transaction costs and land titling that initially plagued small-scale landowner access to the program have been resolved (Pagiola, Arcenas, & Platais, 2005). A significant barrier for entry to the PES contracts of landholders with small farms is transaction costs and scales of economy for all parties involved (Zbinden & Lee, 2005). A system of 'global contracts' was developed where a number of small farmers can join the PES program collectively by working through a local organization, in part alleviating this problem (Pagiola, Arcenas, & Platais, 2005). Locally, the NGOs CODEFORSA and FUNDECOR have provided global contracts. A similar factor affecting landowners with small farms in the study region was that relatively expensive and bureaucratically prohibitive land titles were required to be able to receive payments from the governments; an issue resolved programmatically in 2002 (Ortiz Malavasi, 2003; Pagiola, Arcenas, & Platais, 2005). Finally, a significant development that affected the study region was a conflict between IDA and the PES program. IDA argued that the lands were given to recipients for agricultural use and should not be able to receive payments to keep it in forest as they would be receiving double benefits (Camacho Soto, Segura Bonilla, Reyes Garjens, & Miranda Quiros, 2002). This was negotiated to allow IDA farmers to enter Global contracts (Ortiz Malavasi, 2003).

Results from Expert Interview Data Analysis

Analysis of data from the expert interviews was guided using the social systems from the SEStM as the initial coding categories (Figure 4). This gave a regional but grounded perspective on the key social systems that influenced land use decisions in the case study landscape. All the major land uses throughout the region including pasture (for beef, dairy, dual purpose, breeding), perennial crops (heart of palm, ornamentals, banana) and annual crops (pineapple, yucca, sugarcane) were examined in terms of the six social system components in the model (economics and technology, politics, infrastructure, demographics, culture, and nature) (Figure 4). The remainder of this section focuses on how these components interact during landowner decision making for the spectrum of existing land uses. The purpose is to begin to understand how these influences push and pull landowners toward one land use or another. Highlights of the social system components involved in land use decisions in the region are presented below to demonstrate how the model can be used to understand the agents' context or 'terrain'. The three land uses selected as examples capture the range of major influences across the region from early settlement to more recent developments; forest, pasture and pineapple.

Natural Forest

Analysis including coding and display of data regarding natural forest revealed multiple social systems involved in the conservation of forest in its predominantly natural state. While most of the land in the region was originally forest, the majority of it was reported to have been selectively harvested since colonization began in the 1950s, or highgraded for the most profitable species. The analysis identified three key social systems involved in the retention of the remaining forest; government policy (politics), economics, and institutions.

Legal restrictions in the form of command and control efforts and the more recent environmental service payment (PES) programs were identified to be key elements of forest retention. The long standing protected status of riparian forest on the banks of rivers and around springs has resulted in effective forest conservation. Another policy example is the linking of Braulio Carillo National Park with the La Selva Biological Station in 1986 which closed the frontier and open access to cheap land. The Forestry Law of 1996 with its legal restrictions on forest conversion and program for environmental service payments was also reported as being a key factor for forest protection. However, it was mentioned that the payments are very small for landowners with small forests; "it is a very small amount per hectare…but is profitable for large areas of forest such as 30 and above, but forest areas of 8 or 10 hectares there will be too much paperwork to make it worth their while" (*Interview 1*). Therefore, while the legal restrictions are reported to influence all landowners, those with larger patches of forest were thought to be more interested in the PES due to profitability.

Analysis showed that private reserves for ecotourism were also key factors for forest conservation with a number of them identified in the region such as Rara Avis, Selva Tica, and Laguna del Largato Lodge. Study participants reported that these endeavors often were driven by economic and conservation interests of the owners and financial capital flowed into the area from outside the region since the reserves were often owned by foreigners. Data revealed that generally across the region there were high expectations beginning in the early

1990s about how tourism could contribute to the local economy but these haven't yet been realized: "the people believe that there will be a boom in tourism and all of the world will eat from it" (*Interview 4*), but that "the small farmer and their families haven't been able to take advantage of these economic benefits" (*Interview 5*).

Institutions as a component of the social system were seen to be both critical for conservation and, contrarily, as proponents of deforestation. Both FUNDECOR (Foundation for the Development of the Central Volcanic Mountain Range) and CODEFORSA (Forest Development Commission of San Carlos) were identified as key agencies responsible for promoting forest stewardship and for facilitating the PES. The 1996 Forestry Law was also seen to contribute to potential regeneration of forest by giving a legal definition to forest; "a silvacultural definition about how many trees of a certain diameter exist per hectare" allowing for greater oversight (*Interview 3*). Institutional cooperation was cited with ICE (Costa Rican Institute of Electricity) as another way of promoting forest conservation and working with the NGO FUNDECOR and hydroelectric companies worked collaboratively to raise funds for the PES program. However, institutional competition between conservation organizations and IDA (Institute for Agricultural Development) was also identified. There are large amounts of land under the colonization and redistribution projects administered by IDA which are often given to landowners specifically for agricultural development. Conservation of forest was seen to be outside of IDA's mission. The final key institution mentioned was MINAE (Ministry of Environment and Energy). Data revealed that MINAE was unable to enforce the legal restrictions on forest conversion because they had too few workers for such a large area.

Pasture

The primary land use in the region is pasture. There were four types of cattle production identified including beef cattle, dairy, cattle breeding and dual purpose. The first two are outlined below.

The key political factor involved in the establishment of early pasture in the region was reported to be land titling laws. These laws stated that a landowner had to demonstrate use to obtain title to the land and to protect it from squatters. The most effective way to demonstrate use was to clear the forest land and put in cattle. This factor combined with the adaptability of cattle to be produced under a variety of conditions was reported to have facilitated their spread. Cattle were reportedly able to be used as a functional production system about anywhere in the region. The analysis showed that cattle are generally raised extensively and for beef production and need very little care and low labor. One expert described this situation as, "the cattle here are extensively raised, that said, nothing more than put the animals in the field and after a number of months go get them and take them to market" (*Interview 1*). This feature facilitated the large absentee land ownership in the region by professionals and city dwellers who were not interested in production systems that necessitated daily attention. Also, over time an infrastructure developed around cattle production in the form of organizations and government agencies offering technical assistance (e.g. pasture, breeding, health) and increased marketing opportunities with the development of subastas (auction houses) throughout the region where previously ranchers had to go to the central valley to market their cattle. Furthermore, many of the migrants to the region knew how to manage cattle because they were from Guanacaste and San Carlos provinces and parts of Nicaragua where cattle ranching was part of their culture.

Another key element of the social system involved with the spread of cattle in the region was economics. Credit was easy to obtain and was offered at very low rates during earlier periods (1960s -1970s). Cattle could also be used as collateral for loans which was useful because if there was a bad year the bank took the cattle, but not the farm. Credit was reported to currently be much harder to obtain for cattle ranching. While marketing is easy, and cattle can be held until small fluctuations in prices pass, larger drops in the market like in the early 1990s were reported to have negatively influenced the decision to work with cattle.

Dairy production decisions were reported to involve slightly different factors. The two key factors identified regarding the production of milk in the region were natural setting, labor and economics. The natural setting of a cooler climate facilitated the production system for the breed of cattle used. Therefore, dairy farms were usually found in the foothills and on the mountainside of the central volcanic range. Because these lands tended to be much more expensive it was necessary for dairy farming to be more intensively managed than beef cattle.

Study participants identified financial capital for investment, a key export company for marketing, and national economic policy as factors of the economic component of the social system. A large investment in farm equipment is required for dairy production including equipment and stable for milking and milk tanks. Additionally, farm infrastructure including divided pastures for rotation and road access were required. This production system is much more intensive and requires daily labor generally milking twice a day. While a cultural tradition of milk production was identified as an influence, the current systems are much more technical. The main market for dairy is Dos Pinos, a company located in San Carlos but who sells milk products throughout Central America. Tariffs (national economic policy) protecting the milk industry in Costa Rica have allowed Dos Pinos to offer a number of services and pay high amounts to ensure quality. Dos Pinos, as an institution, provides technical and veterinary assistance, has stores throughout the region with equipment and inputs, and provides a secure and lucrative market through membership in it cooperative. While this assistance was reported to be very beneficial, expert participants were concerned about the quota system of membership with Dos Pinos which excludes other producers from entering the dairy market.

For all cattle production systems, there were a number of other factors that were involved that were described as being influential including infrastructure, politics and culture. Those geographic areas with less access to services like schools and electricity were reported as some of the first to be abandoned with price drops in the beef markets. As a related factor, the Contra war was identified as an early (late 70s through mid 1980s) factor for migration away from the frontier with Nicaragua with reports of insecurity and robberies of cattle and equipment.

On the other hand, a cultural affinity for having a cattle ranch was identified as a continued reason for maintaining cattle on a farm, even when it is not a comparatively productive land use. "Yes, because your father and grandfather had cattle and to be a rancher is important, to walk around with your hat….it is a way of life" (*Interview 5*). This cultural affinity and knowledge is further intensified by Nicaraguans immigrants who act as caretakers or laborers on many farms and are knowledgeable about working with cattle.

Due to combinations of the reasons cited above, using cattle as a production system began earlier and has evolved to become part of the structure of the economic, institutional, political and cultural components of the social system. However, trends in 2004 document the buy out of many of the large cattle farms in the region by national and international companies and their conversion to pineapple for export.

Pineapple

Key factors involved in the production of pineapple are primarily economic but with cultural, demographic, and institutional components of the social system also having some impact. Costa Rica has had long history of producing pineapple (20-25 years) but with a limited extent of land under cultivation. Since the late 1990s there has been an explosion of pineapple in the study area with two major types being produced. The Monte Lirio variety is more acidic and is and has been used for a longer period by local companies for making fruit juice. The other variety is the MR2 which is a large yellow sweet pineapple used for export. There has been an explosion of this second variety across the region reportedly due to a drop in international production and a rise in prices. Pineapple that is used for export needs well drained soils and relatively flat land because it is highly mechanized. There are a large number of both national and international companies involved with the national companies collaborate with the international companies for exportation. In particular, Dole and Chiquita were reported to be involved in exportation using the infrastructure and shipping from their banana industries. Regional companies have begun buying up large farms throughout much of the region with a specific focus on the area around Pital, Rio Cuarto and La Virgen where the land tends to be more level and the roads well developed. Due to the explosion of pineapple across the region a number of experts have become concerned about overproduction. However, since it is an annual crop it is easily converted to other land uses, it was not a great concern. As of 2003, pineapple had become the number two exportation crop from Costa Rica earning more than coffee.

Pineapple companies often have their own packing plant right on the plantation and it is a labor intensive process. A large part of the employees are reportedly Nicaraguan though many Costa Ricans with smaller farms are working the plantations as well. The overwhelming majority of the production is from large producers, but with a large number of small landholders also producing pineapple. Small land holders primarily grow the older variety of pineapple for local juice production as obtaining the more expensive MR2 seeds can be expensive and criteria to meet exportation guidelines can be complicated.

A number of institutions have been organized to help landowners with small farms, and government agencies and banks are involved offering credit and technical assistance to help integrate landholders with small farms into the export market. However, it was noted that the boom in pineapple is very much market driven and managed by large and medium companies instead of through government incentives. This demonstrates how a component of the social system takes on very different roles and functions.

Land Use Transitions

Land use transition patterns identified by expert interviews were used to identify factors (biophysical or social) that may constrain or enable the transition of one land use to another (Figure 6). The tree style graphic started with forest, which essentially covered the region prior to colonization. Phases of land use transitions were sequentially ordered by participants. The ordering did not specifically relate to a time period because the changes were part of an ongoing process. The first transitions from forest in the region were to pasture and subsistence farms by frontier colonizers. Colonizers were reported to clear land for pasture, and not specifically to harvest the timber. There was also a transition directly from forest to banana plantations. This was by large international companies and in response to global markets and national incentives. Bananas were reported to be a terminal land use with few transitions back to pasture as banana companies consolidated their lands. While subsistence agriculture and staple crops of beans and corn and rice were some of the original land uses (see Figure 6), they had reportedly largely disappeared on any significant scale from the landscape due to the elimination of price supports and crop diseases. Both annual crops such as pineapple and yucca and perennials like the heart of palm and ornamentals were reported to have replaced some pasture lands. Pasture was also reported as being converted to banana plantations or as being abandoned or fallowed. Pasture is the primary land use that most all other land uses in the region transition to and/or from. Forest was reported to primarily transition to pasture or bananas and not directly to other land uses. Once lands were in perennial crops, however, transition was physically much more difficult and transitioned primarily with severe reductions in that crop (dashed lines in Figure 6). This was mentioned with regard to heart of palm and ornamental crops. Though these crops had few biophysical requirements (they did well anywhere) they tended to be spatially correlated due to marketing and a Costa Rican aptitude for “watching your neighbor” and learning from their successes and failures. Annual crops were generally reported not to shift except to another annual crop. Results from the data analysis suggest this is because these crops were located on lands that were more productive and therefore more likely to maintain crops which produce higher returns to the land. Pasture continued to transition to most other land uses including reforestation. Reforestation also was derived from some crop land and reportedly from areas in forest recovery that had formerly been pasture. A small amount of recovery was thought to make it to forest, though a legal restriction on harvesting secondary forest was identified as an influence making that less likely to happen. Forest recovery was reported to be a temporary use and shifting to other productions systems was common.

The land use transition data suggest that some uses are more fluid than others because of the biophysical 'qualities' of the land and/or features of the crops themselves. The land uses that don't transition easily to other crops were banana (due to its high investment in associated drainage systems and infrastructure and large corporate backing), heart of palm and ornamentals (due to difficulties in clearing after planting) and reforestation (due to its long term harvest regimes). Pineapple is currently experiencing explosive growth and yields much higher income than extensive cattle ranching. The high value would indicate that it would be more permanent, but the annual nature of planting and concerns reported about over-production may make it a fairly fluid land use. The most fluid land uses were pasture as the dominant land use in the region and forest recovery which was much smaller but commonly transitioned.

Comparing Contextual Analyses: Systemic and Narrative Approaches

Both expert interview and document sources of data provided insights to land use change in the region. The data sources were triangulated between and within sources. The two types of sources revealed slightly different emphases. All the main social factors identified in the contextual analysis of the expert interview data were corroborated in the analysis of the document data. However, the analysis of document sources offered a much more detailed analysis of the interactions of the social systems and the evolution of the influential factors.

The contextual analysis of the interview data identified the key factors involved in the decision to have pasture for cattle as influenced by land titling, credit availability, market prices, the Contra war and the natural attributes of cattle. There were a variety of ways cattle could be managed including extensively for beef, intensively for dairy, smallholder dual purpose use and for breeding and each with their own unique role. There was an emphasis on the adaptability of cattle and how that production system was widely applicable across the region. In particular, the low labor aspect of production was reported to be conducive to absentee land ownership. This production factor facilitated the ability of speculators from other regions to be able to maintain land in their possession against squatters. From the local perspective, market prices were noted to vary, but the opportunity to sell remained consistent and marketing was easy as the system was understood and widely available. Pasture was also identified as a very fluid land use indicating that if other cropping opportunities arise such as pineapple, they are easy to implement. Additional insights from the analyses of expert interviews were on the implications of the Contra war on landowner security and subsequent out-migration from the border region.

The systems perspective (Lambin, Geist, & Lepers, 2003) from the document analysis insured a much wider perspective was examined and allowed the linkage between the social factors influencing cattle production to emerge. For example, the governments desire to earn foreign exchange and the support and advice of international institutions resulted in cheap and easy access to credit to develop the cattle industry during the colonization period. This is an example of linkages that are unlikely to be identified at the local level, but are critical for understanding land use change. Easy credit and tax breaks were first offered for cattle and bananas during the colonization period, and then later for non-traditional crops like heart of palm and pineapple during the 1980s. The numerous incentives were identified as key factors for transitioning from pasture to the non-traditional crops. Both sources of data identified speculation as a factor of land use change in the region, but the systemic approach was able to associate speculation with high interest rates which were influenced by the economic crisis of the early 1980s.

In the analysis of the text from the expert interviews three key influences of forest protection in the region resulted including legal restrictions and incentives, economic benefits from ecotourism, and institutions. Specific nuances of these factors such as the local expectations for economic development from ecotourism are difficult to identify at the national or systemic level. Additionally, insights about inter-institutional collaboration and confrontation and/or ineffectiveness are important at the local level where the implementation of the national policies is carried out.

Systems focused data analysis enabled the tracing of the origins of the different forestry laws and policies that are implemented at the local level. By understanding the context of world conferences and treaties that were attended and signed by the Costa Rican government it is possible to see the global influences on the local landscape. In particular, world values for biodiversity and carbon sequestration have been used to justify payments from the World Bank to local landholders for forest maintenance. Additionally, international conservation organizations and other countries throughout Central America have accepted the Mesoamerican Biological Corridor as target areas for sustainable development.

A benefit of using the systems perspective (Lambin, Geist, & Lepers, 2003) is that it guided or provided a structure for exploring synergistic effects of different land uses. In other words, there are social factors that are involved in the production of one land use that were described as having impacts on other land uses in the region. For example, the banana company that established plantations in the late 1960s opened the area to colonization with new infrastructure and a demand for labor drawing people to the region. The roads facilitated access to an otherwise closed area and created opportunities for colonists to enter the region and establish pastures. However, establishing context in time is critical as well. These same opportunities for wage labor in bananas in the region in the early 1990s (and more currently pineapple) have had the effect of drawing landowners from the frontier region to more urban corridors. In the process they sometimes abandon or reforest their pasture. Another temporal shift has occurred with regard to absentee landholders. In the early colonization period, speculators were investing in land to avoid high interest rates and as a financial investment by making improvements (clearing forest), establishing title, and then selling the land. Landowner attitudes, at the time, considered forest as an impediment to development. More recently, however, many absentee landholders of large forest are enrolled in the PES program or have established ecotourism operations or are otherwise actively maintaining their forest. Attitudes regarding the value of forest have changed among landholders in the region.

Additionally, historical legacies of past land uses have structured the current context. Identification of land use transitions helped identify physical restrictions on land use change and indicated what transitions may be blocked due to other factors. For example, the historical legacy of cattle production due in part to local knowledge of how to manage cattle, land tenure policies, and adaptability of cattle production have led to significant physical infrastructure including subastas (cattle auction houses) and social structures such as the desire to have a cattle farm. Similarly, the physical and social structures developed long ago for banana production (from roads to ports to marketing to local knowledge producing pineapple) facilitated entry into widespread pineapple production. Land colonization projects and Nicaraguan immigration led to cheap labor for industrial production. And though road building associated with the support for the Contras extended the road network, security issues related to the war led to out-migration from the border region. While the contextual analysis of interview data afforded us insights into the major trends in the region from a local perspective, elaboration on how those trends evolved and were connected was provided in the systems perspective as identified using documents as a source of data.

Conclusion and Implications

This paper began with the presentation of a model that frames human-environment interactions as recursively structured systems that include social and biophysical systems. The conceptualization of land use and land cover change as both a medium and outcome of social and ecological structures recursively organized was used to provide a link between the systems. The social and ecological systems were visualized as separate but mirrored systems to illustrate both the similar and different mechanisms by which they operate. This model was then applied to analyze the historical context where Costa Rica's forestry laws and PES program dynamically competed with and/or reinforced other social systems to impact land use decisions within the San Juan – La Selva portion of the Mesoamerican Biological Corridor. Three main conclusions or implications for the model and the case are presented: 1) the model was successful for identifying the key social systems influencing landowners land use decisions for this case; 2) some refinements to the model at the empirical level of analysis have been identified; and 3) implications for the future use of the model are given.

Successful Identification of Key Social Systems

The contextual analysis of documents provided a detailed account of the components of the social system that have influenced land use in the region. Through the development of a historical timeline, documents provided an image of the dynamic and interacting social systems (Lambin, Geist, & Lepers, 2003). Interviews with local experts provided additional insight or a grounded/narrative to how these systems influenced landowner decisions. We found that the variables identified in the model from the land use change meta-analysis on tropical deforestation did serve as valuable indicators of the important social factors driving land use change in the region. Analysis of data from both sources of data and methods (documents analysis and expert interviews) provided converging lines of evidence corroborating the history of land use change over the study period as presented in this chapter. Each data source provided supplemental information to the other, but neither identified additional social systems that would have been missed.

Model Refinements at the Empirical Level

However, while applying the social system variables to this model a few adjustments needed to be made. The original adjustment of the model to include infrastructure at the social system or underlying structural level of analysis was determined to be appropriate as infrastructure was commonly referenced in its role for enabling or constraining landowner decisions. For example, access to basic resources such as electricity and schools was reportedly related to absentee land ownership and road access to the capital and important factor in the decision to maintain a ranch in the region as a second home. Additionally, the decision to include natural factors as a key social system or structure facilitated discussion on the key environmental factors important to land use decisions. For example, natural factors were critical for the site specific production of dairy cattle and crops. However, the adaptive ability of cattle (their natural attributes) to be used as a production system almost anywhere in the landscape was suitable to speculators and to others wishing to show use of the land without providing local labor were also key natural factors impacting land use decisions. In other words, natural qualities of the land, the product (cattle or crops), and the production system were combined with the landowner's livelihood strategy to determine which aspects of the natural factor was critical.

An adjustment to the social system variables that could be included in future analyses was the use of technology as a primary social system for analysis. In this study technology was mentioned primarily as a modifier of other systems and largely in combination with or as a subset of economic decisions. For example, the technology used for pineapple production was seen to be associated with market prices and production systems and not as a separate entity. We also found that it was useful to analyze a range of land uses in the region when conducting an agent context analysis. This is because we found that the key social components influences differ across land uses, and they are often synergistic effect across land uses. For example, policies favoring cattle influenced forest cover and policies favoring pineapple influenced cattle markets. Therefore, it is suggested here that analyses of land use change identify drivers for all land uses in the region instead of focusing primarily on those that change one particular land use (e.g. a focus solely on the factors influencing forest cover).

Finally, due to the fact that this model includes actors, we found it useful to refer to the social factors as influences on land use decisions instead of 'drivers' or 'causes' which reflects too direct a structural influence for this model. It also recognizes that actors can be differentially situated in terms of capabilities and motivations and what may be a 'cause' for one landowner may be a constraint on another.

Future Uses of the Model

This model incorporates the concepts that others have identified as critical for understanding linked human-environmental systems. Lambin and others (2003) suggest that agent-based systems and narrative perspectives all need to be combined to effectively understand land use change. By explicitly outlining the process of structuration, this model represents one way to overcome the proximate/underlying divide "so as to allow for more complex interplays of human agency and structure in processes of land use change" (Geist & Lambin, 2001, p. 99). Additionally, it is suggested that this model can incorporate spatial heterogeneity in both social and ecological systems through the incorporation on hierarchical patch dynamics, which others have identified as critical for linked human environmental systems (Pickett et al., 1997; Wu & Loucks, 1995). Furthermore, that this model meets the requisites outlined in Grove (1997) for understanding social and ecological systems (Grove & Burch, 1997, p. 264) and goes further to present a framework for unacknowledged conditions and unintended consequences for both social and of ecological systems.

In sum, it is suggested here that both the model and its application to the study of Costa Rica's PES program were robust. Finally, it is hoped that the SEStM model will be the subject of further elaboration in both design and application.

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Tables

Table 1: Structuration with integrated empirical research frameworks.
Integrating structuration theory (Giddens, 1984; Stones, 2005) with empirical models of land use change (Geist & Lambin, 2001) and landowner decision making (DFID, 2003)

Structuration Theory		**Variables for empirical study**
Structure	Schemas/Rules	**Underlying causes** • Economic • Political • Technological
	Resources	• Infrastructure • Demographic • Cultural • Natural
	Unacknowledged conditions and Unintended consequences	Unacknowledged conditions and Unintended consequences
Agency/power	Allocative	**Livelihood assets** • Financial • Physical • Natural
	Authoritative	• Human • Social

Table 2: Sources of evidence and data collection methods.

Source of Evidence	Data Collection Methods	Sampling	Purpose
Expert: NGO/Agency Field Staff (18 expert interviews)	Small group semi-structured interviews (individual agency)	Snowball sampling: Politically important/ expert, knowledgeable	Explore land uses, social systems, and their possible connections. Explore history of area. Identify farm types. Identify land use transitions.
Expert: Member check (4 expert interviews)	Multiple agency group presentation with feedback	Representatives who participated in individual agency interviews; representative from same agencies but from different locations	To check conclusions and interpretations made by the researcher.
Document analysis (>100 documents)	Academic journals and institutional reports	Census relevant material	Background and review of social forces identified.

Figures

Figure 1: Social structuration: Quadripartite nature of structuration.

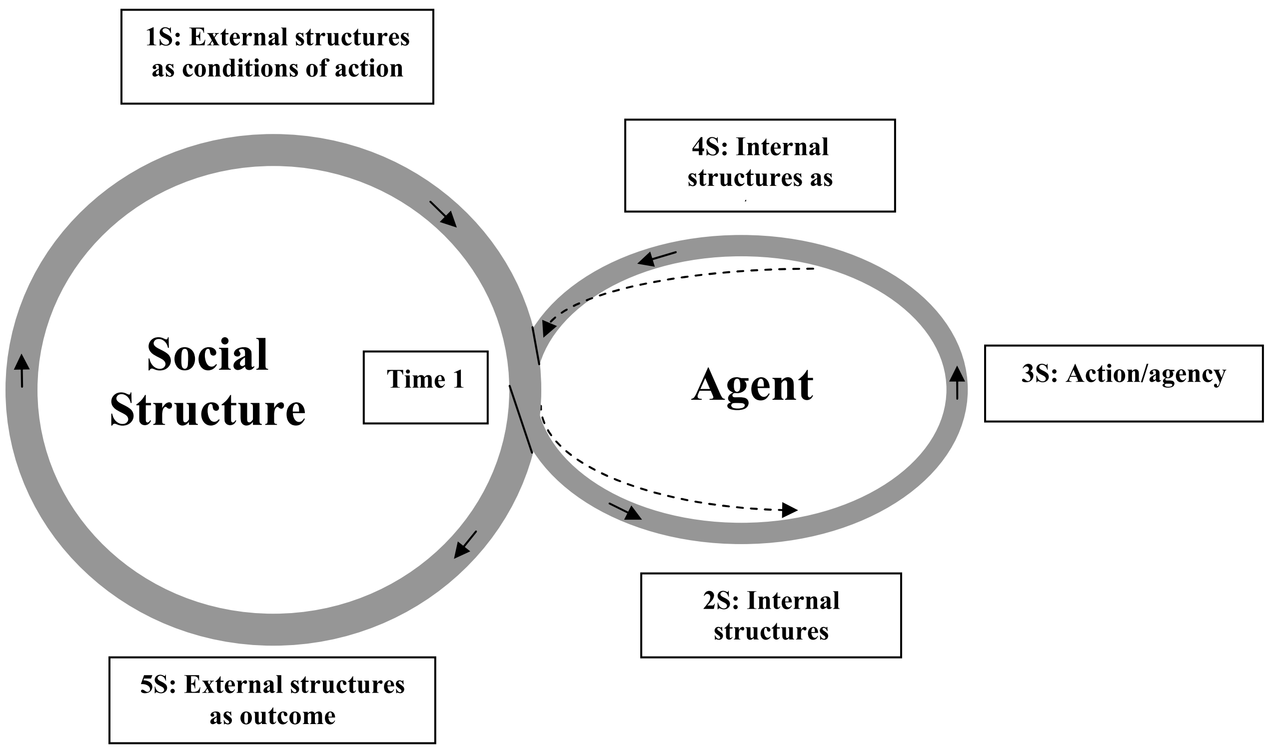


Figure 2: Ecological structuration: Hierarchical patch dynamics.

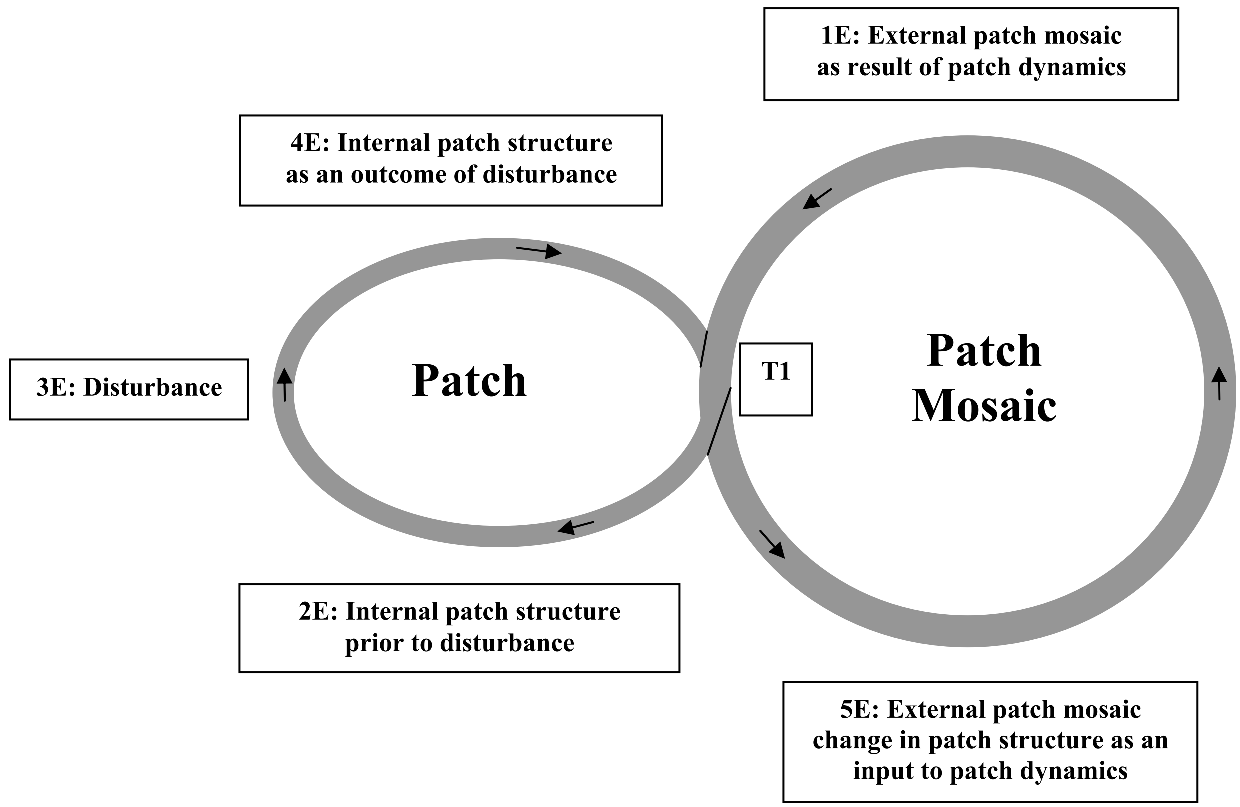


Figure 3: Social Ecological Structuration Model (SEStM).

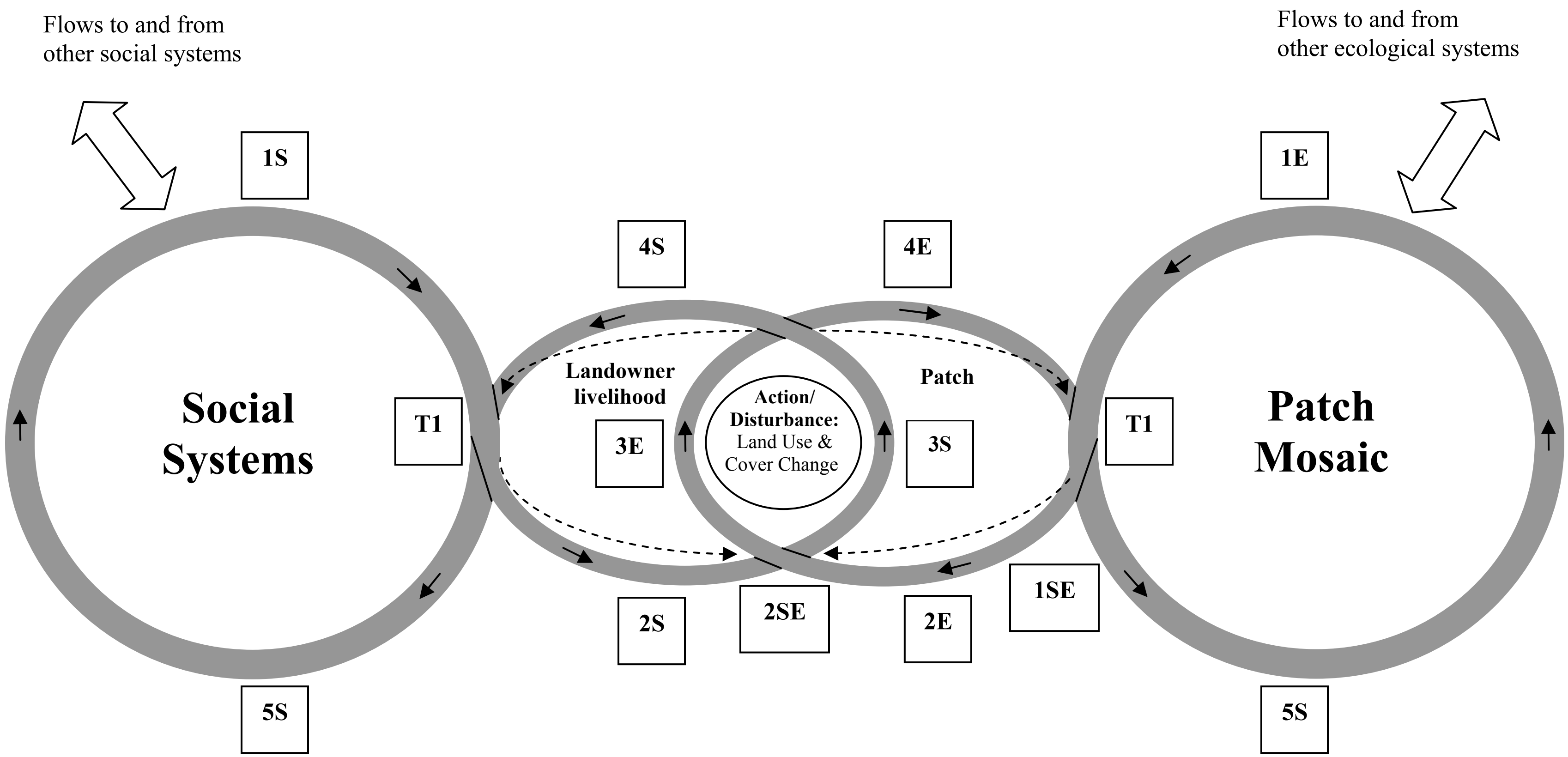


Figure 4: Integrated structuration model with research variables.

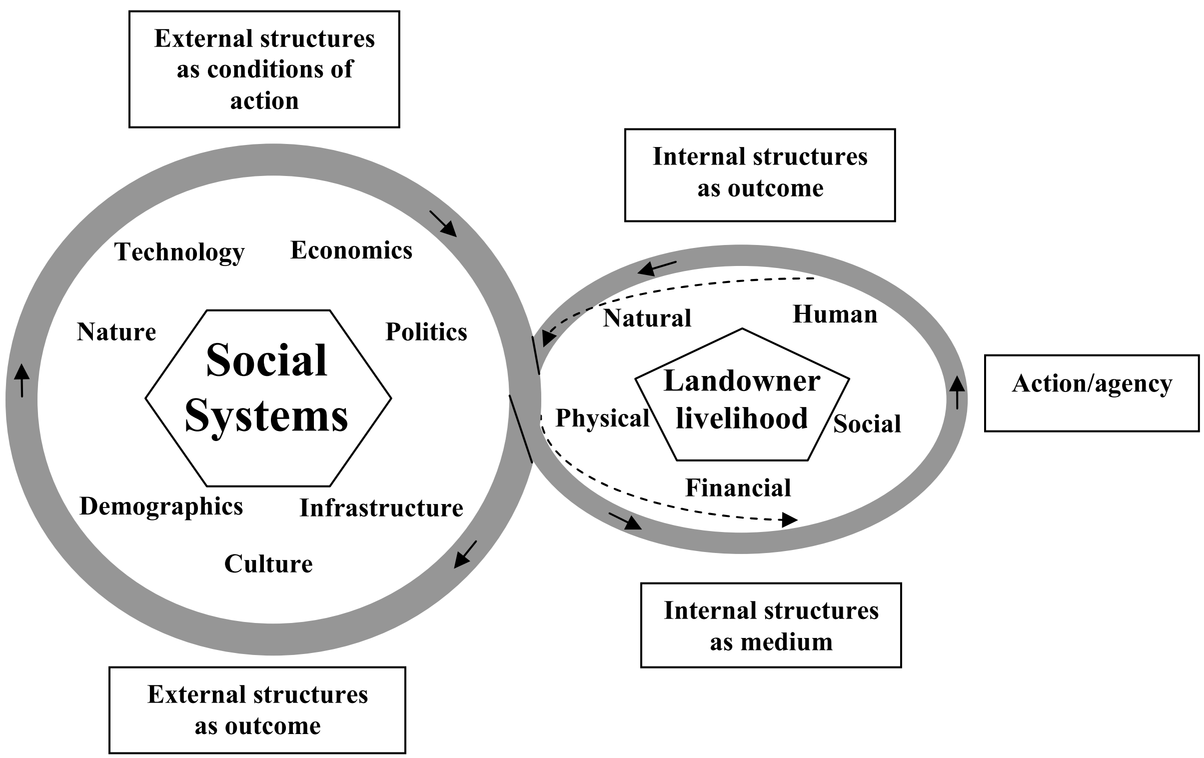


Figure 5: Historical timeline for agent context analysis.

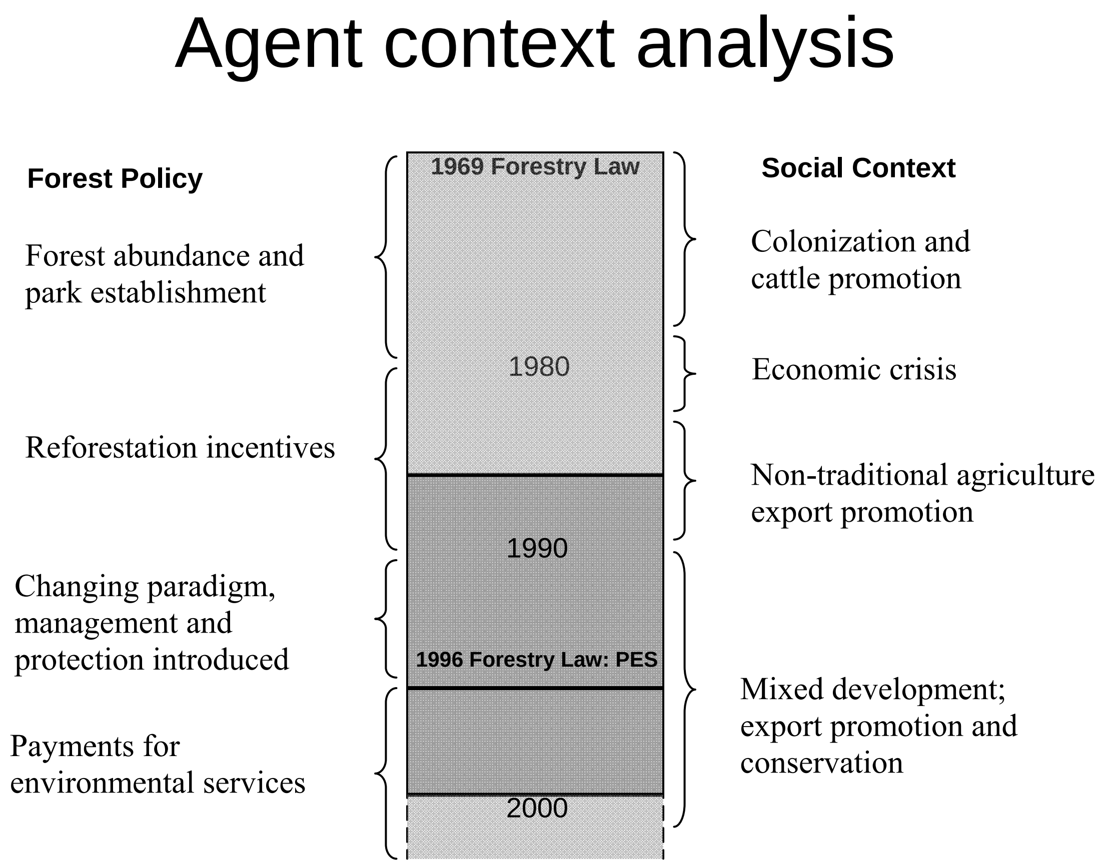
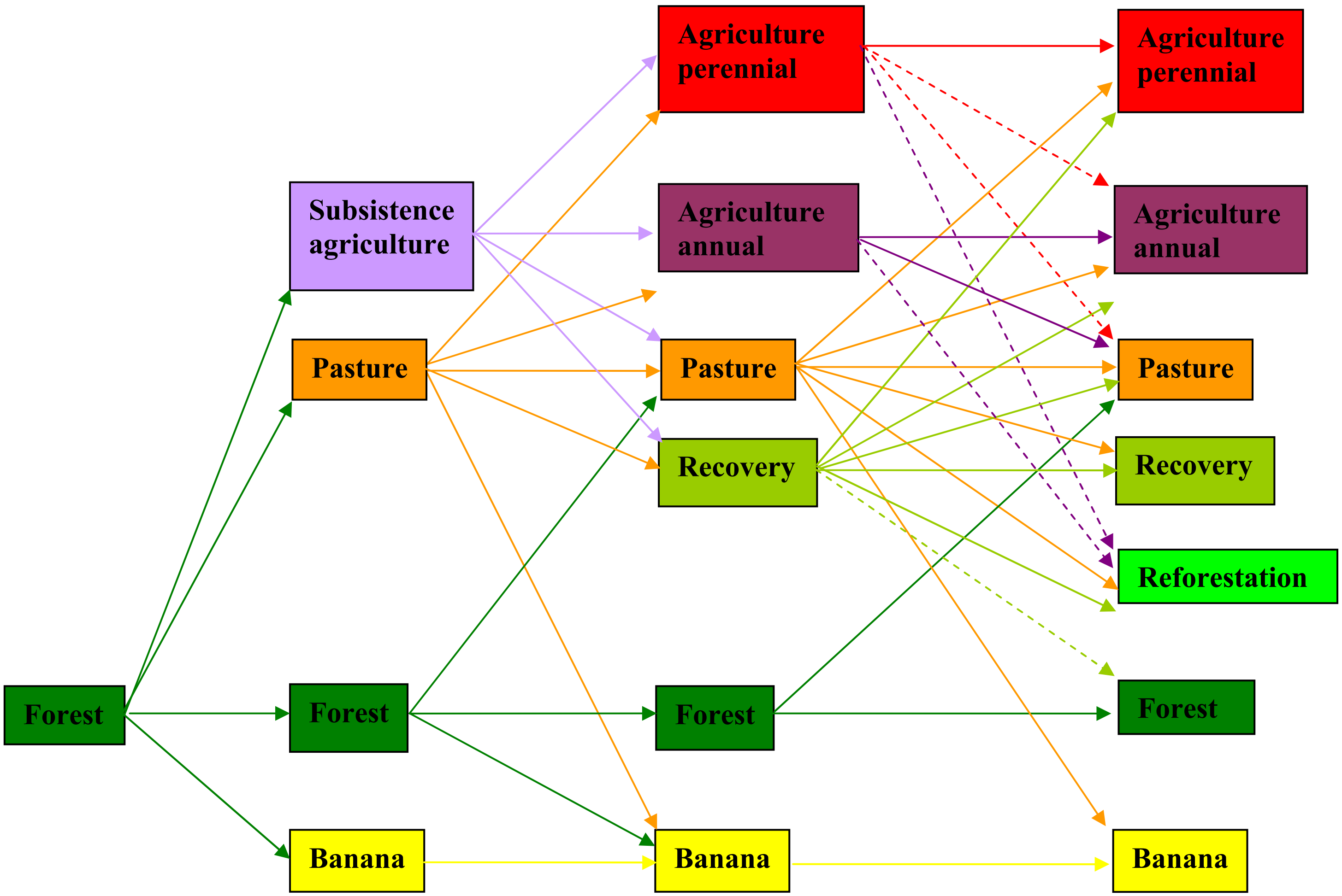


Figure 6: Progress of land cover transition by land use type



CHAPTER 3

Additionality, Baselines, Leakage and Equity:

An Analysis of Costa Rica's Program of Payments for Environmental Services

Abstract

A new era of programs are using a direct approach to conservation by paying landowners directly for the environmental services their lands provide. Several issues critical to understanding the efficiency of payments for environmental services (PES) include additionality, baseline conditions, leakage, and equity. These topics have been relatively unexplored with empirical data. This study examined each of these issues by comparing forest cover and land use change decisions between participants in Costa Rica's PES program with non-participants (N=207). Participants and non-participants were randomly sampled within the San Juan-La Selva portion of the Mesoamerican Biological Corridor. This region was selected because of the high concentration of PES participants and relatively recent frontier status. Results indicate that PES for forest protection has partially helped to reduce the deforestation rate and that incentives for reforestation has been relatively effective at increasing forest cover. Both protection and reforestation can be seen to contribute to rural development. However, the development impact is due to the expenditure of the PES to hire local labor and not through the direct payments as they tend to go to relatively wealthier landowners. Leakage from the PES was not observed between farms, but is likely occurring with the removal of remnant trees from pastures. Recommendations are offered on how to adjust the program to increase its ecological and economic efficiency.

Introduction

Ecosystems provide a variety of essential services critical to the well being of all species. These services range form the provision of clean air and water to habitat for biodiversity (Daily, 1997; de Groot, Wilson, & Boumans, 2002). The ability of ecosystems to provide these services is in decline at the same time as our need for them grows (Millennium Ecosystem Assessment, 2003). To address these critical issues, calls for a new conservation paradigm have emerged that focuses on sustaining ecosystem services (Bawa, Seidler, & Raven, 2004; Berkes, 2004). Within this paradigm, one approach advocates using economic incentives by paying landowners directly for the environmental services that their land provides (Pagiola, Bishop, & Landell-Mills, 2002). The motivation to integrate the economic values of conservation with the decision making of local farmers through incentives has been stimulated by: 1) the need for conservation outside of park boundaries (McNeely & Scherr, 2003); 2) longstanding economic market failures for providing public goods like environmental services, (Landell-Mills & Prorras, 2002); 3) perceived shortcomings of integrated conservation and development programs (Brandon, Redford, & Sanderson, 1998; Brechin, Wilshusen, Fortwangler, & West, 2002); and 4) the call for efficient use of conservation funding (Ferraro & Kiss, 2002).

Payments for environmental services (PES) are arguably one of the most promising conservation innovations in recent times (Wunder, 2005). PES are based on the economic argument that ecosystem services are public goods that provide positive externalities to society at large (Baumol and Oats, 1998). While a multitude of environmental services have emerged (de Groot, Wilson, & Boumans, 2002), watershed protection, carbon sequestration, biodiversity habitat, and aesthetic beauty are the basis for the majority of PES initiatives (Landell-Mills & Prorras, 2002). The approach assumes that these services will be undersupplied to the market unless those who provide the services are compensated (Pagiola, Arcenas, & Platais, 2005). PES offer the opportunity to attract much needed private sector funding and have a number of characteristics that improve upon or compliment other conservation initiatives such as command and control, regulatory, land acquisition and integrated conservation and development programs (Wunder, 2006).

PES schemes can be administered in a variety of ways, from private market transactions involving a negotiated price between environmental users and providers, to public schemes where the government acts as an intermediary between providers and the various user constituencies (Wunder, 2005). In all cases, there are a number of issues that must be considered when evaluating the efficiency of a PES program including: 1) additionality; 2) baseline conditions; 3) leakage; and 4) equity (Smith & Scherr, 2003; Wunder, 2005). The ability of PES to deliver in these areas forms the core of debates regarding these relatively incipient programs (Wunder, 2006), and is the focus of this research.

Efficiency Considerations

A central question regarding the efficiency of PES payments is whether the services provided through the payment program are additional to what might have been provided without the program (Smith & Scherr, 2003). This question has been extensively debated regarding forestry as a means for carbon sequestration under the Kyoto Protocol's Clean Development Mechanism (CDM) (Wunder, 2005). The concept is termed *additionality*, or the specific provision that the conservation of the environmental services are conditionally based on the payments (Subak, 2000; Wunder, 2006). To be able to quantify additionality however, it must first be known how the background or baseline conditions of forest retention and/or recovery are defined.

Baseline conditions of forest cover are the conditions that might have occurred without a PES program due to other direct and indirect factors (Sierra & Russman, 2005). This condition recognizes that other factors influence forest cover, including government agriculture incentives, land tenure policies, international markets, and cultural and demographic factors (Angelsen & Kaimowitz, 1999; Geist & Lambin, 2002; Lambin et al., 2001). A *declining baseline* would suggest that deforestation is projected to continue. A *static baseline* would indicated that the current and background conditions are likely to continue without change into the future. Finally, an *increasing baseline* suggests that some reforestation or forest recovery is likely to occur even in the absence of project activities. The increasing baseline has been described as a 'forest transition' (Mather & Needle, 1998; T. K. Rudel, Bates, & Machinguiashi, 2002) and follows a 'Kuznets curve' (For a discussion of the empirical backing of a Kuznets curve see D. I. Stern, 2004). These propositions suggest that as countries develop they are likely to retain or gain forest cover as the public begins to value environmental amenities higher and regulates land use accordingly. Identifying appropriate baseline conditions can be subjective, "adopting the wrong baseline can thus lower PES efficiency, or, in the worst case, waste all the money spent: if no de facto change in behavior is achieved, no additional environmental services will be provided" (Wunder, 2005, p. 9).

There are two main pathways for obtaining additional forest, reforestation and avoiding deforestation. Reforestation can occur either through natural forest recovery or through forest plantations. For this paper, *natural forest* refers to the original forest (previously thinned or untouched), *reforestation* will be used to denote forest plantations and *recovery* will be used to identify natural forest recovery. With an increasing baseline for reforestation, one would expect some reforestation to be occurring on its own through general market conditions without PES. In this case, if a landowner was already planning to establish a forest plantation based on market conditions, but enlisted in the PES program to receive the incentives, the services provided by that plantation should not be considered additional from the PES. If there was no background reforestation prior to the introduction of a PES incentive program, gains in this type of forest cover from an incentive program could be considered additional under a static baseline. A declining baseline for reforestation would indicate that reforestation has lost its competitive advantage and the amount of land in forest plots will likely decrease. In all cases, additionality can occur when reforestation is less profitable than other land uses and/or there are significant barriers to entry (Smith & Scherr, 2003).

The other means for obtaining additional environmental services is that of deforestation avoidance. It is argued that slowing deforestation could contribute to the provision of additional services in countries where forest loss is problematic (Wunder, 2005). In such cases, if a landowner's protection of their remaining forest is contingent on receiving PES, then avoided deforestation could be considered additional. However, if a landowner was already planning on maintaining a forest area due to slope, access, or soil conditions, those forests arguably should not be included as additional protection and not receive PES. Additionally, if a forest was maintained for aesthetic reasons or for profitable use for ecotourism, it is arguable that those forests also should not be considered additional under a PES scheme (Subak, 2000). Avoided deforestation is difficult to appraise is not viewed as a reliable form of avoided carbon emissions (Pagiola, Bishop, & Landell-Mills, 2002) and is not accepted as part of the CDM for 2008-20012 (Smith & Scherr, 2003).

Another issue related to additionality is *leakage*. Leakage results if the PES program were to provide for conservation in one area only to divert the environmental impacts elsewhere (Smith & Scherr, 2003). For example, leakage would occur if a PES program were to target one location for conservation of forest if there was a resulting shift of deforestation outside of the target area. Leakage can also occur within an individual farm. It would be considered leakage if reforestation in one area of natural forest on a farm leads to deforestation of another area of natural forest. Similarly, if protection of natural forest in one area leads to deforestation of other tree or forest resources on the farm such as riparian forest, live fences, remnant trees in pasture or live fences, these could be considered leakages. This type of leakage is important to consider as the environmental services afforded by these other tree resources can be substantial (Harvey & Haber, 1999; Pearce & Murato, 2004). Leakages would need to be subtracted from what could be considered *additional* gains from any PES project since they result in displacement instead of actual gains in environmental services.

A second area of interest regarding PES payments is related to *equity/development* goals (Wunder, 2006). PES have the potential to contribute to rural development and poverty alleviation (Grieg-Gran, Porras, & Wunder, 2005; Landell-Mills & Prorras, 2002; Pagiola, Arcenas, & Platais, 2005). This is an important consideration as remaining forests in tropical countries are often on the agricultural frontier and occupied by relatively poor landowners (Grieg-Gran, Porras, & Wunder, 2005). Development goals affiliated with PES programs are compatible with the clean development mechanism (CDM) of the Kyoto Protocol which states that CDM projects should help host countries achieve sustainable development (Smith & Scherr, 2003). The most direct way that PES can contribute to rural livelihoods is through the payment itself (Pagiola, Arcenas, & Platais, 2005). If the recipients of PES are poor, the direct payment contributes to rural development and poverty alleviation.

Poverty alleviation can also be assessed by identifying if the land use promoted by a PES program (reforestation or forest protection) increases employment (activity-enhancing), or limits employment opportunities (activity-reducing) (Wunder, 2006). Reforestation, for example, will likely have some positive employment benefits related to planting, maintenance, harvesting and milling. However, the employment benefits should be considered relative to the next most likely use of the land. If the next most likely use of the land is extensive cattle ranching, employment benefits of reforestation may be positive. However, dairy farming and crop production may well offer greater employment opportunities than reforestation.

Deforestation avoidance, or the protection of existing forest, could be considered to have negative employment impacts when compared to most other agriculture land uses. However, this is the case only if the land were actually going to be cleared and put to another use. If the land were to remain in forest without incentives, initiating a PES program may offer some employment benefits. Enlisting in a PES programs does provide employment for forest engineers and non-profit organizations in the region that develop forest management plans and monitor and enforce the plans (Miranda, Porras, & Moreno, 2003).

Further employment benefits depend on how and where participants spend the payment they have received. If participants spend their money hiring additional employees to work their farm, and they live and spend their payments in poor regions of the country, there are likely positive development impacts. A pilot project paying for environmental services of silvopastoral systems in Costa Rica and Nicaragua expects to provide both additional environmental services and increase employment as silvopastoral systems are activity enhancing compared to low density extensive cattle ranching (1 cow per ha) (Pagiola et al., 2004). However, to date, few empirical analyses have been conducted that examine the linkages of PES payments to improving the livelihoods of participants and the contribution to rural development (Landell-Mills & Prorras, 2002; Pagiola, Arcenas, & Platais, 2005; Sierra & Russman, 2005).

This research was designed to provide an empirical analysis of efficiency considerations for a PES program in one region of Costa Rica. The central research objectives were to identify the additionality and equity impacts of the PES through landowner surveys. General research questions included: 1) How has the 1996 Forestry Law and PES program influenced landowner decisions regarding forest cover?; 2) What are landowner motivations regarding forest cover on their farm?; and 3) What are the equity implications of the PES program? This study provides comparison of PES participant's and non-participant's land use choices with a particular focus on PES participation and on-farm tree management. Analysis of participants and their motivations to participate is critical for evaluating the efficiency of these programs for providing additional forest and equity/development (Ferraro & Pattanayak, 2006; Pagiola, Arcenas, & Platais, 2005; Thacher, Lee, & Schelhas, 1997; Zbinden & Lee, 2005).

Study Site

This research was conducted in the San Juan-La Selva portion (2,425 km^2) of the Mesoamerican Biological Corridor (MBC) in northeastern Costa Rica. The MBC is a multinational project designed to integrate the conservation of ecosystems and biodiversity with sustainable cultural, social, and economic development (Miller et al. 2001). The MBC is a network of core protected areas and buffer zones linked together by proposed corridors throughout Central America. Costa Rica has established this portion of the corridor as a priority area for targeting PES payments as one of the largest aggregations of remaining lowland forest connecting the National Parks of Costa Rica's central volcanic region with the Indio Maize protected area in southern Nicaragua.

Costa Rica has an international reputation for its extensive parks and protected areas system (Evans, 1999), but has historically had one of the highest deforestation rates in the world (de Camino, Segura, Arias, & Perez, 2000; Peuker, 1992; Sader & Joyce, 1988). As early as 1969, Costa Rica's first Forestry Law established the legal foundation to develop and administer a system of National Parks which has led to a protected areas system currently covering ~25% of the country. This command and control approach to protected area designation followed the traditional model for protection established by developed countries (Campbell, 2002; Steinberg, 2001).

While conservation of natural forest in protected areas is critical, nearly 70% of Costa Rica's remaining forests are located on private property and require approaches beyond command and control (de Camino, Segura, Arias, & Perez, 2000; Read, Denslow, & Guzman, 2001). In 1979, the Costa Rican government began to counter forest loss on private lands with a series of incentive programs designed to increase reforestation and slow deforestation outside of protected areas (Brockett & Gottfried, 2002). These programs promoted reforestation through tax credits, deductions and municipal funding for private landowners (De Camino 2000). These early incentive programs had variable success and primarily benefited wealthy large landowners and companies (Thacher, Lee, & Schelhas, 1997). There were also reports of leakage to the system of incentives, where areas of natural forest were cleared to subsequently collect subsidies for reforestation (Morell, 1997; Pagiola, Bishop, & Landell-Mills, 2002). Adjustments to the Forestry Law in 1986 and 1988 enabled landholders with smaller farms to participate through the offering of upfront payments and tradable bonds providing the financial capital for planting (Pagiola, Bishop, & Landell-Mills, 2002). By 1990, incentives were being offered for sustainable management of forests and expanded in 1995 to include forest protection (Miranda, Porras, & Moreno, 2004).

Building on the institutional legacy of these programs, Costa Rica initiated a program of payments for environmental services. The Forestry Law (No. 7575) of 1996 codified the legal and institutional support for the PES program (Snider 2003). The law cites four environmental services to be included in the program, carbon fixation, hydrological services, biodiversity protection, and aesthetic values (Chomitz, Brenes, & Constantino, 1999). Three modalities of contracts were originally available: reforestation, protection, and sustainable forest management. Sustainable forest management was suspended in 2001 due to concern of environmentalists who preferred strict protection. Payment contracts for the protection program are for 5 years for with equal payments of ~$44 per hectare per year (FONAFIFO, 2006). Reforestation payments are also for 5 years, but with contractual obligations lasting 10 - 15 years until harvest (Pagiola, Bishop, & Landell-Mills, 2002). Reforestation payments are higher and follow a front-end loaded schedule to help defer planting costs.

In response to a need to eliminate government subsidies as mandated by a structural adjustment loan from the International Monetary Fund, Costa Rica changed the source of funding for the new PES program from government subsidies of reforestation to a polluter-pay and user-pay system (de Camino, Segura, Arias, & Perez, 2000). The National Fund for Forest Financing (FONAFIFO) was institutionalized to raise and administer funds for the program (FONAFIFO, 2006). Monies to pay for the services are subsequently generated through a gasoline tax, carbon sequestration agreements, international institutions (in particular a large loan from the World Bank and Global Environmental Fund), and agreements with local hydroelectric power companies (Pagiola, Bishop, & Landell-Mills, 2002; Zbinden & Lee, 2005). While the gasoline tax currently provides the bulk of the funding, carbon credits are expected to become the main source in the future (Pagiola, Arcenas, & Platais, 2005).

In this public PES scheme, the Costa Rican government raises the funds, sets priority sites, establishes payment rates, and then through forest engineers (regents) contracts with landowners for the environmental services they provide (Sinclair 2003). Priority areas for targeting payments currently are biological corridors and poorer regions of the country with an emphasis on protection (FONAFIFO, 2006). Contracts are processed on a first-come, first-serve basis within the priority areas and programs (Sierra & Russman, 2005). Forest regents act as intermediaries between landowners and the government by providing administrative and oversight services generally charging the landowners between 12-18% of the payment amount (Miranda, Porras, & Moreno, 2003). While there are economic and conservation incentives for independent regents to target large farms due to scale efficiencies of transaction costs and conservation goals of protecting large patches of forest (Zbinden & Lee, 2005), Costa Rica has made substantial efforts to make it easier for poorer households and smaller landholders to participate (Pagiola, Arcenas, & Platais, 2005). The PES program in Costa Rica has set minimum requirements of 2 hectares for protection and 1 hectare for reforestation programs and a maximum of 300 hectares for a single contract in an attempt to give preference to smaller landholdings (Grieg-Gran, Porras, & Wunder, 2005; Rojas & Aylward, 2003).

Several local organizations (FUNDECOR, CODEFORSA) that were developed to promote sustainable forest stewardship have their own regents and have taken lead roles in administering the PES facilitating participation of landowners with small farms. These organizations are allocated a number of hectares to contract each year from FONAFIFO. Among other commitments, these groups actively seek out participants, develop management plans, facilitate paperwork, and provide technical assistance. These organizations also act as intermediaries for grouped small farm owner contracts, called global projects (Zbinden & Lee, 2005). Global projects reduce the transaction costs thus increasing the benefits for small and medium-sized landholders (Chomitz, Brenes, & Constantino, 1999).

The 1996 Forestry Law also prohibits forest conversion to other land uses (Rodriguez, 2002). As such, Costa Rica is enabling landowners with an incentive to protect their forest, but also constraints in the form of a law that strictly forbids forest conversion (Pagiola, Arcenas, & Platais, 2005). If this aspect of the law is enforced, it would mean that Costa Rica's natural forests would not decrease in the future, legally eliminating the potential for a decreasing baseline. Additionally, the law requires management plans and issues permits for the harvesting of any tree from natural forest or other areas of the farm. While permits to sustainably harvest natural forest are limited, harvesting plantation trees has been deregulated and permits for harvesting trees in pasture have been made easier. The legal stipulation that natural forests cannot be cleared creates a situation where the production opportunity cost for forested land nears zero for those areas where sustainable forest management and harvesting is not legal or profitable. Benefits from tourism would be one of the only other production opportunities from lands where harvesting was not permitable.

In administering Costa Rica's PES program, FONAFIFO has been given the general objective to further equity/development goals by targeting payments at small and medium sized landholders thus providing income and employment in rural areas (FONAFIFO, 2006; Silva, 2003). Since the government currently prioritizes payments within lower income regions of the country, additionally targeting small and medium landholders is assumed to prioritize lower income individuals and enhance rural development opportunities.

Methodology

Data for this analysis were collected in 2004 by conducting a survey of landowners in the region. A stratified random sample was developed to allow for comparison between participants and non-participants in the PES program. A FONAFIFO spatial database of all PES participants (n=510) within the San Juan-La Selva portion of the MBC was used to randomly select a sampling frame of 150 households. Those receiving reforestation incentives from previous programs were included as participants in the PES programs because their payment contracts were continued under the 1996 Forestry Law. A second sampling frame of 150 households of PES non-participants was randomly selected from the spatially referenced Ministry of Agriculture's 2000 Costa Rican Cattle Census (n=928). Spatial random sampling was done to provide control for similar biophysical land use opportunities and socioeconomic conditions such as distance to major roads and markets, soil types and terrain. Convenience sampling among these sample frames was conducted as the research team targeted regions across the study area. There were 213 landowners sampled with only 6 refusals. Nanty-nine PES participants and 108 PES non-participant surveys were completed. Completed surveys provided a sampling error of ±9% for each both populations (Salant and Dillman 1994). The unit of analysis was the household, and a research team administered questionnaires via face-to-face survey interviews averaging one hour per household.

The survey instrument explored the influence of the 1996 Forestry Law and PES on land use decisions, motivations to enroll land in PES programs, production options, and future plans for forest currently enlisted in PES. Additionally, data was collected about on-farm tree management including natural forest, charral, secondary forest, tree plantations, and riparian forest. Participants and non-participants were compared to identify differences in farm land use patterns, motivations for land use decisions and tree management to identify if these factors were influenced by participation in the PES program. PES participants within the protection program were compared to non-participants who met the program requirements of over 2 ha of forest. PES participants within the reforestation program were compared to all non-participants who met the minimum requirements of over 1 ha of farm land. Summary data are presented comparing participants and non-participants on specific factors related to additionality, baseline conditions, leakage, equity and demographic factors.

Results

Additionality through Protection

The efficiency of Costa Rica's PES program primarily rests on the additional contribution made to the provision of environmental services. The assumption of a declining baseline is essential for claiming additionality to avoid deforestation. Establishing a baseline is a subjective decision (Subak, 2000) and is based on a number of assumptions about future socioeconomic conditions and scale. Two methods used for assessing baseline conditions are quantifying past deforestation rates using remote sensing to identify baseline rates, and providing historical analysis of other factors that are likely to have influenced land use giving a qualitative assessment of likely future trends. More detailed analyses using both of these methods are provided elsewhere (Chapters 2 & 4).

A third method for assessing baseline conditions is to ask landowners about their actions related to natural forest retention. The desire was to assess what might have happened if the PES program had not been initiated, a condition more recently labeled the *counterfactual* condition (Ferraro & Pattanayak, 2006). To assess this, survey respondents were asked: 1) why they had not cleared their forest in the past?; 2) what were the main benefits to you of joining the PES program?; 3) if they were not enrolled in the PES program, why not?; and 4) what would they have done with their land if the 1996 Forestry Law restricting forest change and offering incentives had not been passed? These questions were designed to elicit landowner motivations for forest changes comparing those in the protection program with eligible non-participants to explore for differences and potential selection or participation bias (Ferraro & Pattanayak, 2006).

Of all survey respondents, two-thirds had natural forest and 53% of those were enrolled in the PES protection modality. By definition, 100% of those in protection had natural forest, while only 34% of all non-participants had natural forest greater than the 2 ha required for entry to the protection program. The mean forest area for those with protection contracts was 122 Ha (median 70 ha), with less than 25% of these individuals having under 25 ha of natural forest. This is significantly different ($p<.001$) than non-participants who had a mean of 22 ha (median 5.6 ha) of forest with more than 75% owning under 25 ha of natural forest. This indicates that the farms with larger forests are much more likely to be enrolled in the protection program.

The primary reasons for not previously clearing forest were dominated by environmental themes for both participants and non-participants (Table 1). For both groups, water conservation was the most important reason for not clearing their forest. While water conservation is often considered a utilitarian value, more intrinsic values such as the motive to protect biodiversity and conserve aesthetic beauty were commonly reported as primary motivating factors for forest retention. Together, these environmental reasons accounted for three of the top four primary motivations for participants and the top three motivations for non-participants respectively. Associated with these other conservation motivations, the potential to use their lands for tourism was a motivation of a number of protection mode participants (9%), but not for non-participants (0%).

An important consideration with protection contracts is that much of the land had been harvested in the past and can be sustainably harvested after the protection contract ends with an appropriate management plan and permit. A number of participants (24%) gave as their primary reason for not clearing their forest that they had already harvested and/or that they planned to harvest in the future. Biophysical limitations such as slope and poor soils were seldom given as primary motivations. While these may still be important factors, they were not often the landowners' primary motivations for maintaining forest. The final two elements on Table 1 were interesting for what they identified as less motivational factors in forest retention. Neither the legal restriction of forest change imposed by the Forestry Law of 1996 nor the falling returns for cattle were given as key motivations for maintaining forest for either group.

These results indicate that landowner conservation attitudes toward protecting natural forests have had more impact on protecting natural forest than the legal restrictions and market conditions. Interestingly, more participants identified production uses of their forest including previous harvests and tourism potential more often than non-participants indicating that economic gain from their forest is relatively more important to participants. Moreover, these results suggest that the two comparison groups are matched well in terms of environmental attitudes and, contrary to some expectations (Ferraro & Pattanayak, 2006) participants are not any more likely to have a pro-environmental ethic than non-participants. The biggest difference between comparison groups identified is in the size of forest on their farm, which can be explained in part by regents targeting larger farms (Zbinden & Lee, 2005).

The most often mentioned benefit from joining the protection program were the PES incentives (64%). The legal protection from squatters was given as a primary motivation by 26% of participants. The latter result is understandable in this region as historically it has had one of the highest rates of squatting in the country (Montagnini, 1994). Therefore, financial incentives and legal regulations specific to the PES contract accounted for a major proportion of primary motivations to participate. However, environmental reasons such as water conservation, biodiversity protection and aesthetics accounted for 40% of top motivations. This indicates that for many the decision to participate in the protection program is primarily motivated by efforts to actualize conservation motivations and not primarily means to alleviate opportunity costs or gain income. The intent to maintain the value of the wood in an area under contract was given by 13% of PES protection participants and is a reminder of the relatively short term nature of these contracts. Technical assistance and the potential for land value to increase were frequently mentioned as benefits of the program, but were not often listed as one of the two most important benefits. These results contrast slightly with those of Miranda (2003) who found benefits of the PES program (a slightly different question) were primarily environmental, followed by economic considerations and protection against squatters.

To further understand participation in the PES protection program, non-participants were asked their reasons for choosing not to participate in the protection program. More than a third of non-participants mentioned that their forest patch was too small to make enlisting in the program worthwhile, while a further 27% mentioned that the program paid too little per hectare. Additionally, one third of non-participants with forest reported that they did not know of the program or how to apply. This finding corresponds to that of Zbinden (2005) who found that both size of forest and knowledge of the PES program were significant determinants for participation. Another segment (16%) mentioned that they had no confidence in the government and/or did not like the legal restrictions imposed by the contract (14%). Only 8% of non-participants mentioned that they did not apply in the past because they lacked land title which suggests that the frontier has been settled and the efforts of the Costa Rican government to overcome this restriction to participation have largely been successful (Pagiola, Arcenas, & Platais, 2005).

A key survey question that specifically tied baseline conditions to additionality focused on choices the landowner would have made if the Forestry Law of 1996 restricting forest change and providing incentives for protection had not been passed. This question was used to identify potential counterfactual conditions and give a more cautious and better estimate of how much change can be attributed to the PES program (Ferraro & Pattanayak, 2006). Fifty percent of participants in the protection program stated that they would have kept their forest regardless of the 1996 Forestry Law. However, 32% stated that they would have cleared at least *some* of their forest land for pasture and an additional 8% would have cleared some for crops if there had been no 1996 Forestry Law. This means that 40% of all of those in the protection program reported that they would have cleared at least some of their forest. Another 10% stated that they would have harvested some additional timber from their forests in the absence of the 1996 Forestry Law. The exact percentage or number of hectares each landowner would have like to have cleared or harvested was not obtained. While much of the forest would have been conserved without the 1996 Forestry Law and PES program, this provides evidence that some additional forest would likely have been cleared without the 1996 Forestry Law and PES. The reduction in this rate of deforestation would be considered additional. However, 40% should be considered an absolute maximum estimate of deforestation avoided, as most farmers were not likely to clear all of their forest even if they were able to.

Additionality through Reforestation

Costa Rica uses a static baseline for reforestation with background rates expected to be zero (Chomitz, Brenes, & Constantino, 1999; Wunder, 2005). Prior to reforestation incentives there was almost no reforestation in the country (de Camino, Segura, Arias, & Perez, 2000). However, reforestation incentives were introduced in 1979 and adjusted over time. Prior to the 1996 Forestry Law, well over 100,000 have been reforested with incentives (de Camino, Segura, Arias, & Perez, 2000). However, there were reports of low success rates of plantations making it to harvest and little evaluation of the effectiveness or efficiency of the subsidies (de Camino, Segura, Arias, & Perez, 2000; Rojas & Aylward, 2003; Thacher, Lee, & Schelhas, 1997). The rate of reforestation through incentives dropped significantly with the passage of the 1996 Forestry Law and the distribution of incentives for other programs, primarily protection (Ortiz Malavasi, 2003; Subak, 2000). Landowners were asked a series of questions to identify how much additional reforestation was likely due to the forest plantation incentives and how likely forest plantations are to remain a part of the landscape. Participants in the incentive programs were contrasted with non-participants to identify differences.

While 31% of all survey respondents had forest plantations, 41% of those had developed their forest plantation without the aid of incentives. The mean reforestation plot for those with incentives was 53.5 ha (median 28 ha). The mean reforestation plot for non-participants was a similar 42.4 ha but with a median plantation size of 4 ha, indicating that over half of their reforestation plots were very small.

The key motivations for reforestation were similar among both participants and non-participants with differences in a few motivations (Table 2). The value of the wood as an investment was listed by a majority of participants as a key motivation for both groups. A smaller number of both participants and non-participants mentioned that a time limitation in the form of other jobs was a primary motivation for reforesting. Reforestation is a production system that is conducive to landowners who have a lack of time to dedicate to farm activities because it is a production system that requires little maintenance. Economic incentives offered to establish forest plantations were listed by 32% of participants as one of their primary motivations to reforest. In total, combined economic justifications accounted for the major portion of motivations for both groups indicating that reforestation is primarily considered a production system. Results for this study are significantly different than a previous study of participation in reforestation incentives programs in southwestern Costa Rica in the emphasis on economic motivations and that incentives play a significant role as a motivating factor (Thacher, Lee, & Schelhas, 1997).

Conservation was also identified by nearly a third of both groups as a key motivating factor. Nearly equal percentages of both groups identified poor access and biophysical limitations as motivating factors. These data indicate that while the biophysical location does influence a number of participants, reforesting the least productive and least accessible areas of a farm does not appear to be a major driver. The desire to have access to reforestation plots to extract the wood meant that many were located directly alongside roads. This result is in contrast to results presented by Thatcher (1997) who found that reforestation plots were primarily located on marginal and less productive lands.

Falling cattle markets were primary drivers for a switch to reforestation as an income generating activity for few participants, and no non-participants. Instead, and contrasting results for forest protection reported earlier, a small number of non-participants identified tourism potential as a reason for reforestation. In summary, the economic investment opportunity (including incentives) and other wage earning opportunities are the major motivations for reforestation. While conservation motivations are important, the economic production possibilities associated with reforestation appear critical for adoption.

Primary motivations for participation in the PES reforestation program were the economic incentives (83%). The value of the wood (26%) and technical assistance offered through the program (20%) were also listed by many participants as important motivations for their participation. A substantial number of participants also identified conservation (17%) as a key motivation for participation in the reforestation program. Paralleling the motivations to reforest, motivations to participate in the reforestation program were also economic. This indicates that the adoption of reforestation is primarily a production decision.

When incentive program participants were asked directly if they would have reforested without incentives 68% reported that they would not have reforested. This strongly indicates that the incentives tipped the balance in favor of reforestation compared to other production systems. Therefore, much of the reforestation on the landscape was directly influenced by the PES incentives and previous subsidy programs. Participants were about evenly split on whether the incentives were sufficient to cover the costs of planting and maintenance of their plantation. This means that at least half of the participants had to have other sources of money to fulfill their contractual obligations for the reforestation program.

Landowners with reforestation were also asked whether they intended to reforest after they harvested the current plots. This was done in the recognition that forest plantations are a production system and only a temporary feature on the landscape (~8-15 years). The majority of both incentive program participants (61%) and non-participants (55%) intended to reforest after harvesting plantations. However, 21% of participants and 30% of non-participants decidedly do not plan on replanting forest while the remaining were undecided. Interestingly, 84% of all non-participants thought their reforestation plot was growing well, while only 70% of participants felt theirs was growing well. It is unclear why participants felt they were having less success, especially considering the fact that they were much more likely to have received technical assistance than non-participants. One possible explanation is that participants had more unrealistic expectations about growth rates and returns when compared to non-participants.

Leakage

To assess additionality, it is also necessary to consider potential leakage effects. In Costa Rica, between farms leakage was assumed to be small since forest recovery was already seen in many areas of the country and the intensity of pressure on natural forests reduced (Chomitz, Brenes, & Constantino, 1999). To assess potential between and within farm leakage, we asked all those surveyed if they had harvested trees within the last five years, and which parts of the farm those trees had come from. It was thought that since the legal restrictions on natural forest change apply to all landowners, there could be a difference in the types of tree resources harvested that was influenced by participation. Participants in any of the PES programs were contrasted with non-participants to identify any significant differences that might suggest potential sources of leakage.

Nearly half of all those surveyed had harvested some trees in the last five years, with equal percentages of participants and non-participants harvesting (Table 3). Equal percentages between the groups harvesting suggests that participation in PES does not instigate a shift in conservation ethic to protect other trees on the farm. The majority of those surveyed that harvested indicated that they had taken trees from their pasture. Both groups primarily harvested large remnant trees in their pasture with 47% of participants and 68% of non-participants taking advantage of this tree resource. The higher rate of harvested trees from pastures for non-participants likely reflects the higher percentage of non-participants who have pasture on their farm. Younger trees that had regenerated after the pasture was cleared from forest were also a source of wood, but more so for non-participants. The large percentages harvesting trees from pastures for both groups is likely due to the tightening of restrictions on harvesting natural forest and the easing of restrictions on cutting trees in pasture. Significant numbers of both participants and non-participants reported harvesting fallen or dead trees from their natural forest. Differences in the number of participants who indicated that they pulled trees from managed natural forests and reforestation plots is an attribute of the numbers of participants who were involved in the PES sustainable forest management and reforestation programs. The differences in farm composition make it difficult to attribute the differences in the types of tree resources harvested to participation in the PES program. It may also be argued that the harvesting would have happened without the legal restrictions or incentive programs. However, it does indicate that the most likely form of leakage from the legal limitation on forest change and the PES programs is from the harvesting of remnant trees in pasture.

Another potential source of leakage regards reforestation. If reforestation of an area of a farm results in the clearing of a forested area of the farm, this would be considered leakage. This was suspected for Costa Rica's early reforestation incentive programs and was explored here (Pagiola, Bishop, & Landell-Mills, 2002). Landowners were asked to report what the land use was prior to establishing reforestation. In this case both participants and non-participants with reforestation reported nearly 90% of their reforested land previously being used as pasture. All of the remainder of the land for both groups was land previously used as crops. Neither group reported any reforested land replacing natural forest. These finding matches that found in another study of forest plantations in this same region (Piotto, Montagnini, Ugalde, & Kanninen, 2002). This trend also matches the descriptions of colonization in the area that document that forest was cleared primarily for pasture to obtain title and as part of a land speculation wave in the region (Montagnini, 1994; Read, Denslow, & Guzman, 2001; Schelhas, 1996).

Equity

Equity is a multi-dimensional concept. Equity can be considered for: 1) equal ability to participate in the program; 2) equal amounts paid among participants in the program; and 3) developing equality through development and poverty alleviation. Costa Rica has been a leader in modifying their system of PES to allow participation of poorer landowners and this dimension of equity is thoroughly discussed elsewhere (Pagiola, Arcenas, & Platais, 2005). Equity between participants relates to fair distribution of payments among the participants and is briefly discussed below. Analysis of equity in terms of development and poverty alleviation is one of the focal points of this paper.

Equity among Participants

It has been noted that *equity* in Costa Rica is perceived as equal payments to all participants on a per hectare basis (Chomitz, Brenes, & Constantino, 1999). Fixed prices per hectare are simple, easily understandable, and straightforward to administer (Chomitz, Brenes, & Constantino, 1999) minimizing the potential for political gamesmanship. Costa Rica established a payment amount for the protection program that was equal to the opportunity cost of the land, or the value of its next best use. Reflecting the most common land use transition, the payments were set at the approximate value of land in pasture used for extensive cattle production (Castro, Tattenbach, Gamez, & Olson, 2000). Opportunity cost for other production systems is an amount easily identifiable by most landowners (Wunder, 2005) who could then decide whether the program was ‘worth it’. This also ensured that highly productive agriculture lands would not be incorporated into the PES system.

The payment amount applied to all lands that fell under the protection program in the government targeted priority areas, regardless of their potential to provide the four environmental services identified by FONAFIFO. A set rate per hectare for all participants recognizes that calculating values of environmental services is problematic. For example, the ecological properties of environmental services are not always well understood and can be very localized (Chomitz & Kumari, 1998; Kremen, 2005), calculations are complex and double counting can be problematic (Boyd & Banzhaf, 2006; National Research Council,

2005) and calculations are not easily transparent or understandable to landowners. While it could also be considered inequitable to offer the same payment for lands that provide unequal environmental services, any recommendation to adjust payments to fit environmental services offered by particular lands needs to take these equity considerations and the very local and complex nature of calculating the value of environmental services into account (Farber, Costanza, & Wilson, 2002; Limberg, O'Neill, Costanza, & Farber, 2002; Turner et al., 2003).

The current payment amount is just above the rental value of pasture land for this region assuming a stocking rate of 1 cow per hectare. The mean rental value for pasture land identified in this study ranged between $33 - $37 dollars per year with a median rental payment of ~$2.28 per animal per month (1,000 colones in 2004). No significant differences were identified for rental payments for pasture lands between participants and non-participants in the protection or reforestation programs. As pasture is still the most likely production use in the region, the opportunity costs for extensive grazing on pasture lands may still be considered equitable among participants. As mentioned, however, these opportunity costs are contingent on converting natural forest to pasture, which is illegal, leaving the appropriate opportunity cost difficult to identify (Grieg-Gran, Porras, & Wunder, 2005).

Equity/Development for Poverty Alleviation

To establish whether program goals of targeting small and medium farms and contributing to rural development were being achieved in this region of Costa Rica, participants and non-participants were compared: 1) across size of farm; 2) income levels; and 3) how much of their total income originated from PES. In addition, participants were asked how they spent their PES payments to identify potential multiplier effects or employment benefits of the conservation program.

Small, medium, and large farms size categories were developed through self-reported categorization from the entire survey. This was done because farm size may be relative to the region in the country and from the perspective of the landowners themselves. Regional perspectives vary because natural productivity and what can be produced vary significantly. For example, what may be considered a large dairy farm in a cooler mountain climate may be much smaller than what is considered a large beef cattle farm in an arid

Pacific region. Additionally, the total farm size for the landowner was used instead of the contract size because it more directly addresses development impacts. For example, a landowner with 300 ha who has a protection contract for 25 ha would be categorized as a large farm instead of a small farm. Box plots and the 95% confidence intervals were used to identify the best breaking points between the groups (Figure 1). There was large agreement that small farms were any farm up to 50 ha while the confidence intervals for medium and large farms overlapped to some extent. By using mean and median farm sized within each group (Figure 2) a breaking point was determined at 125 ha for medium and large farm size in this region. The distribution of farms for protection and reforestation are given along with the total number of hectares contracted under each farm size category (Table 4). A combined row of small and medium farms was developed as targeting these individuals is a stated goal of the program.

In this sample, the number of contracts combined from farmers who have small and medium farms was about evenly split with large farms. This suggests that for this region, Costa Rica has been relatively successful at enlisting small and medium landholders. However, this result could be very misleading in terms of the amount of money that goes to the owners of small and medium sized farms. Since payments are made on a per hectare basis, the amount of payments went overwhelmingly (>80%) to those with large farms in this sample for this region. This is also consistent with findings in the Varilla watershed in Costa Rica where the majority of the payments went to farmers with larger land holdings (Grieg-Gran, Porras, & Wunder, 2005; Miranda, Porras, & Moreno, 2003). If, however, one were to consider only the contract size for forest protection (and not the size of the landowners farm), the program has had much greater success at targeting small and medium sized forest contracts. Under these conditions, 79% of all forest contracts and 50% of all hectares of forest protection contracts fall under the 125 hectare limit of small and medium sized farm for this region. While it is difficult to ascertain the size of a landowner's holdings (often multiple farms), it is argued here that that using farm size is a better calculation for assessing equity/development impacts (even when done post hoc) than using the size of the forest contract.

Because the intent of targeting small and medium landowners is to further development goals, income was contrasted with farm size to identify trends. Income was banded into quintiles to allow for relative comparison to all participants *and* non-participants within the region. Table 5 provides details of the income distribution by farm size for the region for PES participants. There is evidence of a heavy and expected loading of large farms and higher income, but both small and medium sized farms show no correlation with higher income. Forty-four percent of all contracts went to those with lower or middle income households, of which 70% would have been correctly identified by targeting small and medium landholdings. Therefore, there is some evidence that by targeting small and medium sized farms, if done by farm size and not contract size, relatively low-to-moderate income households can be targeted.

Another method to evaluate development impacts of payments is to identify how many participants, and how many hectares of payments, went to the different income groups. The fact that size of farm is not a perfect indicator of income, relative income was used as the basis for an evaluation of equity/development goals. Table 6 demonstrates that 27% of participants with protection contracts were in the lowest 40% of income groups and had 13% of the hectares. This table also demonstrates that over 55% of participants and over two-thirds of all payments (per hectare) for the protection program go to the higher income earners.

Another method to identify development impacts of the payments is to understand what percentage of a participants' household income the PES payment represents. On average, participants in the protection program do receive a considerable percentage of their income from the PES program (Table 7). These percentages are on par with other preliminary studies in Costa Rica's Varilla watershed showing landowners with small farms on average earn less of their income from PES (Miranda, Porras, & Moreno, 2003). Additionally, there were notable differences in the mean and median percentages. This may be explained by the number of households that obtained nearly all of their income from PES payments. A number of these farms were owned by retired individuals who had sold or divided up the working components of their farms among their siblings, and retired on the PES payments for the forest that they maintained (personal observation).

How Landowners Spend the PES

Though the direct payments are considered the main development mechanism of PES, there are also potential ramifications for the regional employment and multiplier effects from participants spending their payments. To understand this, participants were asked: 1) where they lived; 2) how they spent their payment; and 3) if they hired additional labor (Table 8). Results were markedly different between the programs suggesting that there are dissimilar distributional patterns of the payments.

Well over 50% of the entire sample population did not live on their farm full time with significantly more participants living off farm in regional cities or the capital, San Jose than non-participants. This indicates that that a large number of landowners have left the region and these farms are not primarily production farms. This result is indicative of a forest transition where landowners leave the frontier and agricultural pursuits to pursue urban or industrialized opportunities. The empty frontier has also been identified for a smaller portion of this study site (Schelhas & Sanchez-Azofeifa, 2006).

Half or more of both groups hired some additional labor to meet their contracts. Contracts for protection required that landowners clear the boundaries of their forest, maintain signs against cutting and hunting, and develop a forest plan among others. The data show individuals were hired for manual labor skills and for short term projects such as clearing boundaries to parcels, clearing and planting reforestation plots, thinning reforestation plots, and harvesting wood. The only consistent full time work was for a farm caretaker for those who did not live on the farm. However, most farms had such a caretaker already and simply added the contract requirements to their list of duties.

While both groups spent significant amounts on simply meeting the contract requirements for participation, there are noteworthy differences. Primary appropriations of the payments were reported by protection participants to be for meeting contract obligations. When combined with the percentage primarily dedicated to farm improvements such as fence and road maintenance, farm equipment, purchasing livestock and the hiring of a caretaker, this total rose to 66%. Therefore, the majorities of the PES Protection payments were invested back into the farm or to those working on the farm and could be considered a contribution to rural development. However, the remaining 33% of the primary uses of the money went to the general household budget and were not earmarked for the farm. Because the majority of participants in the protection program do not live on the farm, this money was less likely to contribute to rural development near the farm.

For reforestation, the reinvestment of PES back into the farm was even more significant. The vast majority of the funds primary uses were specifically used for establishing the reforestation plot with an additional 9% reportedly dedicated to farm development. Only a very small fraction of the reforestation payments were targeted primarily for the general budget of landowners. In the case of reforestation, almost all of the payment funds go to work on, or contracting labor to work on the farm, and therefore likely contribute to rural development. So while both the protection and reforestation payments were largely invested in the farm, the reforestation payments were much more efficient in their contribution to rural development.

Discussion

Protection

In all cases, the percentage of additionality attributed to deforestation avoided depends on the baseline selected. Furthermore, no matter which baseline is selected, it is critical to understand how the incentives weighed in the landowner decision process. Without this knowledge all reductions in the deforestation rate might mistakenly be attributed to the PES. Landowner surveys were used to assess forest cover decision making. In contrast with expectations that past forest maintenance would be due to its biophysical limitations for production and/or a declining cattle market (Arroyo-Mora, Sanchez-Azofeifa, Rivard, Calvo, & Janzen, 2004; de Camino, Segura, Arias, & Perez, 2000), conservation motivations dominated forest retention decisions. Positive attitudes toward forests cannot be attributed to predisposition to participate in, or developed from participation in the PES program, as non-participants had an even higher proportion of their environmentally-based forest conservation motivations. This indicates that differences in environmental attitudes were not problematic for comparing groups. It also implies that there was a larger shift in conservation attitudes beyond the PES program which was also identified in Schelhas (2006). This is consistent with the concepts of a forest transition and the Kuznets curve that indicate a shift in societal values toward forest and environmental conservation (Mather & Needle, 1998; Rudel, Bates, & Machinguiashi, 2002).

However, positive environmental values in this region have not been accompanied by forest recovery as in other parts of the country (Arroyo-Mora, Sanchez-Azofeifa, Rivard, Calvo, & Janzen, 2004; Sanchez-Azofeifa, 2000). This has led some to term this type of recovery a "hollow frontier" where the frontier is depopulated but the forest does not recover (Rudel, Bates, & Machinguiashi, 2002; Schelhas & Sanchez-Azofeifa, 2006). Our results were different than these and others evaluating PES in Costa Rica (Sierra & Russman, 2005), in that we found that some of the deforestation avoided was contingent on the incentives for protection. Therefore, it is likely that the PES program contributed to some deforestation avoided in this region of Costa Rica and accelerated the process of a 'forest transition' where total forest cover is increased.

It is important to be cautious regarding how much of the avoided deforestation can be attributed to PES. Nearly half of the participants in the protection program stated that they had no interest in converting any of their forest, and these lands should not be considered additional as their conservation was not contingent on the payments. Furthermore, there is some evidence of leakage in the form of removal of large remnant trees from pastures. However, this leakage may be a product of the legal restriction on forest conversion and not directly a product of the incentive program. Therefore, this leakage may not need to be subtracted from additionality measures of deforestation avoided.

Multiple facets of equity were discussed with the development/poverty alleviation focus presented in this study. The PES program objective of targeting small and medium farmers to contribute to rural development was analyzed. Two measures of development impact were addressed: who receives the payment and how it was spent. All analyses of who receives the payments indicated that though nearly half of the recipients are small and medium size landholders, the overwhelmingly majority of the payments (per hectare) go to relatively richer landholders with relatively larger landholdings who do not live on their farm. Similar results have been found for the region and elsewhere in Costa Rica (Miranda, Porras, & Moreno, 2003; Zbinden & Lee, 2005). These results mean that the direct payments to landowners for PES are less likely to have a development impact in rural areas. However, if one also considers how the payments are spent, the majority of primary expenditures for those in the protection program goes back into the region and thus contributes to rural development. Therefore, attention should be given not just to whom the participants are, but also to how and where the money is spent. As noted elsewhere, "livelihood impacts are not only about poor land-holding service providers, but also about effects on other groups" (Grieg-Gran, Porras, & Wunder, 2005, p. 1513).

Reforestation

Analysis of additionality for reforestation is also contingent on baseline conditions. Costa Rica uses a static baseline, which correctly represents the period prior to the first incentive offered in the early 1980s. This study indicates that once the forest incentives began, the majority of reforestation was directly contingent on the payments and could be considered additional. Primary motivations for reforestation were economic with incentive payments apparently tipping the balance to promote this form of land use. As an economic production system, reforestation has some of the same benefits identified as cattle production in the region including low labor inputs once it is planted and proof of land utilization against squatters (Ibrahim, Abarca, & Flores, 2000; Schelhas & Sanchez-Azofeifa, 2006). Reforestation projects do not necessitate daily or even monthly care and upkeep and thus are a practical land use for those with other employment. Conservation motivations also played a substantial part in the decision to reforest. However, no ‘guilt’ for past deforestation or religious based conservation ethics were identified as they were in other areas of Costa Rica (Jantzi, Schelhas, & Lassoie, 1999; Thacher, Lee, & Schelhas, 1997). Leakage problems of cutting natural forest to obtain reforestation incentives were not identified in this study or in previous studies in this region (Piotto, Montagnini, Ugalde, & Kanninen, 2002) and would not impact additionality totals.

Development impacts through direct payment for reforestation were similar to those for protection. Participants tended to have larger landholdings and have higher income than non-participants in the region. However, almost all primary expenditures of PES payments were directed specifically at the farm to hire manual labor and conduct farm improvements and therefore contributed to regional development. In this study, reforestation could be considered more efficient for rural development than protection when expenditures of the PES are used as the equity/development indicator instead of participant attributes.

The effectiveness of the incentive program to influence landowners to try reforestation (68%), along with the majority of those adopting the practice for a second round (61%), documents the ability of the incentive program to influence forest cover in the region. However, the significant number of landowners who are undecided or not interested in continuing their reforestation (39%) indicates that the amount of forest plantations currently in the landscape may not be maintained in the future. Recognizing that reforestation is a production system and temporary component of the landscape, the dramatic drop in incentives offered for reforestation due to the overwhelming priority given to protection contracts since 1996 may lead to a decrease in this type of forest cover across the landscape (Ortiz Malavasi, 2003; Subak, 2000). The process that may lead to a decreasing baseline of deforestation would just now begin to be apparent as pre-1996 Forestry Law reforestation plots began to be harvested. Given the small amount of forest recovery in this region, a decrease in reforestation is unlikely to convert to forest recovery and would be expected to convert back to pasture or to crops such as pineapple which during this research was rapidly replacing many pastures in the region.

A study in a smaller portion of this study site found evidence of a hollow frontier, or a depopulated frontier region with no forest recovery (Schelhas & Sanchez-Azofeifa, 2006). This study found similar evidence of absentee ownership in the region, transition to non-farm income generation and positive environmental attitudes toward forest cover all of which are consistent with forest transition theory (Mather & Needle, 1998; T. K. Rudel, Bates, & Machinguiashi, 2002). However, analysis of the PES incentive programs at this study's larger scale show that these incentive contributed a substantial increase in the rate of reforestation. If reforestation (forest plantations) is considered part of a forest transition, then the region would not be considered quite so hollow.

Conclusion and Recommendations

The primary motivation for this paper was to identify potential additional forest cover and equity/development impacts of Costa Rica's program of payments for environmental services. The efficiency of the program for providing forest rests primarily on the additional forest cover that the program provides. The efficiency of the program for providing equity/development impacts rest primarily on whom the program participants are and how they spend their money. Our study suggests that PES has influenced forest cover in a positive way and both program modalities are seen to contribute to rural development, but at different degrees. Two recommendations as to how to improve the ecological and equity/development efficiency of Costa Rica's PES program are based on designing an appropriate incentive package (H. Rosa, Kandel, & Dimas, 2004).

Participation in the PES protection program is highly desired, with demand far outstripping supply in the form of available payments (Pagiola, Bishop, & Landell-Mills, 2002). This would be expected when the opportunity cost of most forested land nears zero where harvests are not permitted because most of the other preferred land uses are illegal. In this context, payments have been described as tokens for good conservation behavior and forest stewardship (Kosoy, Martinex-Tuna, Muradian, & Martinez-Alier, 2006). The combination of legal restrictions and payments has been justified based on the logic that weakly enforced laws can be supplemented with payments to encourage compliance (Wunder, 2006). However, this makes the appropriate opportunity cost to pay for compensation less obvious (Grieg-Gran, Porras, & Wunder, 2005).

Targeting done by regents and local organizations to prioritize the protection of larger forest patches because of lower transaction costs and conservation benefits helps explain why participants tend to have larger forests (Zbinden & Lee, 2005), but it does not explain why smaller forest holders do not consider the payments to be sufficient to induce participation. Landholders with small farms see the scheme as unprofitable (H. Rosa, Kandel, & Dimas, 2004) and this study and others showed that these landholders receive a relatively lower percentage of their income from PES (Miranda, Porras, & Moreno, 2003). A likely explanation is that because payments are set for an opportunity cost of an extensive production system of cattle, they may not yield high enough payoffs to provide an incentive beyond transaction costs for landowners with small areas of forest. While global contracts are designed to reduce transaction costs for landowners with smaller forests, it is likely that without this program, small forest owners would generally not participate.

Based primarily on the argument that demand for PES far exceeds the monies available (Pagiola, Bishop, & Landell-Mills, 2002), a number of recommendations for improving the ecological and equity efficiency of payments have been suggested. A reverse auction system whereby landowners bid for PES payments has been suggested as a means of increasing area under conservation by reducing the per acre payment (Rojas & Aylward, 2003). Other ideas include increased spatial targeting for better service provision and to counteract higher threats (Sierra, Campos, & Chamberlin, 2002), tailoring payments to match the value of environmental services provided (Wunder, 2005), expanding the resource base by increasing the willingness to pay (Grieg-Gran, Porras, & Wunder, 2005), keeping transaction costs as low as possible (Pagiola, Arcenas, & Platais, 2005) and designing incentives to deliberately favor the poor (Rosa, Kandel, & Dimas, 2004). Based on the results from this study and previous recommendations, a two part recommendation is offered. The first part is to expand the resource base from carbon sequestration payments and tourism to provide more funds for PES programs. The second recommendation is to adjust the payment amounts to better reflect transaction costs.

Costa Rica's PES program has diversified its resource base to include income from hydroelectric services, water service users (industrial and municipal), fuels sales tax, carbon sequestration, and international lending agencies (Pagiola, Bishop, & Landell-Mills, 2002). Historically, the majority of the funds for the program have come from the fuel tax, but future increases are expected to largely come from carbon sequestration investments through the Kyoto Protocol's Clean Development Mechanism (CDM) (Pagiola, Arcenas, & Platais, 2005). Institutional capacity to market carbon sequestering services has long been in place and is the most obvious area for expanding the PES funding resources. Resources that are earmarked for carbon sequestration will shift emphasis on reforestation because additionality for deforestation is not allowed under the CDM for the first commitment period 2008-2012 (Smith & Scherr, 2003). As demonstrated in this research, the payments for reforestation are overwhelmingly invested back into the farm and thus contribute to rural development. Increasing the number of contracts under reforestation would contribute to both and increase in number of hectares delivering related environmental services and an increase in equity/development goals because of reforestation's increase efficiency in this regard.

The second potential area for obtaining additional resources is tourism. While analyzing a sub-program of the PES, Subak (2000) notes an apparent contradiction to the program that "while scenic beauty is recognized as a benefit of forests in the 1996 Forestry Law, ecotourist ventures do not currently contribute" to funding the program, but instead often receive PES (Subak, 2000, p. 288). While it is well argued that private reserves are a critical for extending the network of public parks and reserves for biodiversity habitat (Langholz, Lassoie, & Schelhas, 2000), these lands are unlikely under threat of forest conversion which would make for credible additionality claims (Wunder, 2007). Beyond the PES, private reserves have multiple incentives including elimination of property taxes, technical assistance, and squatter protection (Langholz, Lassoie, & Schelhas, 2000). While much has been made of ecotourism's importance to the overall economy as the number one foreign exchange earner, others have noted the lack of a direct connection between ecotourism and conservation (Stem, Lassoie, Lee, Deshlere, & Schelhas, 2003). Other authors have also noted the potential for ecotourism to contribute to PES (Grieg-Gran, Porras, & Wunder, 2005). A small tax at the airport (as part of the exit fee) could be earmarked for PES and justified for the scenic beauty and biodiversity programs for ecotourists and as carbon sequestration program compensating for air travel for non-tourists. In this way, tourism and other travel to Costa Rica would contribute directly to conservation ends. The popularity of carbon offsets might be used to gain acceptance for such a tax.

The second recommendation is for adjusting the payment amounts to reflect transaction costs and offers a new perspective on opportunity costs. It is argued here that opportunity costs of extensive production systems are lower than for intensive systems and therefore should be compensated at a lower rate. Using this perspective, it is worth more to a small landholder who needs to intensively manage their land to give up production potential and they should be compensated accordingly. This perspective is in contrast to that offered by Grieg-Gran et al. (2005) who reported that a flat fee would most likely benefit the poor who use relatively rudimentary production systems. Furthermore, since Costa Rica's PES program pay per hectare, transactions costs are relatively higher for smaller contracts (Grieg-Gran, Porras, & Wunder, 2005; Pagiola, Arcenas, & Platais, 2005). Here, we recommend that keeping transactions costs low is critical, but also that the payment amount could be designed to address these relative disadvantages for small landholders (Pagiola, Arcenas, & Platais, 2005; H. Rosa, Kandel, & Dimas, 2004).

One program design for incentives that would address these issues is a regressive payment system, where the first group of hectares is paid at a higher rate than subsequent amounts (Table 9). As small and medium sized farms are the target for equity/development goals, the system could also be designed so that while small farms gained, medium contracts could maintain the same payment amount. As this research showed, the overwhelming majority of payments went to the relatively rich and large landholders on a per hectare basis. Because of this discrepancy, a payment rate system that paid less per hectare for large extensive contracts could cost less than the current one, freeing resources to put additional hectares under contract. The increased rate for small contracts and decreased rates for large contracts would provide incentive for small farm owners to participate, address opportunity costs and transaction costs more equitably, increase development impacts, and increase ecological impact by bringing more hectares into the system.

Limitations and Future Research

As is the case of most studies, there are limitations associated with this study. First, this is a case study in northeastern Costa Rica with a particular socioeconomic context and land use history. As a case comparison for the analysis of PES in other regions of Costa Rica it is quite insightful for addressing efficiency considerations. However, it should not be considered representative of all of Costa Rica. For example, perceptions of the size of farm, income levels, production possibilities of local land, threats to forest conversion, impacts of the PES, and motivations of landowners can have wide regional differences (Miranda, Porras, & Moreno, 2003; Rojas & Aylward, 2003; Sierra & Russman, 2005). However, there are also commonalities among this growing body of research that are becoming apparent such as the likelihood of payments to go to landowners who have relatively larger farms and are relatively richer (Grieg-Gran, Porras, & Wunder, 2005; Miranda, Porras, & Moreno, 2003; Pagiola, Arcenas, & Platais, 2005; Thacher, Lee, & Schelhas, 1997; Zbinden & Lee, 2005). It is also becoming apparent that an incentive payment system that uses an opportunity cost of an extensive land production system for a payment rate will mean that landowners with small farms will receive a lower percentage of their income from PES (Miranda, Porras, & Moreno, 2003; H. Rosa, Kandel, & Dimas, 2004). Special care should be used in applying these insights to other countries as well. In particular, Costa Rica has a developed institutional and legal support structure for PES and property rights that are not found in other regions (Echavarria, Vogel, Alban, & Meneses, 2003; Tomich, Thomas, & van Noordwijk, 2004; Wunder, The, & Ibarra, 2005). Future research of PES could include a national study with sample sizes sufficient to match and compare participants and non-participants across regions and across groups within regions. Ferraro (2006) addresses a number of evaluation techniques that can build upon those that have already been addressed in this research (Ferraro & Pattanayak, 2006).

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Tables

Table 1. Natural Forest: The two most important motivations for not previously clearing natural forest.

Motivation	Protection N=72	Non-participants N=42
Conserve water	55%	76%
Protect biodiversity	39%	42%
Aesthetics and heritage	16%	24%
Tourism	9%	0%
Already harvested	24%	0%
Use wood in the future	10%	12%
Biophysical limitations	5%	6%
Legal restrictions	8%	15%
Poor returns for cattle	1%	0%

Table 2: Reforestation: The two most important motivations to reforest land. Participants and non-participants in Costa Rica's PES program for reforestation. (Note the small N for both groups.)

Motivation	**Reforestation with incentive** N=38	**Reforestation no incentive** N=26
Wood value/investment	68%	69%
Incentives	32%	0%
Time limitation/other job	13%	12%
Conservation (water/biodiversity/aesthetics)	34%	31%
Biophysical limitations	16%	12%
Poor returns for cattle	8%	0%
Tourism	0%	8%

Table 3: Harvesting: Percentage of individuals who have harvested (47% of participants and 50% of non-participants harvested). Respondents selected all tree sources from which they harvested.

Location of tree harvested	PES participants	Non-participants
	N=99	N=108
Remnants in pasture	47%	68%
Trees regenerating in pasture	6%	16%
Charral	0%	1%
Fallen/dead in natural forest	13%	16%
Managed natural forest	15%	1%
Reforestation plots	32%	11%

Table 4: Distribution of contracts by landowner farm size.

Farm size	Protection	Reforestation
Small	N=14	N=9
1 – 50 ha	252 ha	140 ha
Medium	N=19	N=8
51 – 125 ha	1,043 ha	196 ha
Small & Medium	47% of N	45% of N
Combined	17% of ha	17% of ha
(% of total)		
Large	N=38	N=21
126+ ha	4,704 ha	1,677 ha
Total	N=71	N=38
	6,000 ha	2,013 ha

Table 5: Farm size contrasted with relative income for PES participants (relative income defined by all respondents).

N=92	**Income Very Low 0-20%**	**Income Low 20-40%**	**Income Medium 40-60%**	**Income High 60-80%**	**Income Very high 80-100%**	**% of total by farm size**
Small 1 – 50 ha	**5**	**3**	**4**	**4**	**2**	**20%**
Medium 51 – 125 ha	**6**	**4**	**6**	**2**	**4**	**28%**
Large 126+ ha	**1**	**4**	**7**	**17**	**19**	**52%**
% of total by income group	**13%**	**12%**	**19%**	**29%**	**27%**	

Table 6: Percentages of participants and hectares of forest contracts by income group (Protection only). Income is relative to the entire group of survey respondents and categorized into quintiles.

N=67	**Very Low 0-20%**	**Low 20-40%**	**Medium 40-60%**	**High 60-80%**	**Very high 80-100%**
% of N	15%	12%	18%	30%	25%
% of total hectares	7%	6%	20%	40%	27%

Table 7: Percentage of household budget from PES payments for protection by farm size.

Farm size	N	Mean	Median
Small 1 – 50 ha	11	11.7%	8.7%
Medium 51 – 125 ha	19	33.7%	23.3%
Large 126+ ha	33	28.1%	15.7%
Total	63	24.5%	15.9%

Table 8: Distributional impacts of PES payments.

	Protection	Reforestation
Live on the farm	29%	18%
Contracted additional employees	50%	66%
How participants spent PES payments (% of total listed expenditures not by participant)	Contract obligations 37% Farm improvements 23% Caretaker 6% General budget 33%	Contract obligations 85% Farm improvements 9% Caretaker 0% General budget 3%

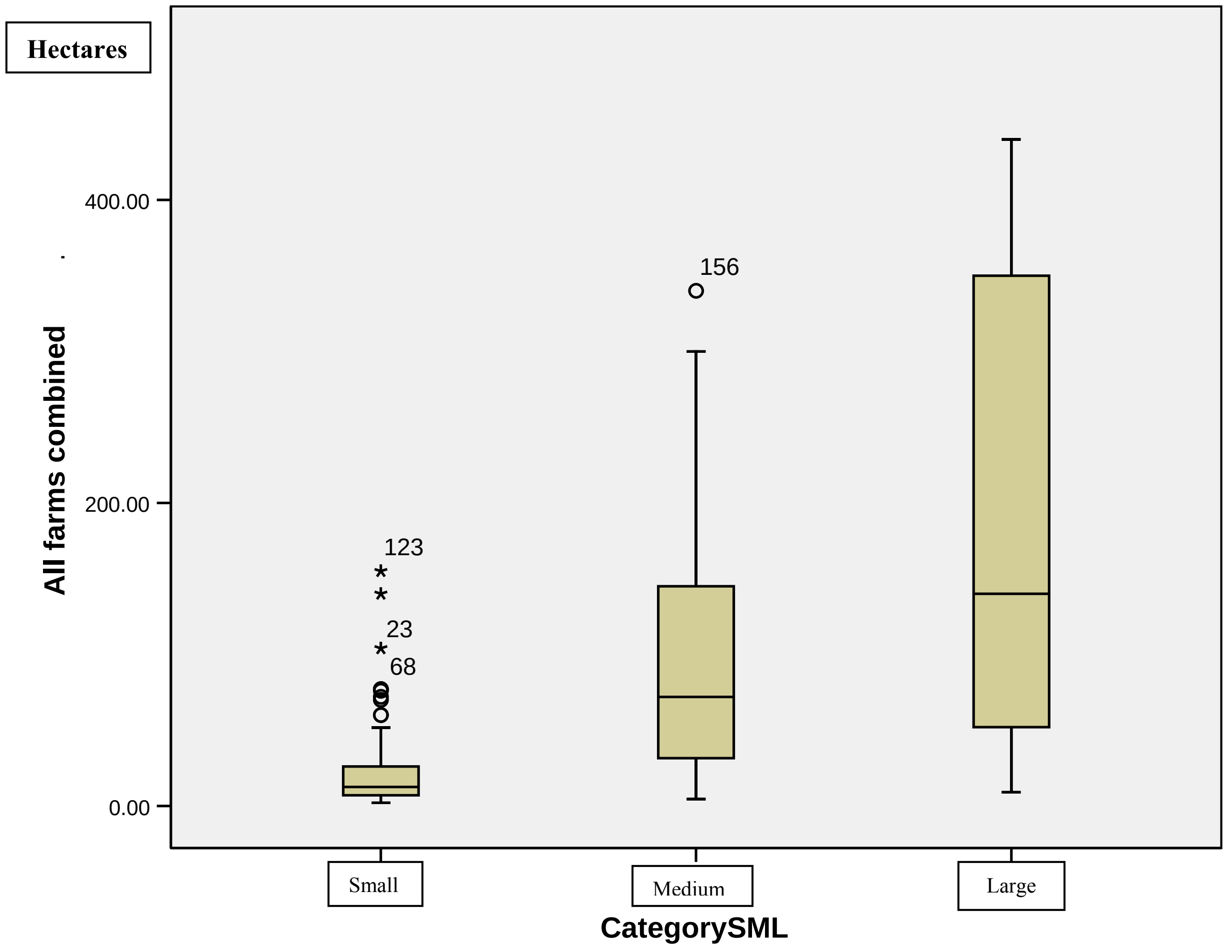
Table 9: Example regressive payment rate. In the case presented here both small and medium farmers (up to 125 ha) would earn more then they would under a flat fee system.

Number of hectares	Payment amount	Example for landowner with 300 ha	Example with flat fee of $50/ha	Benefit transfer
2-25	$70	25*$70=$1,750	25*50=$1,250	+$500
26-50	$60	25*$60=$1,500	25*50=$1,250	+$750 ($250 + $500)
50-100	$50	50*$50=$2,500	50*$50=$2,500	+$750 ($250 + $500)
100-300	$20	200*$20=$4,000	200*$50=$10,000	-$6,000
15,000	Total	$9,750	$15,000	-$5,250*

*This is only the savings if all contracts were 300 hectares. The higher number of smaller contracts that are paid at the higher rate, the lower the savings will be. The payment amounts given are just an example and could be adjusted to fit actual conditions. The point is simply that smaller farms could be paid more and compensated by lowering the profit for larger farms.

Figures

Figure 1: Box plot for landholder reported size of farm.



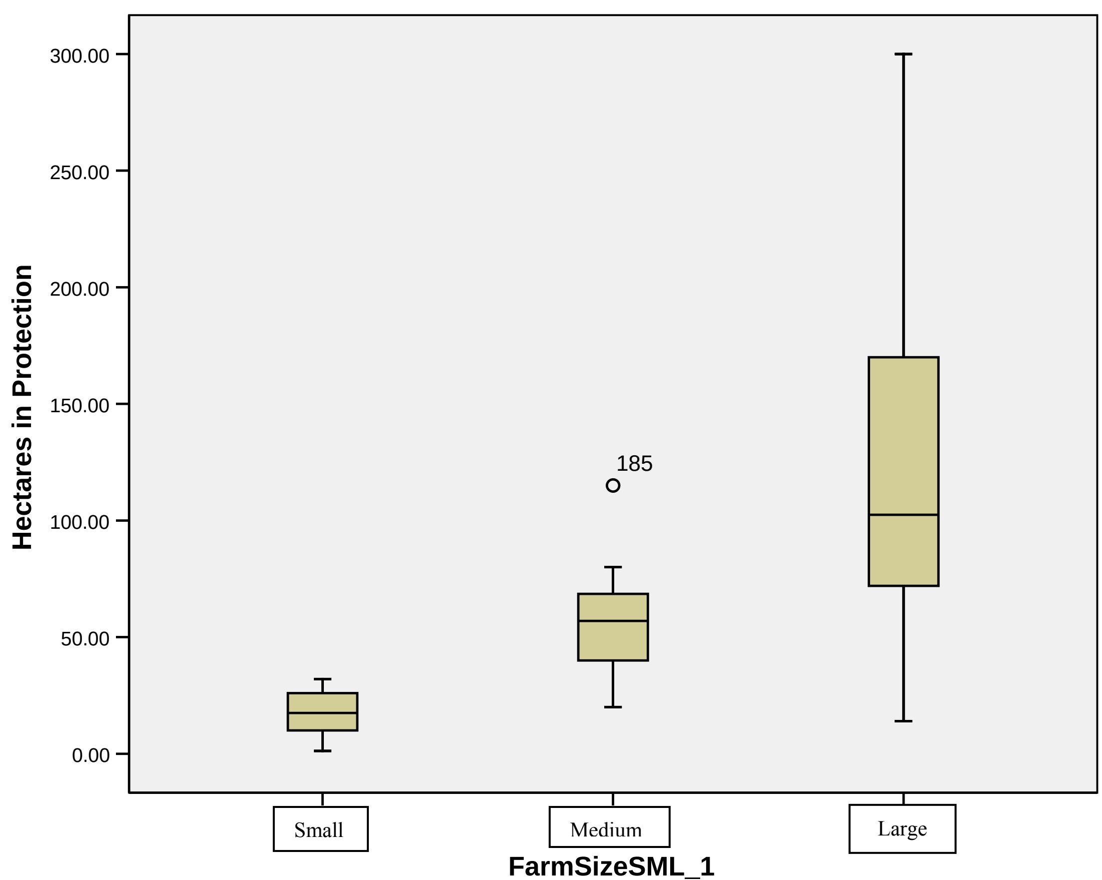
Case Processing Summary

	Category	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
All farms combined SML	1.00 Small	88	100.0%	0	.0%	88	100.0%
	2.00 Medium	83	100.0%	0	.0%	83	100.0%
	3.00 Large	26	100.0%	0	.0%	26	100.0%

Figure 2: Means and medians for self-reported farm size for all survey respondents (N=207).

	Statistic	Hectares	Std. Error
Small	Mean	23.9	3.1
	95% CI lower bound	17.8	
	95% CI upper bound	29.9	
	Median	12.5	
Medium	Mean	97.1	8.9
	95% CI lower bound	79.3	
	95% CI upper bound	114.9	
	Median	72	
Large	Mean	181.2	29.2
	95% CI lower bound	121	
	95% CI upper bound	241.5	
	Median	140	

Figure 3: Size of forest contract by farm size



CHAPTER 4

Consequences of Environmental Service Payments for Forest Retention and Recruitment in a Costa Rican Biological Corridor

Abstract

Compensation to landowners for forest-derived environmental services has gained international recognition as a mechanism to combat forest loss and fragmentation. This approach is widely promoted with little evidence demonstrating its prospects for encouraging forest stewardship and conservation. Costa Rica provides a compelling case study where a 1996 Forestry Law initiated environmental service payments and prohibited forest conversion to other land uses. We examined these novel policies to determine their influence on landowner decisions that affect forest change, carbon services, and connectivity in a 2,400 km^2 biological corridor. Landsat images were used to compare landcover changes before and after 1996, and these data were linked to landowner surveys investigating land use decisions. Carbon services provided by secondary forests were examined both above- and belowground. Forest change observations were corroborated by landowner survey data, indicating that environmental service payments contributed positively to forest retention and recruitment following implementation of the 1996 Forestry Law. Rates of natural forest loss declined from -1.43 to -0.20 % yr^{-1}. Forest cover and connectivity increased through tree plantations and secondary forest recruitment, but these forest types sometimes replaced natural forest prior to 1996. Secondary forest carbon storage approached values found in primary forest after 25-30 years of succession, though few landowners retained natural regeneration. Secondary forests and attendant carbon services will persist as minor landscape components without legal or financial incentives. The Costa Rican experience provides evidence that environmental service payments can be effective in retaining natural forest and recruiting tree cover when focused in biological corridors.

Introduction

Forest loss and fragmentation represent a global threat to biodiversity, ecosystem processes, and human welfare (Millennium Ecosystem Assessment, 2005). Demands on forests and the environmental services they provide are projected to increase as development pressures reduce remaining private forests lacking protected status (Defries, Hansen, A., Newton & Hansen, M., 2005). In response to these threats, incentive programs encouraging private forest stewardship have emerged, offering compensation to landowners who retain forests and associated services that might otherwise be lost to alternative land uses (Pagiola, Bishop & Landell-Mills, 2002). Direct payments to landowners to plant or protect forests are promoted as an effective mechanism for providing environmental services (Ferraro & Kiss, 2002), consistent with the 1997 Kyoto Protocol and the 1992 Convention on Biological Diversity. However, the effects of these payments on forest cover and targeted environmental services remain relatively unknown.

Costa Rica presents a compelling case study to analyze an environmental service payment program (*pago por servicios ambientales*, PES) that provides direct payments to landowners for reforestation, sustainable forest management, and natural forest protection. Reforestation incentives for private landowners to establish tree plantations were first initiated in Costa Rica following several decades of high deforestation (Watson et al., 1998). During the mid-1980s, tradable bonds (CAF) and upfront payments (CAFA) became available to cover costs associated with establishing and maintaining tree plantations (Watson et al., 1998). Additional incentives initiated in 1990 targeted sustainable forest management (CAFMA) and were expanded in 1995 to include forest protection. Costa Rica built on the legacy of these programs with the 1996 Forestry Law (no. 7575) that implemented four novel features including: 1) a national definition of forest; 2) prohibition of natural forest conversion to any other land use; 3) deregulation of tree plantation management; and 4) a voluntary PES program to compensate landowners for watershed protection, biodiversity conservation, carbon sequestration, and aesthetic values.

Legal and institutional support for the PES program is provided by the National Fund for Forest Financing (FONAFIFO), an organization designed to promote sustainable rural development among small and medium-sized landowners (Snider, Pattanayak, Sills & Schuler, 2003). National PES priorities have concentrated efforts in biological corridors and poorly developed regions of the country with more than US$124 million expended on >5000 km^2 of land (FONAFIFO, 2006). PES contracts with landowners typically last for five years and payments range from ~$220 ha^{-1} for the forest protection program to $560 ha^{-1} for reforestation.

The objectives of 1996 Forestry Law and PES are to provide environmental services through forest stewardship; however their impacts on carbon storage, forest structure, and connectivity in fragmented landscapes are unclear. Further, the relative influence of forest policies and programs on landowner decisions to maintain or increase forest cover remains poorly understood. Accordingly, we applied an integrated research approach to determine the extent to which the 1996 Forestry Law and PES incentives for landowners to maintain or replant forests translate into enhanced forest conservation, carbon services, and connectivity. We studied these processes in the San Juan ─ La Selva Biological Corridor, a PES focal area designed to retain linkages between protected areas in Costa Rica and southern Nicaragua (Figure 1).

Studies of landcover change detection, ecosystem ecology, and rural sociology were unified to address five specific questions: 1) Has the annual rate of forest loss declined substantially for private forest land in the Corridor as expected under the 1996 Forestry Law?; 2) To what extent are changes in forest cover attributable to the ban on forest clearing and/or payments to protect forests?; 3) Have incentives for reforestation been a major catalyst for landowners to establish tree plantations?; 4) What is the outlook for recruiting forest cover via secondary succession as a potential source of valued carbon services under the 1996 Forestry Law?; and 5) Are PES programs an effective conservation mechanism for retaining habitat connectivity between protected areas?

Study Area

The present case study focuses on the San Juan – La Selva Biological Corridor (2,425 km^2) in northern Costa Rica where PES contracts occur on ~22% (538 km^2) of the land area (Rojas and Chaverría 2005). A larger surrounding study area (6,349 km^2) was selected to facilitate forest land change comparisons in areas bordering the Corridor (Figure 1). The Corridor contains one of the largest aggregations of remnant forest in the region, and private forests outside of protected areas represent an important connection between formerly continuous montane and lowland forests (Butterfield, 1994a). Diverse vegetation types in the

Corridor cross five Holdridge Life Zones and three transitional zones given the region's varied climatic conditions along altitudinal and longitudinal gradients (Holdridge, 1967).

Costa Rica passed its first Forestry Law in 1969 (no. 4465) that has since undergone several revisions. However, agricultural development and colonization programs have taken precedent over forest stewardship, leading to forest cover reductions in the country's northern region since c. 1950 (Butterfield, 1994b). Colonization programs expanded roads and settlements during the 1970s to open territory to landless farmers (Butterfield, 1994b), while low interest loans for cattle production and high beef prices further enhanced land colonization and conversion of forest to pasture (Schelhas, 1996). Forests were used as an open access resource by colonists, contributing to rapid deforestation and highly fragmented landscape conditions (Butterfield, 1994a).

A severe economic crisis at the end of the 1970s forced Costa Rica to accept monetary assistance (Montanye, Vargas & Hall, 2000) tied to a series of structural adjustment loans that led to the promotion of non-traditional export crops (e.g. pineapple, heart of palm) (De Camino, Segura, Arias & Perez, 2000). Cattle exports dropped significantly in the early 1980s and cattle herd sizes declined after 1988 (Ibrahim, Abarca & Flores, 2000). This trend reduced pressure to clear natural forest and led to temporary abandonment of some pastures. However, many pastures were soon converted to crops or used for government land redistribution programs (Butterfield, 1994b). Costa Rica continued the promotion of export crops simultaneous with conservation initiatives throughout the 1990s. Evolving development strategies continue to raise questions about how forests will fare under new policies.

Methodology

Several data integration efforts were used to address the research questions above. We compared forest retention, recruitment, and other landcover changes derived from satellite images before and after 1996 with landowner surveys to evaluate the influence of forest policy and PES incentives on observed forest patterns. We also examined secondary forest carbon storage using plot-level data linked to landcover changes and landowner decisions regarding secondary forest establishment. Finally, we employed forest connectivity metrics as a unifying measure of forest retention and recruitment within the Corridor.

Forest and Landcover Change

We selected five Landsat Thematic Mapper (TM) satellite images (WRS Path 15 Row 53) with low cloud cover from years 1986, 1996/97, and 2001 to observe landcover changes before and after implementation of the 1996 Forestry Law. For simplicity, we refer to the time period before the 1996 law (1986-1996) as T1 and the period afterward (1996-2001) as T2. ENVI v.4.1 image processing software (RSI 2004) was used to prepare and classify images. All images were individually co-registered to a 1996 TM image referenced to locations on the ground for spatially accurate comparisons.

Forest and landcover categories were selected based on prior landcover information for northern Costa Rica from 1996 (Pedroni, 2003). Five forest categories were used for landcover change detection analyses including: 1) natural forest (closed canopy or selectively logged old-growth forest and natural palm swamps); 2) a *charral* phase (native shrub and herbaceous regeneration); 3) secondary forest (native tree-dominated regrowth up to 15-20 years old); 4) tree plantations (mainly traditional single species exotic or native reforestation); and 5) gallery forest (forest retained along watercourses comprised of remnant trees and forest regrowth). Additionally, we identified two agricultural land use categories: 6) pastures; and 7) annual or perennial crops (e.g. pineapple, sugarcane, bananas, heart of palm).

A supervised image classification was implemented using the Rulegen extension in ENVI v. 4.1 and the Quick, Unbiased, Efficient, Statistical Tree algorithm by Loh and Shih (1996). Elevation, topographic moisture index, percent slope derived from a 90 m digital elevation model (DEM), and the Normalized Difference Vegetation Index (NDVI) were used in addition to TM bands 1-5 and 7 to enhance discrimination of forest and landcover types. Training sites for each category were selected from aerial photos, forest inventory maps, and ground reference points collected in the field between 2004 and 2005. The spatial grain of each landcover category was set at a 1 ha minimum mapping unit for comparisons between image dates.

A classification accuracy evaluation for landcover data obtained an average of 94% overall accuracy with a difference of ±3% between dates and an average kappa score 0.93 scaled at -1 to 1 for all image dates (cf. Congalton and Green, 1999). Forest categories showed an acceptable degree of accuracy that averaged from 71% for gallery forests to 95%

for natural forests. Landscape complexity increased with time generating lower, but acceptable class accuracy above 80% in later image dates for all classes but gallery forests.

We used area summaries for landcover categories from each image date to compare the larger case study area and the Corridor where PES programs are focused. Differences in rates of change in forest categories were used to compare forest retention and recovery in T1 and T2 within the Corridor. An annual rate of change for each period and forest category was estimated using a standardized rate formula by Puyravaud (2003),

$$r = (1/t_2 - t_1)) \times \ln(A_2/A_1)$$

where A_1 is the forest area at the first time interval (t_1) and A_2 is the forest area at the second time interval (t_2). Additionally, Wilcoxon Signed Rank tests compared the size distribution of patches ≥1 ha in size converted from a forest type to another land use category across T1 and T2. The FRAGSTATS spatial statistics package (v. 3.3 build 5; McGarigal, 2002) calculated patch cohesion, percentage of like adjacencies, and mean Euclidean nearest neighbor metrics as indicators of connectivity, aggregation, and isolation for the Corridor. We compared fragmentation indices across the three image dates at the landscape level and for each forest type.

Landowner Decision Making

To help explain landcover changes in T1 and T2 and identify whether forest policies and PES incentives positively influenced landowner decisions to retain natural forest and participate in reforestation programs, we conducted a livelihoods analysis examining household decisions in the context of national and international economic markets and policies (Geist and Lambin, 2001; DFID, 2003). A household survey instrument was used to collect data about historical on-farm tree management including natural forest, *charral*, secondary forest, tree plantations, and gallery forest. The survey measured the five livelihood assets (social, human, financial, physical, and natural) and explored the influence of the 1996 Forestry Law and PES on land use decisions, motivations to enroll land in PES programs, production options, and future plans for forest currently enlisted in PES. As PES is a voluntary program, participants and non-participants were compared across livelihood assets to identify variables likely to influence participation.

We used a FONAFIFO database of all PES participants (n=510) to randomly select a sample of 99 households within the Corridor. Those receiving reforestation incentives from previous programs (e.g. CAF, CAFA) were included as participants because their payment contracts were continued under the 1996 Forestry Law. A sample of 108 non-participants was selected from the Ministry of Agriculture's 2000 Costa Rican Cattle Census and paired spatially with those in the participant sample. Sample sizes provided a sampling error of ±10% (Salant and Dillman 1994) with only 6 refusals. The unit of analysis was the household, and a research team administered questionnaires via face-to-face survey interviews averaging one hour per household.

Summary data were developed from specific questions regarding on-farm tree management and motivations to participate in PES programs. A decision tree analysis was used to compare the livelihood assets of incentive program participants and non-participants. Decision-tree thresholds provide the break point values used to identify boundary levels of assets where incentives may induce landowner participation in a PES program. Participants with forest protection and management contracts were analyzed separately from those with reforestation because ownership of ≥2 ha of forest land is required by the former two PES options.

Above- and Below-Ground Carbon Storage in Secondary Forests

We selected a chronosequence of twelve secondary forest sites developing on former pasture to examine secondary forest development and the potential of these forests to provide environmental services via carbon storage. Secondary forest development as a mode of forest recruitment was probed in landowner surveys, and the selected study sites represent *charral*, secondary forest, and pasture landcover types identified in the land change detection. Sites included: 1) three young sites in the *charral* phase of development, characterized primarily by shrubs and herbaceous cover; 2) nine older secondary forest sites eligible for legal classification as forest by 1996 Forestry Law standards; and 3) four active pastures grazed for at least 18 years. Fifteen sites were located on acidic, highly weathered Ultisols derived from volcanic parent material, and the remaining site was located on an Inceptisol derived from alluvial deposits.

At each site, soil samples were collected from four locations in each of three plots at depths of 0-10, 10-20, and 20-30 cm. Three samples per depth were composited for percent soil carbon determination, and the fourth sample was used for bulk density determination.

We derived soil carbon content at the Idaho Stable Isotopes Laboratory, and data are reported on a volume basis.

Within the nine secondary forest sites, three 50×50 m plots were established to determine species and diameter at breast height (1.37 m, dbh) for all trees, palms, and lianas ≥5 cm dbh. When present, dbh measurements were made above buttresses. Data were used to estimate total aboveground biomass using the equation for wet forest stands by Chave and others (2005) that accounts for differences in wood density among species. Estimates of aboveground biomass were multiplied by 0.5 to determine aboveground carbon storage. Remnant trees comprised of stems ≥60 cm dbh (<1% of all stems at these sites) were removed from the dataset.

For soil carbon analyses, we employed the statistical language R (v. 2.0.1, R Development Core Team 2004). Mean soil carbon storage was analyzed separately by depth class, and linear mixed-effects models (Pinheiro & Bates, 2000) were used to examine changes across land use types. Significant differences detected with analysis of variance (ANOVA) were further examined via multiple comparisons procedures.

Results and Discussion

Patterns of Natural Forest Retention

Notable differences in the status of natural forest occurred between the larger study area and Corridor over a relatively short time period (15 yrs). Land change estimates showed a striking decrease in the annual rate of natural forest loss from -1.43% yr^{-1} in T1 to -0.20% yr^{-1} during T2 inside the Corridor (Table 1). Natural forest loss in T2 occurred primarily outside the Corridor in areas that became an increasingly heterogeneous mixture of pasture, crops, and tree plantations (Fig. 2a; b). This pattern indicates that areas outside the Corridor remained vulnerable to forest loss regardless of the 1996 Forestry Law's forest change restrictions. Reduced forest loss in the Corridor, where a high density of forest protection and management contracts were established during T2, was concurrent with implementation of the 1996 Forestry Law and PES. High rates of forest loss during T1 were consistent with other forest change studies conducted in the region (Read, Denslow & Guzman, 2001; Sánchez-Azofeifa, Daily, Pfaff & Busch, 2003). Significantly larger natural forest patches were converted to other land uses in T1 relative to T2 (p <0.001). Large contiguous forest patches (>150 ha) were removed prior to 1996 (67 in T1 vs. 5 in T2), creating highly fragmented forest conditions in the northeastern portion of the Corridor (Figure 3).

Data from landowner surveys showed that 65% of the total sample population owned natural forest and 59% of these individuals received payments for protection. Forty-four percent of landowners receiving PES did not intend to clear or harvest any forest. However, 33% of respondents with PES indicated that they would convert some of their forest to pasture or crops, while 19% would harvest some timber in the absence of PES and the Forestry Law's legal restrictions on forest land use change. Therefore, PES payments provided protection against forest clearing and harvesting. This is in contrast to findings from landowners interviews on Costa Rica's Osa Peninsula where PES was found to have little to no immediate impact on forest protection (Sierra & Russman, 2006).

A landowner's dependence upon his or her farm as a primary source of income constituted the principal livelihood variable differentiating PES participants from non-participants in the forest protection and management programs ($p < 0.0001$). Participants had a lesser dependence on their farms for income than non-participants, suggesting that individuals whose livelihoods depended less directly on farm income were more likely to participate in PES. Our observations confirm similar patterns found in this and other regions of Costa Rica (Miranda, Porras & Moreno, 2003; Zbinden & Lee 2005). However, the PES program for forest protection effectively competed with other opportunity costs of forest land, in that it was common for landowners with up to 73% of their income derived from the farm to participate in PES. Production options for private forest remain limited to timber extraction because of the 1996 Forestry Law's ban on forest clearing. Permits to harvest are limited, so those unable to obtain permits have an opportunity cost of foregone production near zero, and thus, can only gain by entering into a PES contract. Pagiola, Bishop & Landell-Mills (2002) noted an excess national demand for the PES protection program, implying that the same amount of forest protection could likely be provided at lower payment rates (Rojas and Aylward 2003).

Forest Recruitment: Reforestation

Results from landcover comparisons show that forest cover increased over both time periods with positive consequences for environmental services, primarily during T2. A net gain in forest cover of 0.5% yr^{-1} occurred in T1 and 0.6% yr^{-1} in T2 (Table 1), although gains after 1996 were concurrent with greatly reduced natural forest loss. In general, land withdrawn from forest cover may constitute a loss of environmental services such as biodiversity and carbon sequestration (Snider, Pattanayak, Sills & Schuler, 2003). Increased forest cover in the Corridor for both time periods was mainly the result of a large increase in tree plantations (Figure 2a) established in pastures. Tree plantations increased from 19 km^2 in 1986 to 268 km^2, representing 11% of the total land area in 2001 (Figure 3). These figures compared favorably to the cumulative total of ~380 km^2 reported to have been planted regionally up to 2001 (COSEFORMA, 1995; Méndez, 2003).

The rate of tree plantation establishment decreased from 24 to 4.6% yr^{-1} during T1 and T2, respectively (Table 1), with significantly smaller pastures planted after 1996 ($p < 0.05$). A number of tree plantations were either harvested or overtaken by natural regeneration by 2001 (data not shown). Although we detected substantial increases in forest cover under plantations, regional figures show that on an area basis, PES for forest protection (51%) and management (33%) were favored over reforestation programs (17%) (Méndez, 2003). These statistics reflect national priorities to reduce forest loss via PES for forest protection (Snider Pattanayak, Sills & Schuler, 2003) rather than promote forest recruitment through reforestation. Because forest plantation conversion to other land uses is permitted, their long-term contribution to forest cover and environmental services in this landscape is uncertain.

The trends described above indicate that reforestation incentives fueled a rapid expansion of tree plantations in the Corridor since 1986. Nearly one third of all landowners interviewed (31%) maintained tree plantations on their farms, and the majority (60%) were established through PES reforestation contracts. Primary motivations for plantation establishment included perceived value of the wood (40%), meeting conservation objectives such as biodiversity protection (20%), and availability of payments (17%). Most reforested land was converted from pasture (88%) while 12% was formerly crop land. Fifty-three percent of landowners indicated satisfaction with the level of PES payments, with remaining landowners indicating that payments did not meet expected costs. Of those with PES, a majority (68%) would not have reforested without payments to cover establishment and maintenance costs, demonstrating the importance of financial incentives to induce landowner participation in reforestation activities.

Of those with reforestation under the PES program, a majority (59%) intended to plant another crop of trees after harvesting their current plantation while a quarter (24%) indicated they would not replant, and 17% remained undecided until final harvests. Landowners reforesting without PES incentives showed similar patterns. The majority of landowners have adopted forest plantations as a viable economic activity, competitive with other land use options and economic opportunities.

Reforestation incentives were a critical factor in forest cover gained from tree plantations during T1 and T2. A landowner's dependence on his or her farm as a primary source of income was the primary livelihood variable differentiating PES reforestation participants from non-participants (p <0.0001). However, a division between groups occurred at the point where 16% of the household income was derived from the farm, with individuals more likely to participate below this point. Results show that PES for reforestation remains uncommon for landowners moderately dependent upon their farms as a source of income, indicating that payment rates are not adequate to motivate most farm-dependent individuals to forgo current production systems.

Forest Recruitment: Secondary Vegetation and Gallery Forest

Successional vegetation occupied between 8 and 10% of the Corridor area at any one point in time, maintaining persistent areas of natural regeneration in the Corridor (Figure 3). However, the total land area in the early successional *charral* phase declined during the study period from 9% in 1986 to 4% in 2001 (Figure 2a), indicating that the outlook for recruiting new secondary forest stands was lower after 1996. Although land area in secondary forest increased slightly after 1996, the patch size of both secondary forest and *charral* areas recruited significantly declined (p < 0.001). Additions to the area occupied by secondary forest (Table 1) during T2 accounted for some of the losses in the *charral* phase as succession proceeded.

Our landcover data show that forest recruitment via secondary succession may represent only temporary gains in connectivity and short-lived opportunities for habitat restoration. An overall decline in land area occupied by *charral* (Table 1) indicates that landowners abandoned very little pasture land throughout the study period, as observed previously by Read, Denslow & Guzzman (2001). The low level of secondary forest establishment in the Corridor did not follow patterns of agricultural abandonment conducive to forest recruitment encountered elsewhere in Costa Rica (Arroyo-Mora, Sanchez-Azofeifa, Rivard, Calvo & Janzen, 2005). The amount of pasture land allowed to recover to the *charral* stage was offset by a greater amount being returned to pasture in both T1 and T2. This observation is corroborated by data from landowner surveys indicating that only 13% of respondents had *charral* on their property. Of these individuals, 56% maintained *charral* for economic reasons, while 20% cited conservation reasons. The role of economics in decisions to maintain *charral* shows that natural forest regeneration in the Corridor was likely limited by PES incentives for reforestation, agricultural export opportunities, and restrictions in the 1996 Forestry Law prohibiting land use change.

Survey data supports the observation that much of the land converted to *charral* (68%) or secondary forest during our study period previously existed as pasture (Figure 2; 4). Although *charral* and secondary forest occupy a small amount of land area relative to natural forest, these forest types are ecologically important as sites for forest recruitment, carbon sequestration, and habitat restoration (Holl & Kapelle, 1999). *Charral* typically persists on abandoned land for a short period of time before a tree canopy develops, but restrictions on forest clearing provide incentives for landowners to inhibit the development of secondary forest (Sierra and Russman 2006). Surveyed landowners planned to clear 43% of existing *charral* for pasture or agricultural use in the future, thus limiting the potential for carbon storage (Murty, Kirschbaum, McMurtrie & McGilvray, 2002).

Transitions from pasture to secondary forest reveal differences in carbon storage at shallow soil depths. Pastures contained a greater amount of mineral soil carbon at 0-10 cm relative to *charral* and secondary forest, but there was high variability within land use classes (Table 3). Mineral soil carbon storage in pastures rapidly decreased with depth, and both *charral* and secondary forests had significantly higher soil carbon storage than did pastures at depths of 10-30 cm (Table 3). High levels of soil carbon storage in *charral* at 10-30 cm depth likely occurs from shifts in rooting depth and subsequent alteration of organic carbon inputs to the soil at an early successional phase (Jackson, Canadell, Ehleringer, Mooney, Sala & Schulze, 1996; Jobbágy and Jackson 2000). A decline in soil carbon storage at these depths in secondary forest relative to *charral* was not unexpected, as these sites were dominated by more deeply rooted trees.

Managed crops remain a competitive land use with secondary forest on former pasture (Figure 4), and agricultural transitions can decrease soil carbon stores up to 30% during the first decades of cultivation (Murty Kirschbaum, McMurtrie & McGilvray, 2002). Survey respondents also suggested reforestation as another common land use option on former pasture land (Figure 4), and although plantations often increase soil carbon storage in the tropics (Silver, Ostertag & Lugo, 2000); this is not always the case (Powers, 2004). In relation to competing land uses, secondary forests may provide considerable carbon services.

Above- and belowground carbon storage rapidly increased toward values observed in primary forest following secondary forest establishment. For 0-30 cm, soil carbon storage in secondary forests was slightly lower (70.9 Mg C ha^{-1}) than the regional mean of 82.2 Mg C ha^{-1} in primary forests (Powers & Schlesinger, 2002). Aboveground, secondary forest stands appear to pass through a period of low biomass accumulation and reach the point of stem exclusion after 20 to 25 years of development (Figure 5). Following this phase, 25 to 30 year old secondary forests had aboveground carbon stocks equivalent to those in primary forests of the region (Figure 5; Clark & Clark 2000). The carbon services provided by secondary forest rival those of natural forest and merit greater attention from forest management and policy perspectives. Our data show that forest policies and incentives have effectively influenced land-use decisions for tree plantations, and similar incentives for natural regeneration could enhance carbon storage as a targeted PES environmental service.

In addition to carbon storage, benefits accruing from secondary forest recovery include forest structural connectivity, natural habitat development, and new timber resources (Finegan, 1992; Lamb, Parrotta, Keenan & Tucker, 1997). Secondary forests provide a number of potential economic and restoration opportunities that contribute positively to the goals of the San Juan-La Selva Biological Corridor. The existence of competing land uses with greater financial returns than secondary forest suggests that financial incentives and technical support may be necessary to secure the environmental services provided by these forests. The recent introduction of PES for natural regeneration (FONAFIFO, 2006) represents significant progress in acknowledging the benefits of secondary forest, though the program remains confined to western Costa Rica.

Gallery forests also have important consequences for recruiting forest cover in the Corridor, increasing from 2 to 6% of the total land area during T1 and T2, respectively

(Table 1). Linear forest arrangements of remnant trees and secondary vegetation were retained along waterways as surrounding forests were cleared in T1. We interpreted an increase in post-1996 gallery forests as forest recruitment because few large patches of natural forest were removed in T2. Forest land along perennial rivers and streams has received protection by laws designed to conserve water resources since 1942. Eighty-five percent of landowners sampled in the Corridor had land occupied by gallery forest. Recruitment patterns in T2 reflect a social commitment to protecting water resources as 87% of survey respondents gave conservation-oriented reasons for retaining tree cover in riparian areas.

Forest and Landscape Connectivity

We analyzed the spatial and temporal arrangement of forests in the Corridor as an indicator of physical connectivity among protected and privately owned forests. Connectivity varied across T1 and T2 for total forest cover (landscape indices) and individual forest types (class indices). Landscape indices in the Corridor showed a decline in connectivity and aggregation among all forest patches during T1, and a maintenance of conditions with some enhanced connectivity during T2 (Table 2). These patterns reflected the higher rate of natural forest loss observed in T1 relative to T2 (Table 2), but can be partially explained by the development of increasingly heterogeneous forest conditions. At the class level, natural forests comprised the majority of total forest cover and became increasingly distant from one another over time, reflected by increased isolation and decreased aggregation (Table 2). In contrast, patterns in reforestation, forest regrowth, and gallery forest showed trends with an overall positive impact on forest connectivity and aggregation (Table 2). Patches of reforestation and secondary forest regrowth tended to aggregate in a few areas of the Corridor (Figure 3).

Greater natural forest retention in T2 and recruitment throughout the study period indicates that the 1996 Forestry Law and prior reforestation programs contributed to a net increase in forest connectivity. Landowner decisions to participate in PES programs have increasingly affected the process of reconnecting forests in this landscape. Though monocultures of fast growing exotic species occupy many of the reforested areas, a recent shift toward native tree species has occurred. Native species plantations have the potential to support diverse understory flora (Cusack & Montagnini, 2004) and attract wildlife (Lamb, Parrotta, Keenan & Tucker, 1997), but the overriding homogeneity of tree plantations may detract from natural forest connectivity. During T1 some tree plantations with low species and structural diversity replaced natural forests following short-term use as pasture. After this land use change became illegal in T2, significantly fewer natural forest patches were converted to tree plantations ($\Delta T1 > \Delta T2$, $p < 0.001$).

Secondary forests play a role in maintaining forest structural connectivity, often developing on land adjacent to natural forest (Figure 3). The benefits of secondary forest cover on the landscape in terms of forest connectivity, biodiversity value, and carbon services may outweigh those of tree plantations in light of 1996 Forestry Law objectives. As secondary vegetation reaches a successional stage with at least 60 tree stems >15 cm dbh ha^{-1}, it is legally classified as forest and can no longer be cleared for alternate land uses. Because plantations are harvested on short rotations and can be legally converted to non-forest uses, retention of new forest cover through secondary succession is more likely to be a permanent type of forest cover. However, secondary forests are likely to have a less positive economic impact on local livelihoods when compared to plantations.

Many of Costa Rica's recognized corridor areas resemble stepping stones of forest habitat within agriculturally-dominated landscapes because intensively managed crops typically support little or no tree cover. The implications of the 1996 Forestry Law in conjunction with the data reported here reflect on an emerging importance of forest recruitment via a variety of pathways. As natural forests were replaced by reforestation and secondary forests, a fundamental change in forest structural connectivity occurred. This highlights the need to examine the functional role of these new forest connections where forest cover is best characterized as a mosaic of habitats with variable economic and ecological potential.

Conclusions

Costa Rica's innovative strategies to maintain private forest land and environmental services showed notable progress toward these goals in the Corridor. The rate of natural forest loss was substantially less after 1996 relative to the previous time period. Legal restrictions in the 1996 Forestry Law forbidding land use change reduced the opportunity cost of forest land, influencing landowners moderately dependent on their farms for income to participate in the PES forest protection program. Continued high rates of natural forest loss outside the Corridor after 1996 indicated that restrictions on forest clearing without the benefit of PES were not sufficient to induce forest retention in this region.

PES directly influenced landowner decisions to substantially increase forest recruitment during the study period. Specifically, reforestation incentives prior to PES led to a dramatic increase in plantation forests during T1, while a slower increase occurred following PES implementation in T2. Forest recruitment via secondary forest development occupied a relatively constant amount of land area in the Corridor through time. However, disincentives for secondary forest development existed in the form of lost land use opportunities once an area returned to forest. Carbon services provided by 25-30 year old secondary forests were similar to those in primary forest, suggesting that these forests deserve greater attention from a land management perspective.

Positive outcomes of the 1996 Forestry Law were further illustrated by changes in forest cover dynamics that enhanced forest structural connectivity in the Corridor in T2, relative to T1. In the future, adaptations of the PES program such as that recently implemented for natural regeneration in western Costa Rica will continue to provide flexibility in tailoring the program to diverse and changing landscapes. As a case study, the Costa Rican experience with PES provides evidence that environmental service payment programs in conjunction with legal forest protection are effective in retaining natural forest and recruiting new forest cover when focused in the Corridor as a priority conservation area. PES has been tailored to fit Costa Rica's socioeconomic conditions, but shows promise as an effective conservation approach with prospects for adaptation to other settings.

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Tables

Table 1. The amount of forest lost or gained during each time period estimated by subtracting the total area for each forest category in the corridor from the previous year's land cover data (Δ*T1*=1986-96, Δ*T2*=1996-01). The annual rates of forest cover change by type and net forest gain before and after 1996 were estimated using the formula by Puyravaud (2003) and expressed as percentages. Net forest cover includes all five forest types.

Forest cover type	Δ*T1* (km^2)	Δ*T1* yr^{-1} (%)	Δ*T2* (km^2)	Δ*T2* yr^{-1} (%)
Natural forest	-179	-1.43	-12	-0.20
Reforestation	194	24.15	55	4.57
Charral	-42	-2.25	-60	-8.93
Secondary forest	69	18.95	20	4.31
Gallery forest	36	5.21	48	8.66
Net forest cover	78	0.47	50	0.58

Table 2. Fragmentation indices for the Corridor landscape and individual forest classes indicating changes in physical connectivity at each landcover date. The level of isolation was determined using Euclidean nearest neighbor distance (ENN) to measure isolation, patch cohesion (PC) as an indicator for physical connectivity among like patches, and percentage of like adjacencies (PLA) as a measure of aggregation of similar patches.

	Isolation ENN (m)			Connectivity PC (%)			Aggregation PLA (%)		
Category	**1986**	**1996**	**2001**	**1986**	**1996**	**2001**	**1986**	**1996**	**2001**
Landscape	256.2	241.8	249.0	99.3	99.0	98.9	89.8	88.1	88.3
Natural forest	130.6	135.4	142.7	99.76	99.68	99.68	94.83	94.02	93.91
Reforestation	337.0	202.3	187.9	86.59	97.06	97.91	71.34	81.81	81.36
Charral	164.3	191.1	250.9	93.28	93.33	93.82	74.14	75.20	77.28
Secondary forest	526.4	215.7	227.9	83.46	89.09	92.68	67.39	70.48	74.05
Gallery forest	238.5	216.9	188.1	87.57	89.20	92.19	67.66	71.78	74.57

Table 3. Means of mineral soil carbon storage ± one standard error across all land use types and soil depths. Reported *p*-values were derived from individual ANOVAs performed for each soil depth. Superscripted letters represent the result of means separation performed using pre-planned contrasts in the Multcomp package of R. Different superscripted letters represent significant differences among categories.

Soil depth	Pasture soil carbon (Mg ha^{-1})	*Charral* soil carbon (Mg ha^{-1})	Secondary forest soil carbon (Mg ha^{-1})	*p*-value
0-10 cm	43.69 ± 3.09[a]	34.65 ± 2.31[b]	35.70 ± 1.13[b]	0.012
10-20 cm	18.71 ± 1.38[a]	25.00 ± 1.63[b]	20.65 ± 0.69[c]	0.0048
20-30 cm	12.60 ± 0.65[a]	17.53 ± 1.63[b]	14.57 ± 0.73[c]	0.0167

Figures

Figure 1. Map of the San Juan – La Selva Biological Corridor, connecting national parks and protected areas, and the larger study area. Depicted natural forest cover is for year 2000 (Atlas of Costa Rica 2004).

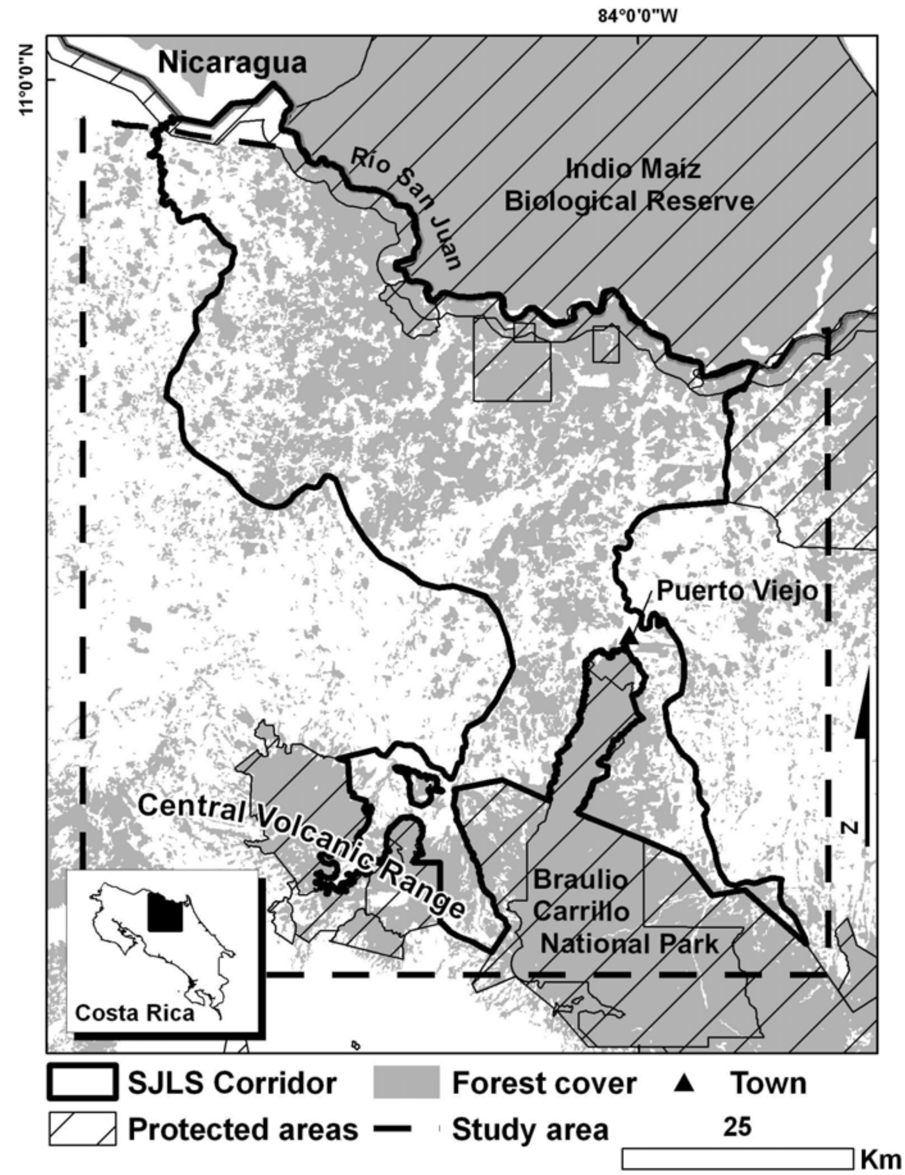


Figure 2. Area differences for each time interval for (a) the five forest categories and (b) two agricultural categories observed at the extent of the study area (6,349 km^2) and the San Juan – La Selva Biological Corridor (2,425 km^2). Dotted lines above the natural forest category show the top of the bar in year 2001, indicating that a greater percentage of natural forest loss occurred outside of the Corridor after 1996.

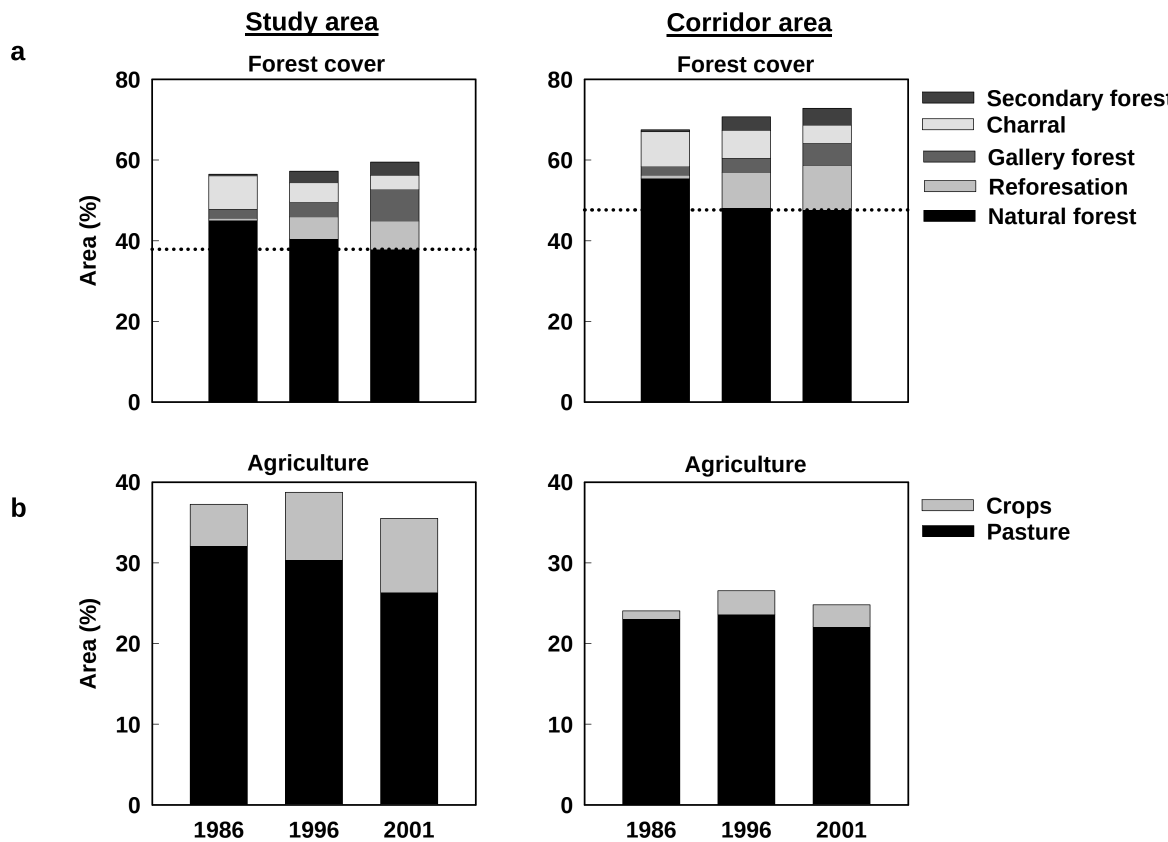


Figure 3. Mapped forest cover in the San Juan – La Selva Biological Corridor depicting major landscape changes at each time interval using the forest categories natural forest (dark green), forest regrowth (*charral* and secondary forest, bright green), and reforestation (orange).

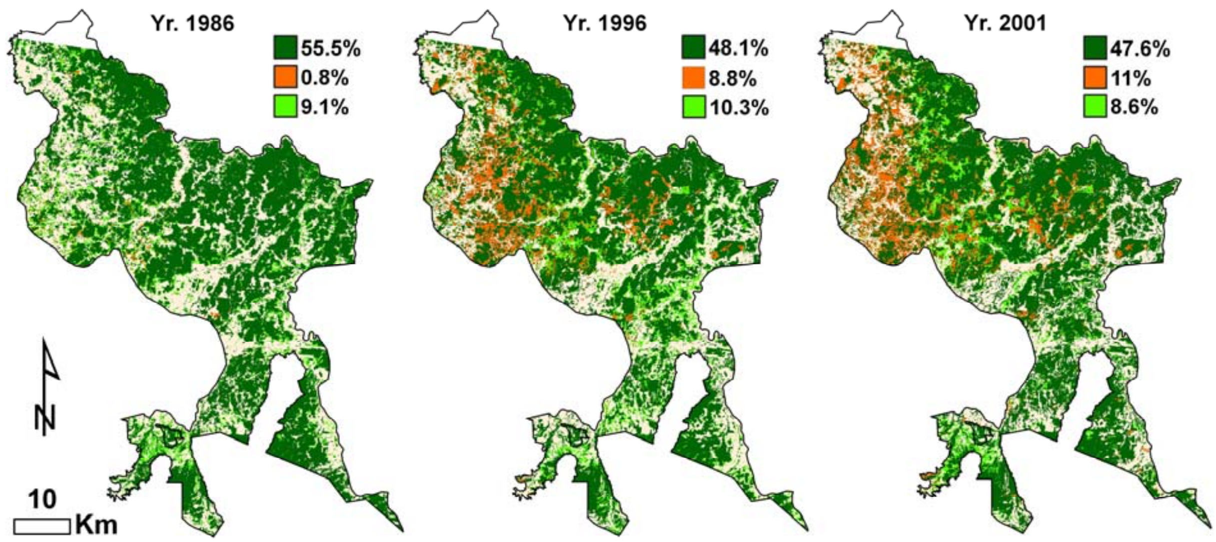


Figure 4. Amount of pasture converted to another forest or landcover type in the San Juan – La Selva Biological Corridor during time periods T1 and T2.

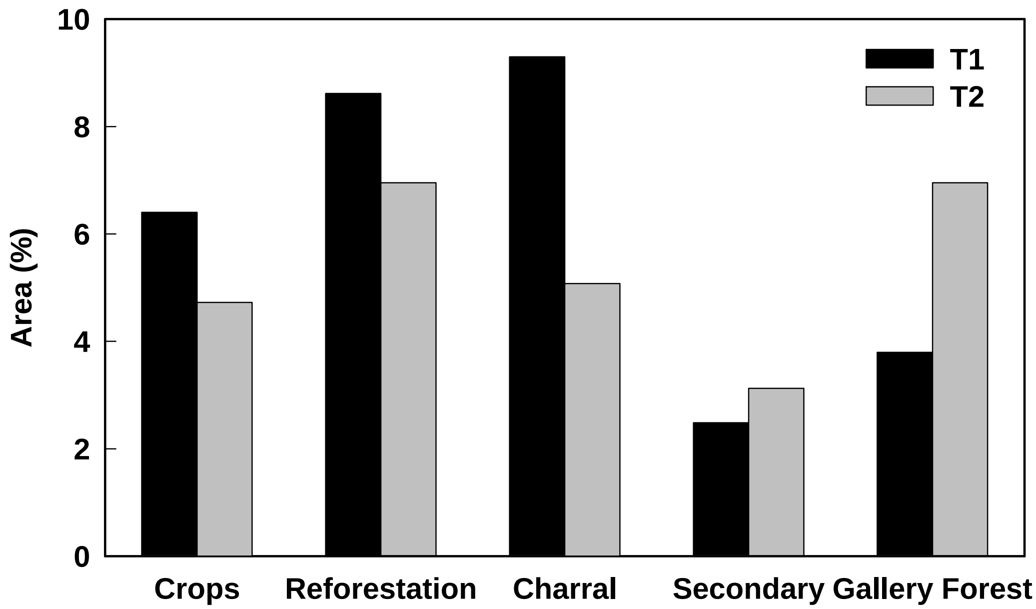
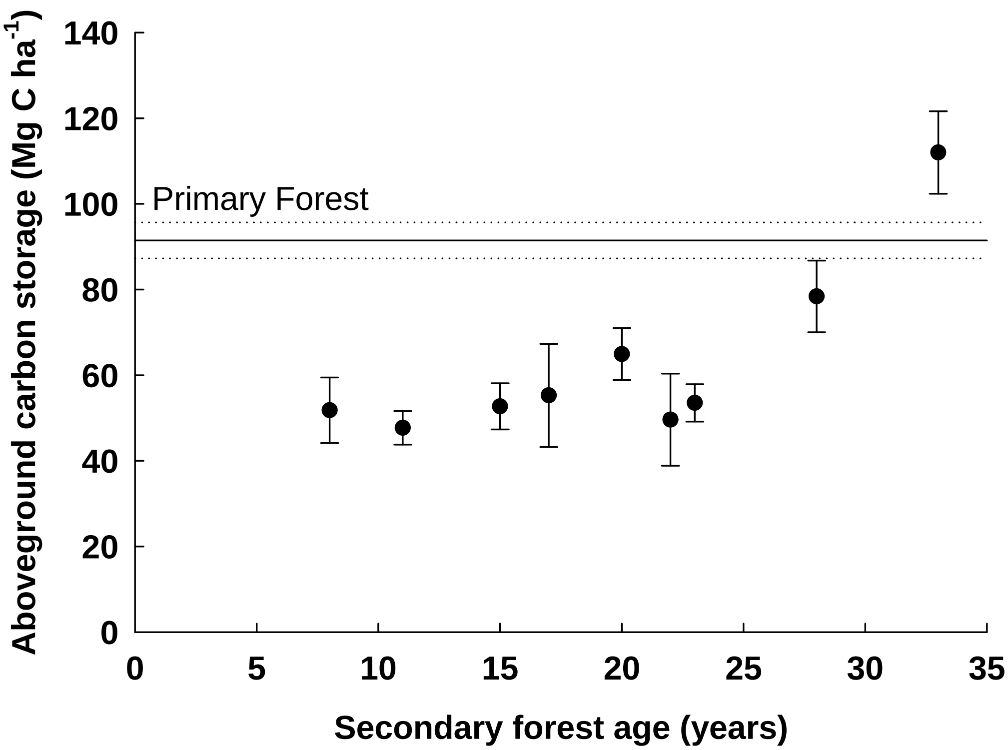


Figure 5. Mean aboveground carbon storage ± one standard error for each secondary forest site. The solid and dotted horizontal lines represent mean aboveground carbon storage and one standard error, respectively, as measured in undisturbed primary forests at the La Selva Biological Station (Clark and Clark 2000). Values were calculated as one half of aboveground biomass estimates for all stems ≥10 cm dbh in plots ≥4 ha.



CHAPTER 5

Overall Conclusions, Lessons Learned, and Future Research

The ability of ecosystems to provide environmental services is in decline at the same time as our need for them grows (Millennium Ecosystem Assessment, 2003). Understanding the ways that humans are responsible for the reduction in the quality and quantity of these services is critical if we are to properly target policy and/or change our behavior. Research on the causes and consequences of environmental change and the interaction of human and environmental systems is necessarily an integrated endeavor (Grimm, Grove, Pickett, & Redman, 2000; Gunderson & Holling, 2002). While many aspects of environmental services have been investigated, empirical evaluations of the impact of policy on the provision of environmental services have not (Ferraro & Pattanayak, 2006; Wunder, 2007). This type of evaluation necessitates a model of how the social and ecological systems interact (Lambin, Geist, & Lepers, 2003).

This research was designed to provide such an analysis of Costa Rica's PES program as part of a larger interdisciplinary research project. It is a case study within the San Juan – La Selva portion of the Mesoamerican Biological Corridor in Northwestern Costa Rica. It addresses the influence of the incentive program on landowner decisions and links those decisions to biophysical outcomes that act as indicators for the provision of environmental services. The goal of the social component of this research was to develop a model of the linked human environment systems and investigate the social processes that led to land use decisions. The other researchers on the project quantified the land use change and explored the process of soil carbon sequestration.

Using theories from both the social and ecological sciences, chapter one outlined a theoretical framework for analysis of both the social and ecological consequences of a PES program. Variables appropriate to the local research questions were identified and were applied to the model for empirical analysis. Empirical analyses were divided into two stages; agent context analysis and agent conduct analysis. Context analysis focuses on the social *terrain* that a landowner faces when they make a land use decision. This included the status of components of the social systems such as economic, political, infrastructure, cultural, demographic conditions. Conduct analysis highlights the motivations and decision making process of landowners. Chapter one presented a context analysis of Costa Rica's PES program. Data analysis of interviews of local land use experts were used to ground the historical analysis of the regional context. Contextual analysis of documents was used to triangulate the results from the interview data. Results indicate that the model was effective in its empirical application. The results of the two sources of data triangulated well for identification of the key influences of land use decisions. The study area is deeply embedded in global processes from international markets for pineapple and banana to funding for environmental service payment programs from the World Bank and through the Kyoto Protocol. Combining the results of the two sources provided a holistic perspective of the social context and how it influences land use decisions.

Chapter two examined a portion of the agent conduct analysis. It focused on the fundamental efficiency considerations for PES including additionality, baseline conditions, leakage, and equity. The study compared the land use choices of spatially matched participants and non-participants within the Corridor (N=207). Landowner motivations for participation in the PES program and for their forest and other tree management decisions were outlined. Results indicate that PES for forest protection has helped to reduce the deforestation rate and those incentives for reforestation has been effective at increasing forest cover. The PES did help to achieve rural development goals, but only indirectly through the expenditure of the payments. Participants tended to be wealthier, larger landholders who were more likely absentee landholders than non-participants. A second portion of the conduct analysis identified landholder capabilities using a livelihoods asset analysis provided additional evidence of these trends. This analysis can be found in Appendix three. Recommendations were offered on how to adjust the program to increase ecological and economic efficiency, specifically through the imposition of a regressive payment rate.

Chapter three was the integrated research analysis. This is the point where the impact of the PES on land use decisions is traced through to its impact on forest cover and the provision of environmental services. The context and conduct analyses described above were combined with a comparison of land cover data from Landsat satellite images from 1986, 1996 and 2001 bracketing the initiation of the PES program. This analysis provided pre and post PES deforestation rates and quantified the types of changes that occurred across the landscape. The focus of the landcover analysis was on retention and recovery of different forest types including natural forest, secondary forest, forest plantations and riparian areas.

Data showed that the rate of forest loss in the region declined after imposition of the 1996 Forestry Law. Carbon sequestration data showed that secondary forest was the most beneficial forest form for this process, especially when soil carbon is included in the sequestration calculations. Data from the context analysis provided information on the social factors that were influencing deforestation rates while data from the conduct analysis identified what percentage of the landowner forest retention and recovery decisions could be attributed to the PES program. The conduct analysis also provided information on the differences between participants and non-participants and can be found in detail in appendix three. As a case study, the Costa Rican experience with PES provides evidence that environmental service payment programs in conjunction with legal forest protection can influence the retention of natural forest and the recruitment of new forest. PES has been tailored to fit Costa Rica's socioeconomic conditions, but shows promise as an effective conservation approach with prospects for adaptation to other settings.

Considering the results simultaneously

A synthesis of this whole research project as a process of structuration will be the focus of a subsequent paper from data collected for this dissertation. Of particular interest is how the PES and other reforestation incentives have developed 'structure' in the region thus elaborating or contributing to a situation where those social systems are likely to be continued in the future. A key example of this process is briefly outlined below using reforestation.

Chapter one used two sources to outline the history of reforestation subsidies that began in 1979. The motivations behind these first incentives were to supply timber for the future and the desire to reduce the pressure on natural forests (Castro, Tattenbach, Gamez, & Olson, 2000). Initial subsidies generally went to large companies or wealthy individuals (Watson et al., 1998). Later subsidies were 'democratized' to include poorer landholders by providing funding prior to plantation establishment (Brockett & Gottfried, 2002). During this time, several local institutions (CODEFORSA and FUNDECOR) were formed to provide technical assistance and promote sustainable forest management. The evolving reforestation and then forest management and protection incentives were heavily applied in this region and these organizations became key institutional supporters of the new PES program (Miranda, Porras, & Moreno, 2003). The wood extracted for forest management had provided support for several local industries such as sawmills and furniture factories (Watson et al., 1998) creating a situation conducive for marketing forest plantation wood.

Both the context analysis and the conduct analysis demonstrated that landowners in the region were largely absentee landholders who generated their income from urban professions and were not using their land primarily for production (Butterfield, 1994; Schelhas & Sanchez-Azofeifa, 2006). For these landholders, low labor and low cost production systems that proved use of the land were the most advantageous. Cattle were the initial choice for fulfilling a need for this type of production system, but reforestation offered many of the same advantages. Additionally, insecurity near the Nicaraguan border during the 1980s meant that cattle were being stolen making reforestation a potentially appealing option. Reforestation was also promoted as an option that could possibly offer significant returns for the investment (Rojas & Aylward, 2003) given that the infrastructure for milling and marketing for timber that already existed in the region.

Results from the conduct analysis indicate that landowner motivations to reforest were primarily economic. Additionally, the majority (68%) of the participants in the PES program reported that they would not have reforested without the incentives. Therefore, we see that given this context, reforestation was a viable option and the incentives proved to 'tip the balance' to try it as a production system. This translated to more reforestation in the landscape and was identified in the first period of the combined research (prior to 1996). Additionally, we found that the majority of the landholders (61%) with reforestation intended to plant another plot of trees once they harvested the current crop. This indicates that reforestation as a land cover will likely continue if the current conditions continue. This also indicates that other structural components in the region that promote reforestation (nurseries, mills, furniture stores, wood pallet factories) will be reinforced. Mills will have more wood, nurseries will have more customers and there will be more locally grown wood pallets.

However, we also learned in the context analysis that when the PES program was initiated, funding that initially went to reforestation was divided and primarily went to fund forest protection. In this case, when the reforestation projects that were influenced by earlier incentives come to harvest, it is possible that there will not be incentives for them to replant. This could influence their decision to replant and in turn reduce the amount of reforestation covering the landscape. Since the motivations for reforestation were primarily economic, it would be expected that the alternative land uses that would replace the reforested lands would be primarily economic such as cattle or crops.

From the model:

- External structure (6S): The social structure of existing markets for wood products, institutional support and promotion, an evolving set of incentives provided the conditions for:
- Internal structure as medium (1S): Landowners whose capabilities or control over resources included an abundance of absentee landholders who were economically motivated for a production system that was low labor, low maintenance and proved use of the land influenced the decision to:
- Action of land use change (3S): Take the action of reforesting their land:
- Internal structure as output (4S): With the outcome of a large percentage of those who reforested gaining knowledge of the planting and marketing of reforestation plots motivated to reforest again after this harvest which led to:
- External structure as output (5S): The reinforcement of the social structures that support the industry such as milling and furniture factories.

Another avenue of synthesis of the results from the context and conduct analyses will be to identify items were they differed in their results. For example, analysis of both sources of data in the context analysis identified legal restrictions as imposed by the 1996 Forestry Law as a key influence of forest retention in the landscape. However, the context analysis demonstrated that landowners' primary motivations for forest retention were overwhelmingly environmental. These motivations were principally for protection of watersheds and biodiversity, followed by aesthetics. All three of these environmental concerns were reported more frequently by non-participants than participants. This indicates that participation in the PES program is not necessarily motivated by environmental concerns, but that the maintenance of forest more generally may be due to conservation motivations. While a number of participants (8%) and non-participants (15%) in the PES program did mention legal restrictions as a primary motivation for conserving forest, almost none of them reported the decline in the beef market as a key motivation for retaining forest.

Additionally, a higher percentage of participants reported that they had already harvested their forest in the past. This was further reflected in the results where over half of participants in the PES program responded that even without the 1996 Forestry Law they would not have cleared any additional forest. Another 10% indicated that they would not have cleared any additional forest, but would have harvested more trees. PES participants were also just as likely to have harvested trees on their farm in the last five years as non-participants. Therefore, the data from the conduct analyses indicate that motivations for not harvesting were related to a change in attitudes toward the forest more than from the legal restrictions, PES incentives, or the decline in cattle prices. These results are contrary to what might be expected (Ferraro & Pattanayak, 2006) and demonstrate the importance of conducting analyses at the level of landowner motivations in coordination with the systems or social context level.

Methodological Limitations

Recently, an article was published that addressed best practices for conducting analyses of conservation initiatives (Ferraro & Pattanayak, 2006). They cite four rules for evaluating conservation interventions:

> 1. Consider ecological and socio-economic factors that co-vary with the program.
> 2. Guess-estimate the direction of potential bias in interpreting intervention effectiveness.
> 3. Construct simple control groups (those that do not receive the intervention).
> 4. Collect data on outcomes and key inputs before and after the interventions.
> (Ferraro & Pattanayak, 2006, p. 0485)

This research did use a number of these best practices, and identifies a number of others missed in this evaluation. The context analysis as presented in this research would identify any number of the confounding effects that might co-vary with the program. It is suggested that the systems and narrative perspectives as identified by Lambin, Geist & Lepers (2003), and similarly applied in this research, would be appropriate frameworks for identification of these issues. It is argued here that identifying participant and non-participant motivations for land use decisions and for participation in the PES programs takes much of the guesswork out of interpreting intervention effectiveness. For example, a number of counterfactual questions were asked in this research such as: Why hadn't you cleared your forest prior to the institution of the Forestry Law? What would you have done with your forest if the Forestry

Law had not been passed?; and Would you have reforested without the incentives? Each of these questions was used to identify potential biases in the interpretation of the effectiveness of the PES. In our particular case, a maximum of 40% of the reduction in the rate of deforestation was attributed to imposition of the PES program and Forestry Law.

Simple control groups were also identified in this research. First participants were matched spatially and by their ability to participate in any of the PES programs. The second quasi-control group was the deforestation rates inside the corridor where PES were targeted as compared to deforestation rates outside the corridor. Finally, deforestation rates prior to and after implementation of the 1996 Forestry Law were quantified and triangulated with the context analysis of the historical influences of land use change for a before and after analysis. The presentation of best methods by (Ferraro & Pattanayak, 2006) was found to lack a spatial analysis necessary for investigations of conservation policies. It was also missing an effective model to demonstrate how policy interventions actually work through a social system to have an impact on the conservation projects they describe.

That said, there are a number of limitations to this research project. Most of these have been identified in the individual chapters so only the major limitations are presented here.

- Researcher effects: It is possible that both or either the expert groups of the individual survey respondents were simply telling the research team what they thought we wanted to hear.
- Control of researcher effects: The attempt to control for this bias was to explain the research project, my affiliation, and how the data would be used. It was a university study with no direct affiliation with any conservation or production group. Additionally, questions were ordered and worded to avoid any bias toward either conservation or production.
- Sample and sample size: While the population data for selecting samples was as complete as possible, there were likely deficiencies. For example, the agricultural census did not include landowners who had no cattle and so the non-participant sample was likely biased toward those with pasture. The PES participant sample was from FONAFIFO, but had obvious duplicates and some of the contact information was outdated. While each data set had its own population that was used for

calculating sampling error, it was not known what the total population was within the entire corridor area as it does not conform to any jurisdictional boundaries within Costa Rica. Additionally, while random spatial matching likely controlled for land quality, market access, and other spatial factors, it did not control for farm size, farm dependence and other variables that may have influenced participation. It was found, however, that the inclusion of large farms in the program was likely as much through targeting by regents (Zbinden & Lee, 2005) as it was by the economic benefits of large tracks of forest that could be enlisted under the PES. Additionally, there was substantial variation in landowners livelihood assets indicating comparisons between larger samples would prove helpful.

- Control of sampling effects: Systematic random spatial sampling was preformed on the two population data sets to avoid selection bias and control for spatial differences in access and land quality.
- Case study: The fact that this is an in-depth case study provides special details on ‘people in places’ (Lambin, Geist, & Lepers, 2003), but necessarily limits how much can be said about PES in Costa Rica in general. However, a number of local case studies have been accruing (Zbinden & Lee, 2005; Sierra & Russman, 2006) and some common insights are beginning to appear as addressed in chapter two.

Future Research

There are a number of recommendations for future research presented in the articles. Conducting more case studies of particular places for additional in-depth analyses would allow the identification of particular nuances that could be found under different social contexts or historical development and land use histories. Comparative case studies following repeated patterns of data collection would also be useful for cross case comparisons. Additionally, a national study with a sample large enough to identify the small between group nuances presented in this research would provide some more general insights on the efficiency of the program at that level. Important insights into the distributional effects identified in this research indicate that how the PES payments are spent is at least as important for measuring development impacts as the livelihood strategies of participants. As an extension of the argument made in Lambin Geist & Lepers (2003), if cases could be conducted by a similar model (such as the one developed in this research) comparisons across cases would be greatly simplified. They also identify three useful perspectives for conducting research of people in places; narrative, systems, and agent based perspectives (Lambin, Geist, & Lepers, 2003) that we believe could all be used within the SEStM.

Application of the model in other contexts would aid in testing its applicability and usefulness. Another aspect of future research that could be conducted related to the model is on how social systems interact. Similarly, the systems level of how heterogeneous landscapes function has been identified as a cutting edge research for landscape ecology and conservation biology (Lovett, Jones, Turner, & Weathers, 2005). In the social context analysis it was clear that there were a number of events that seemed to interact at the structural level. For example, after the economic crisis a series of structural adjustment policies were required for the loan from the International Monetary Fund. These policies required the elimination of subsidies, including the forestry sector. At the same time as the second round of these structural adjustment policies were being administered (1990), the Supreme Court of Costa Rica declared the earlier Forestry Law of 1986 as an unconstitutional restriction on private property rights. Both of these events, and a number of others addressed in chapter one, led to the development of the 1996 Forestry Law and the new justification for previous subsidy programs in the form of the PES program. In other words, it appears that the more 'codified' a social system becomes with laws and rules that are formally adopted and adhered to as rules, the more likely systems are to interact and responded to each other without the direct structuring of actors. Margaret Archer, (Archer, 1995; as cite in Ritzer & Goodman, 2004, p. 384) has a construct that may be of aid to furthering the systems analysis presented in this model;

> "Morphogenesis implies that there are emergent properties that are separable from the actions and interactions that produced them. Once structures have emerged, they react upon and alter action and interactions. The morphogenetic perspective looks at this process over time, seeing endless sequences of cycles of structural change, alterations in action and interaction, and structural elaboration."

In sum, it is suggested here that both the model and its application to the study of Costa Rica's PES program were robust, it is suggested that further studies on the PES program will provide many new insights. Finally, it is hoped that the SEStM model will be the subject of further elaboration in both design and application.

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APPENDIX 1

Acronyms and Abbreviations

CAF	Certificate for Payment for Reforestation
CAFA	Certificate for Advanced Payment for Reforestation
CAFMA	Certificate for Payment for Natural Forest Management
CODEFORSA	Forest Development Commission of San Carlos
CPB	Certificate of Forest Protection
DGF	Forestry Department
FONAFIFO	National Fund for Forest Financing
FUNDECOR	Foundation for the Development of the Central Volcanic Mountain Range
ICE	Costa Rican Institute of Electricity
IDA	Institute for Agricultural Development
MINAE	Ministry of Environment and Energy (Formerly Ministry of Natural Resources, Energy and Mines)
OCIC	Costa Rican Office for Joint Implementation
OTS	Organization for Tropical Studies
PES	Environmental Service Payments
RECOPE	Costa Rican Petroleum Refinery
SEStM	Social Ecological Structuration Model
SINAC	National System of Conservation Areas

APPENDIX 2

Methods and Research Background

Payments for Environmental Services

Most of Costa Rica's forests remain on private property (de Camino, Segura, Arias, & Perez, 2000). Since 1979 Costa Rica has pursued programs promoting reforestation that included tax credits, deductions and municipal funding for private landowners. These incentive programs had variable success (Thacher, Lee, & Schelhas, 1997). Building on the institutional legacy of these programs, and the lessons they learned, Costa Rica initiated a program of Payments for Environmental Services (PES). The Forestry Law (No. 7575) of 1996 codified the legal and institutional support for the payment program (Snider, Pattanayak, Sills, & Schuler, 2003). In this innovative program, payments are made to private land owners to retain native forests and establish tree plantations (Chomitz, Brenes, & Constantino, 1999). The objectives are to protect watersheds, habitat for biodiversity, sequester carbon, and maintain aesthetic values (Pagiola, Bishop, & Landell-Mills, 2002). The National Fund for Forest Financing (FONAFIFO) was institutionalized to raise and administer funds for the program. Fees are generated through a tax on gasoline, carbon sequestration agreements, global institutions, and local hydroelectric power watershed agreements where both the polluters and beneficiaries of the environmental services pay for their maintenance (Zbinden & Lee, 2005). For this public program, the government raises the funds, sets priority sites, establishes payment rates, and then through forest engineers (regents) contracts with landowners for the environmental services they provide (Snider, Pattanayak, Sills, & Schuler, 2003).

Study Site: Mesoamerican Biological Corridor

This research was conducted in the San Juan - La Selva portion of the Mesoamerican Biological Corridor (MBC). The MBC is a multinational project designed to integrate the conservation of ecosystems and biodiversity with sustainable cultural, social, and economic development (Miller, Chang, & Johnson, 2001). The MBC is a network of core protected areas and buffer zones linked together by proposed corridors throughout Central America. Corridors are shaped by human activities forming a matrix of agricultural and forest areas with multiple owners. Matrix areas are key conservation targets influencing the effectiveness of reserves, landscape connectivity, and themselves for maintaining biodiversity (Ricketts, 2001). One enduring challenge in the MBC is the need to simultaneously realize sustainable development and biodiversity conservation goals. The PES program is one of the methods for addressing both conservation and development goals within the MBC that Costa Rica has implemented.

Interdisciplinary Team Work

This research, though complete in and of itself, has been designed in an interdisciplinary manner from site selection, problem framing, formulation of research questions, and finally on to designing integrated outputs of co-authored papers. I am part of a team of three students (including Steve Sesnie and Jessica Schedlbauer) who chose an interdisciplinary integrated approach to study Costa Rica's environmental service payment (PES) program. We evaluated the program through its socioeconomic and political processes in conjunction with land change patterns and ecological processes.

Team Research Questions

What are the impacts of programs and policies on land owner decision making, forest recruitment, and forest retention?

Our research was combined to address the following sub-questions:

- Has the annual rate of forest loss declined substantially for private forest land in the Corridor as expected under the 1996 Forestry Law?
- To what extent are changes in forest cover attributable to the ban on forest clearing and/or payments to protect forests?
- Have incentives for reforestation been a major catalyst for landowners to establish tree plantations?
- What is the outlook for recruiting forest cover via secondary succession as a potential source of valued carbon services under the 1996 Forestry Law?
- Are PES programs an effective conservation mechanism for retaining habitat connectivity between protected areas?

The interactions of both the social and ecological processes are manifested in land use and land cover changes (Grimm, Grove, Pickett, & Redman, 2000). Land use, as identified through the remote sensing land use change analysis, is our common unit of analysis. What we identify as change in land use and land cover are the product of multiple household production and conservation decisions made within a particular social and environmental context over time. These decisions are spatially identified at the landscape level through the land use change analysis using remote sensing technology. Ecological processes are examined through both a forest categorization process at the landscape scale and soil carbon isotope research. The carbon isotope research is scaled up to the landscape level in the remote sensing land use change analysis. We identify where and why forest cover has changed while at the same time examining some of the biophysical impacts of those changes. The three integrated studies provide us with the ability to evaluate both the social and ecological impacts of the program within the San Juan – La Selva portion of the MBC.

Methodology for Social Research

Research Objectives

The objective of this study is to investigate the social systems and farmer livelihood decisions that influence conservation and production decisions about land use in a region surrounding the La Selva – San Juan portion of the Mesoamerican Biological Corridor in Costa Rica.

Design

A research design is the map, plan, or logic that links the research questions, to the data collected, through to the conclusions. It is a blueprint focusing on "what questions to study, what data are relevant, what data to collect, and how to analyze the results" (Yin, 1994, p. 20). The design for this study was a single case study with multiple embedded units (Yin, 1994). A case study uses multiple sources of evidence for an in-depth exploration of an activity, event, process, or group that is definable or bounded in time or space (Creswell, 2003). A case study design was chosen because it is the preferred strategy when "how and why questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context" (Yin, 1994, p. 1).

Paradigm

I believe that the focus of the research, or the research question, is the most important driver for selecting a research approach and methodology for investigation. For this reason, a Pragmatic paradigm was used for this investigation (Creswell, 2003). Placing the research question above the worldview or the types of methodology is what Tashakkori & Teddlie (1998) refer to as the "dictatorship of the research question." In doing so, one worries less about the ontological (what is the nature of reality, what the researcher can know) and epistemological (subjective verses objective) debate and concerns oneself with “what works” and what approaches will best address or find solutions to the problem (Creswell, Clark, Gutmann, & Hanson, 2003). I also believe that the researcher’s values play an important role in selecting and defining a research problem, selecting theories and frameworks as guides, interpreting the results, and the pragmatic paradigm accepts these beliefs. Under pragmatism one can “study what interests and is of value to you, study it in the different ways that you deem appropriate, and use the results in ways that can bring about positive consequences within your value system”(Tashakkori & Teddlie, 1998).

Creswell (2003) suggests that three criteria be used in selecting an approach to research; the problem, the researcher’s experience, and the audience. The research problem at hand requires both qualitative exploratory investigations followed by quantitative testing. The pragmatic paradigm is the most inclusive for using both inductive and deductive logic and for allowing the researcher to take both the subjective and objective epistemological roles (the relationship between the researcher and what is known) that are traditionally used for conducting qualitative and quantitative research (Denzin & Lincoln, 1998; Tashakkori & Teddlie, 1998). Finally, the results from this study were combined with those of the research team and presented to audiences that have both a need for and an interest in qualitative and quantitative results. In particular, our team wanted to generalize to the landscape within the San Juan - La Selva portion of the Mesoamerican Biological Corridor.

Research Strategy

A mixed methods approach using a sequential exploratory strategy was used to guide this overall research project (Creswell, Clark, Gutmann, & Hanson, 2003). In the sequential exploratory strategy, the qualitative approach to data collection and analysis precedes the quantitative approach to data collection and analysis (Creswell, Clark, Gutmann, & Hanson, 2003). The main focus of this strategy is to explore a research problem and then attempt to generalize or expand (transfer the findings to a population) on the qualitative findings. Mixed method approaches are deemed superior to single method studies for answering questions that other methods could not, providing stronger inferences, and presenting a greater diversity of views (Tashakkori & Teddlie, 1998). The ability to answer both exploratory and confirmatory questions makes mixed methods a preferred strategy for this study. Stronger inferences are obtained from mixed method studies because you can combine the different methodologies in a manner which combines their strengths and offsets their weaknesses, thus improving inference quality. The different methodologies used for this research are; *semi-structured interviews* with both experts and farmers designed to explore a range of variables, *document analysis* to augment and corroborate these results, and *quantitative survey interviews* to allow for generalizations to a wider population (Yin, 1994, p. 81).

Case Boundary/Unit of Analysis

A case is the primary unit of analysis (Yin, 1994) or the heart of the study (Miles & Huberman, 1994). A case is "a phenomenon of some sort occurring in a bounded context" (Miles & Huberman, 1994). The boundary is the context, or site, or social and physical setting that a case occurs within and which is further bounded by time and the sampling operations that are preformed on the unit of analysis of the case (Miles & Huberman, 1994). As recommended, the research questions have been used to help define the case (Yin, 1994).

The case presented here is the influence of social systems on farmer conservation and production decisions. The spatial boundary of the case is the San Juan-La Selva portion of the Mesoamerican Biological Corridor where Costa Rica heavily targets its PES payments. The temporal boundary of the case was selected on the basis of the signing of Costa Rica's first forestry law in 1969 with emphasis on land use changes since the mid-1980s (e.g. living memory) for the interdisciplinary study.

Data Collection Methods

To ensure the quality of design, there are several important guiding principals for collecting data for a case study. The principals include using multiple sources of evidence converging on the same set of facts, the assembly of a case study database, and a chain of evidence providing the "explicit links between the questions asked, the data collected, and the conclusions drawn" (Yin, 1994). There were two 'sets of facts' that were pursued in this research including; the social systems influencing landowner decisions and the livelihood assets under the proximate control of landowners representing their capability to act.

The multiple sources of evidence that were used for this research are (Table 1); experts (agency and NGO staff), local farmers, and document evidence from secondary data (Flick, 1998; Yin, 1994). The qualitative data were collected first to provide richness and holism and historical context of the social systems in the region (Miles & Huberman, 1994). The quantitative data provided information about the distribution and range of livelihood assets and motivations of the embedded units of the case and provide the ability to generalize to a larger population.

Methodological Bracketing

A theoretical model was developed to frame the linked human-environment necessary for the interdisciplinary research which addressed the social and ecological consequences of the PES program (SEStM in chapter 3). The conceptual model was used to guide the data collection and analysis. This model helped guide the inquiry by providing the "general constructs that subsume a mountain of particulars" by providing bins to help one be selective, "to decide which variables are most important, which relationships are likely to be meaningful,… and what information should be collected and analyzed" (Miles & Huberman, 1994, p. 18). Within the full model, methodological bracketing is a method designed to further focus the researcher on certain aspects or dimensions of the structuration process (Giddens, 1984).

Stones (2005) presents methodological brackets that include agents conduct analysis and agent context analysis. The conduct analysis is focused on the knowledgability, motivations, reflexive monitoring, desires and capabilities of the agent (Stones, 2005). Agent context analysis (replacing institutional analysis) is intended to be "used to analyze the terrain that faces an agent, the terrain that constitutes the range of possibilities and limits the possible" by focusing on social systems (Stones, 2005, p. 122). The two bracketed methods are intended to provide an outside-looking-in and inside-looking-out analysis of the process of structuration.

Agent Context Analysis

Expert Interviews

The agent context analysis was conducted through semi-structured interviews and a document analysis. As suggested, detailed narrative approaches of specific localities of people in places (Lambin, Geist, & Lepers, 2003) and environmental histories that triangulate data among sources with the "living memories of the land users" (Bebbington, 1999, p. 285) are useful for agent context analysis (Scoones, 1999; Stones, 2005). The document analysis that was used to augment evidence from the expert interviews consisted of a review and synthesis of "formal studies or evaluations of the same 'site' under study" to provide a broad perspective on the historical context and influences on land use change as provided by academic, agency, NGO, and other relevant documents (Yin, 1994, p. 81).

Qualitative data were collected through semi-structured interviews with local land use experts. Experts were defined as any individual or organization that has influenced or had special regional insights to landowner land use decisions. Several local conservation and production NGOs, government agencies, local companies, and a few individuals were identified in the region as land use experts. Eighteen semi-structured interviews were conducted in the fall of 2003 (Table 2). Interviews lasted approximately 1 ½ hour and were led by the lead author and one assistant. The assistant was a North American, but fluent in Spanish. We reviewed my research and she was familiar with the research design, questions, and goals of the work. I led the interviews and my assistant worked with all the visual aids in the interview (flip charts, matrix labels, and maps), helped facilitating dialogue, and participated in post interview wrap-up discussions that were used as a basis for contact summary sheets.

Small groups of individuals were interviewed to allow for discussion and synergistic effects that can develop in group interviews. The first exploratory interview was conducted with regional field staff of the NGO FUNDECOR. The research team had a work agreement with this organization, thus providing entry to my first data source. After each interview, names of other 'experts' in the region who could provide insight into the study were solicited. This was a form of snowball sampling and used to identify additional interviews (Tashakkori & Teddlie, 1998). Additionally, these groups of experts were important for both their intimate knowledge of the land use in the region and for their position to provide access to local farmers in the region for subsequent parts of this research (politically important and expert sampling) (Miles & Huberman, 1994). Interviews were conducted until the amount of new information obtained at each interview declined dramatically and the suggestions for additional 'experts' no longer provided corresponding contacts.

The original intent was to conduct analysis of each interview (transcribe and code) before the subsequent interview. This was to provide for the refinement of the interview guide and mapping exercise. However, due to timing and logistical constraints (it takes a long time to transcribe an interview) several interviews were conducted before previous interviews could be analyzed. In general, about three interviews were conducted before the transcriptions were ready. Instead of using the full analysis for interview revisions, contact summary sheets were reviewed and interviews were updated to follow new leads as they arose. A contact summary sheet is a short summary of information about each contact. In this research it was used as a guide for planning the next contact and a tool to reorient myself to the contact when returning to the field (Miles & Huberman, 1994). It was also used in the reframing and redirecting of probing questions when new insights were encountered. The contact summary sheets included include the types of expert (agency, NGO, business, conservationist), sample strata (if applicable), date, location, main themes discussed and any possible surprises or special insights offered.

The small group semi-structured interviews with land use experts had three main components; 1) a land use – social system analysis using a matrix to guide the interview; 2) a land use transition tree; and 3) landowner typologies. The expert interview was used to explore expert beliefs about how the regional social systems influenced landowner conservation and production decisions about land use. This grounded but regional perspective was considered key to understanding the local influence of social systems. The first section of the interview had the experts generate lists of current and historical local land uses (e.g. pineapple, forestry, pasture) that have occurred in the region. Experts then discussed each land use from the perspective of each social system category developed in the conceptual model (SEStM see chapter 3). The second part of the interview had the experts develop a land use transition tree to identify and restrictions or land use legacy issues or restrictions. The third part of the interview included questions about farmer typologies. The intent of this part of the interview was to identify regional perspective on livelihood asset combinations that might differentiate or be indicative of landowners' livelihood strategies. These different livelihood strategies would likely be influenced by different social systems or affected in different ways.

Data Analysis

Interviews were transcribed and entered into NVIVO software to organize the data for analysis through coding and data display. Coding is part of data reduction and conclusion drawing (Miles & Huberman, 1994). This analysis of the qualitative data used descriptive coding using basic categorical codes as descriptive devices to categorize data. In the case of this research a 'start list' of codes included the categories from the decision model developed in the SEStM model (chapter 3); economics, politics, technology and infrastructure, culture, demographics, and nature. A number of additional codes within each of the start categories in the start list were added as subcategories or trees. The tree 'nodes' aided in search for specific topics, but found no reason to alter the central structure of the theoretical decision model that was developed. Matrix displays were developed that categorized each land use by social system.

Quality Control

One of the main advantages of using mixed method research is the quality of inferences they provide (Tashakkori & Teddlie, 2003). An inference is the term used to refer to the final outcome of a study, be it inductively or deductively derived. Teddlie and Tashakkori (2003) have suggested that for mixed methods studies the terms inference, inference quality, and inference transferability be used to replace the multiple and sometimes incompatible terms used to define valid, or quality research in the qualitative and quantitative traditions.

Inference quality includes both the areas of design quality and interpretative rigor (Table 3). Design quality includes the criteria used to judge best practices of research design and methodological procedures. Multiple sources of evidence encourage converging lines of inquiry during data collection and thus improve inference quality (Yin, 1994). Document analysis and literature review were used to understand the evolution of social systems influencing land use change at the national level (see below). Another consideration in quality design of a study is the potential for researcher effect which occur when participants change, target, or otherwise behave differently then they normally would because they know they are being studied (Miles & Huberman, 1994). To alleviate this potential problem the purposes of the research, researcher affiliation, and how the research would be used were made clear to participants (Miles & Huberman, 1994).

Interpretative rigor refers to the accuracy or authenticity of the interpretations or conclusions of the study (Tashakkori & Teddlie, 2003). Two additional methods were used to ensure interpretative rigor including member checks, and peer debriefing. A member check involves having a participant in the study check the categories, conclusions and interpretations made by the researcher. Four formal member checks were conducted with expert representatives at the end of the expert interview phase. The expert 'story' was reviewed with each expert to identify missing or misinterpreted information. Peer debriefing was conducted to probe the analysis for any potential biases in coding or interpretation (Tashakkori & Teddlie, 1998). This was relatively straight forward process because the coding was developed from the model and was descriptive.

Document Evidence

The interview data provided a local 'story' of which social systems experts thought were the most important to landowners from their grounded perspective. Information gained from the expert interviews was used to target documents for the purpose of corroboration and augmentation of information revealed during the expert interviews (Yin, 1994). Searches were focused on identifying social systems that were described by experts. For example, forest policies were presented as an important determinant of conservation and production choice about land use (and were the focus of one of my research questions), so a document search on forest policies over time was conducted to include the major policy changes in the analysis. Documentary evidence can include "formal studies or evaluations of the same "site" under study" (Yin, 1994, p. 81). There are many types of document evidence that were used including journal articles, company/NGO internal documents, reports generated by each of the government agencies, theses and literature at CATIE, and agriculture and forest policy documents. This information provided that opportunity to track some of the trends over time and 'fill in' the temporal aspect of the historical timeline in much greater detail (Yin, 1994). The results of this document review are presented in the form of a historical timeline of major policy and other social systems that were reported to influence land use in the region.

Agent Conduct Analysis

Farmer Interview

The qualitative information gained from the expert interviews and the document evidence provided a regional perspective of how social systems have influenced farmer conservation and production decisions about land use over time. The next step in this research was to interview farmers and explore why they have personally made land use decisions and to identify the social systems influencing those decisions. The expert interviews and document analysis were used to develop informed probing questions on issues related to how social systems influenced farmer conservation and production decisions about land use.

Sample

Information gained on farm typologies from the expert interviews was used to develop a sample of a range of farmer types for the exploratory but semi-structured interviews. The first of the interviews with farmers were with individuals that are currently enrolled in conservation and development programs with FUNDECOR. The research team had a formal agreement with FUNDECOR and they had agreed to provide 'entry' or access to their constituents. With their cooperation, contact with and meeting arrangements were facilitated. These interviews were used as a lengthy pretest of the survey instrument.

The individual semi-structured exploratory interviews that were conducted with farmers had five main components: 1) general information on the household; 2) livelihoods analysis of farm decision making (information on farm production systems and off-farm economic activities with probing links to regional social systems); 3) trees on farm (motivations and actions regarding their management); 4) PES program participation; and 5) spatial aspects of livelihood systems.

The first part of the interview was to access the basic structure of the farmer's household and focused on the number of dependents and migration patters of family members. The second part of the interview was the most substantial and focused on all livelihood strategies. Initial questions pursued all on-farm production systems and followed the livelihood framework examining the five assets used to make decisions and which were necessary for each land use. Questions regarding inputs to household livelihoods by off-farm work were also pursued. The third part of the interview focused on the various aspect of tree cover, farmer reasons for maintaining the trees, and the future of the trees on their farm. The forth section focused on farmer participation in the PES program, reasons for participation, uses of the incentive, and opportunity costs. The final part of the interview focused on the spatial aspects of the farmer's livelihood strategy. While some of the spatial inquires were successful, others were not.

The concept of a Bioregion (Brunckhorst & Rollings, 1999) was initially pursued examining how individuals view their landscape according to, "how they see it, use it, and what it produces for them." The sense of place discussion, 'how they see it', was not forthcoming during the exploratory farmer surveys. Several versions of question pertaining to defining 'where their community was located' and 'places in the landscape that were important to them' were tried using local Spanish speakers to rephrase the question. There was substantial confusion related to the question and answers focused primarily on the farmer's specific farm or to the city or town nearest to their farm. There are several possible reasons for this including; poor phrasing of the question in Spanish, a concept 'place attachment' not familiar to them, or the relative recent colonization of the region not being conducive to significance of place. Due to confusion, this concept was not included in the farmer survey. However, the other two aspects of a bioregion, 'how they use it and what it provides for them', were identifiable in terms of market networks, locations to buy farm inputs and sell primary outputs (the base of a commodity chain), and social, financial, biophysical, and infrastructure networks. This information was incorporated into the regional farmer survey for analysis.

Counter mapping (Geilfus, 2000; Rocheleau, 1999), or drawing maps with farmers to identify specific management areas was explored in the farmer interviews was also attempted during this phase. This technique was stopped for several reasons: 1) the hesitancy of the landowners to draw the map; 2) the high number of landowners who had multiple farms creating a very time consuming and confusing process; and 3) the high number of absentee landowners who did not have the detailed knowledge of their farm.

The farmer exploratory interviews allowed me to test these questions and probe and explore answers to allow for a more thorough understanding of the different reasons for participation in the various land use choices. Most importantly they helped me eliminate questions and concepts that were confusing or unimportant (e.g. seasonality in labor force), define terms the way the farmers do (e. g. secondary forest is the same as tacotal according to many and the same as selectively harvested forest to others, negating its usefulness as a category of forest), and add questions or focus on questions not previously focused on (e.g. the importance of being contacted by a regent for participation in PES programs). It was a rather lengthy pre-test of the survey instrument.

Farmer Survey

Information gained from the expert interviews, document evidence, and particularly the exploratory farmer interviews was used to develop a quantitative survey interview. The same components examined during the exploratory farmer interviews were addressed in the quantitative survey interviews: 1) general information on the household; 2) livelihoods analysis of farm decision making (information on farm production systems and off-farm economic activities; 3) trees on farm; and 4) PES program participation. The survey interviews included detailed and specific questions about important aspects of production systems and livelihood issues that were learned during the exploratory interviews.

The information was gathered using a survey interview (Creswell, Clark, Gutmann, & Hanson, 2003; Yin, 1994). Face-to-face interviews were conducted because of the possibility that some farmers may not have the necessary reading skills, they could not be efficiently reached by mail, and because of increased response rates (Salant & Dillman, 1994). The survey was designed using the local language (vocabulary and phrases). Response categories were developed from the exploratory interviews and used where appropriate. Beyond the farmer interviews, the survey was further pre-tested on students at the university CATIE (many of whom grew up or currently own farms), with FUNDECOR field staff, and with my local research assistants.

Quantitative data was collected to provide the ability to generalize and draw inferences about a wider population (Creswell 2003). A differential study to compare participants and non-participants in PES programs based on their livelihood strategies (Graziano & Raulin, 2000). The total population for generalization consisted of landowners within the San Juan - La Selva Biological Corridor. I had a team of four assistants and myself to conduct interviews. Interviewers were trained by myself, practiced administering the survey on other students at CATIE and on each other. We were split into two teams and conducted surveys by local regions. Additionally, they watched me conduct two interviews. Interview surveys were conducted in the months of mid-June through mid-August of 2004 and lasted about 1 ½ hours.

Sample

The population of PES participants was derived from a GIS database provided by FONAFIFO. This database was then 'clipped' using Arcmap 9.0 to identify only those PES participants within the corridor. The total population of PES participants within the corridor was 510 households. Those receiving reforestation incentives from previous programs were included as participants because their payment contracts were continued under the 1996 Forestry Law. The FONAFIFO database did have some duplicate entries and spatially misplaced contract sites potentially causing some error. From this group, a spatially random sample frame of 150 PES program participants within the corridor was selected using Hawth's Analysis tools software in the Arcmap 9.0. These randomly selected farms were then cross-referenced with the local NGOs FUNDECOR and CODEFORSA to identify the names and contact information of the PES participants. Due to the considerable expense for each interview contact for face to face survey interviews, it was decided to elicit more information from each farmer in the case study, but from a reduced sample size. Convenience sampling among this sample frame was conducted as the research team targeted regions across the study area. To reduce transportation costs, the survey team would schedule as many interviews within each region for a period of time (generally two weeks), and then move on when time was limited. This ensured that a sample from all geographic regions of the corridor was achieved, but may have biased the sample by our inability to schedule interviews with some participants. One-hundred and three landowners were sampled with only 4 rejections. Because of the low rejection rate the potential bias due to the inability to contact individuals or schedule meeting times is not expected to be great. The number of completed surveys (99) provides a $\pm$9% sampling error for a population of 510 (based on a 50/50 split, or relatively varied population regarding the characteristics of interest) (Salant and Dillman 1994).

A nearest neighbor approach was planned to sample for non-participants in PES programs. The logic behind this selection technique is to attempt to match a similar spatial location in the landscape and a similar farm type, where the only difference is that the farmer does not participate in PES programs. This was to explore the possibility that farmers who have self-selected to participate in PES might make conservation and production choices about land use based on different social influences than those who have selected not to participate in these programs. The idea was to conduct the interview with the PES participant and the visit the nearest neighbor and schedule an interview. The initial use of this technique was problematic in that so many of the farmers in the region do not live on the farm (70% of PES participants, 30% non-participants) all or even part of the year. Farm locations were identified but owners were difficult to contact, and valuable time was used tracking down owners who were not present. To overcome this problem, another source of landowner data in the region was identified. The Costa Rican Cattle Census of 2000 developed by the Ministry of Agriculture had data on local landowners. This data is spatially referenced and included contact information. Using the same techniques as with the FONAFIFO PES data, the census data were clipped for the sample within the San Juan - La Selva portion of the biological corridor in Arcmap 9.0. The cattle census population for the region was 928 households. A second spatially random sampling frame of 150 households of PES non-participants was selected from this list using Hawth's tools in Arcmap 9.0. Convenience sampling among these sample frames was conducted as the research team targeted regions across the study area. One hundred and nine landowners were sampled with 2 refusals. One-hundred and seven usable completed surveys provided a ± 9% sampling error for this group (based on a 50/50 split, or relatively varied population regarding the characteristics of interest) (Salant and Dillman 1994). The randomly selected cattle census farm nearest to the randomly selected PES participant was then contacted to continue with the nearest neighbor spatial pairing technique. There may be some bias in this sample towards cattle farmers due to the use of the cattle census to identify 'neighbors'. However, most farmers who had other production systems (crops) also had a few cattle and were listed in the cattle census as well making the potential for bias less likely.

Data Analysis

The data gathered from the farmer interview surveys was entered into SPSS 14.0 for Windows (SPSS, 2005) for data management and analysis. The database includes information on the respondent, sample strata, physical location in geographic space, variable name, description, and all livelihood data collected. Summary data were run comparing participants and non-participants on specific factors related to additionality, baseline conditions, leakage, equity and demographic factors for Chapter 2. A comparison of livelihood assets was also conducted to further understand participation and equity/development impacts and is presented in Appendix 2.

Appendix 2 Data Analysis

Participants and non-participants were compared across twenty livelihood assets. The assets fall within the five livelihood asset categories as outlined by the livelihood analysis framework; human, social, financial, natural and physical (Carney, 2002; DFID, 2003). Variables measured within the human assets livelihood category included age, university education, the total number of household dependents, and the number of family members who work on the farm as their primary occupation. Three social assets were measured including the number of social and producer organizations a household belonged to, the number of training courses they had attended in the last five years, and the length of time they owned the farm. The length of time a household owned a farm was used as a proxy to indicate an increased opportunity and interest in forming social networks in the region. Financial assets were evaluated using the indicators of banded income, percentage of income from agriculture, the use of credit and land title. The income variable was banded into quintiles due to the wide variation in regional incomes and to facilitate comparison within the region. Natural assets included farm size, area of natural forest, pasture size, the number of cattle and land value. Land value was used as proxy (hedonic price) to indicate land quality (degradation, slope, etc.) and location (road access, distance to market, etc) as factors that would likely have influenced land use decisions. The indicator for land value was determined by asking landowners how much it would cost to buy a hectare of pasture next to their farm. Several indicators of physical assets were explored to understand how they were associated with participation in PES programs including; absentee land ownership, and the availability of electricity, road access and potable water on the farm.

There were seventy two participants identified with contracts under the protection modality. Non-participants who met the minimum protection program requirements of 2 hectares of forest were selected from the total list of non-participants for comparison (N=37). These two groups are compared for the protection modality of PES. There were 38 participants who received payments under the reforestation modality of the PES program. There were 96 non-participants who did not have any reforestation, but met minimum requirements for the reforestation program of more than 1 hectare available for reforestation. Twenty-six individuals were identified that had reforestation on their lands but did not receive PES payments. Both non-participant groups were independently compared with participants in the PES reforestation modality.

Quality Control

The mixed method terms, inference quality and inference transferability, were used to discuss the threats and potential solutions to validity of quantitative work. In both cases, the question as to whether the concepts being investigated are actually the ones being tested and measured are addressed (Graziano & Raulin, 2000) (Table 4).

One problem often encountered in measuring attributes in the social sciences is that the variables are constructs, and therefore it is not possible to directly observe them (Tashakkori and Teddlie 1998). To provide for quality assurance these variables were operationalized based on the literature definitions and as used in the SEStM (Chapter 1). Researcher effects were controlled for by making clear to participants the purposes of the research, researcher affiliation, and how the research would be used (Miles and Huberman 1994).

A cross-sectional survey interview was conducted and therefore will not face the challenges associated with history, maturation, attrition, or pre-testing, that often plague longitudinal and pre-test post-test studies. To increase the quality of inference transferability spatially random samples of the population of PES participants was paired with non-participants. Noting some small potential biases in my sampling techniques, transference to this population is possible. The ability to make generalizations about this population will in itself provide useful and interesting information about why they have chosen to be involved in PES projects and how these payments have influenced their livelihood decisions.

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Tables

Table 1: Data collection protocol.

Source of Evidence	Data Collection Methods	Sampling	Purpose
Expert: NGO/Agency Field Staff (*18 experts)	Small group semi-structured interviews (individual agency)	Snowball sampling: Politically important/ expert, knowledgeable	Explore land uses, social systems, and their possible connections. Explore history of area. Identify farm types. Explore spatial influences of social systems.
Expert: Member check (4 experts)	Multiple agency group presentation with feedback	Representatives who participated in individual agency interviews; representative from same agencies but from different locations	To check conclusions and interpretations made by the researcher.
Document Evidence (>100 reviewed)	Reports, documents, maps, literature about case	Census relevant material	Review and synthesis of "formal studies or evaluations of the same 'site' under study" (Yin, 1994, p. 81). To provide details on national trends and laws and augment the expert interview data.
Interviews of Farmers (*30 farmers)	Semi-structured interviews	Stratified non-random by farm type matching PES and non-PES participants	Identify influential land use-social force connections Explore land use decisions, beliefs about biodiversity, and reasons for PES participation. Pre-test for survey instrument.
Quantitative survey interviews of farmers (*207 farmers)	In-person survey interviews	Stratified Systematic random matching PES and non-PES participants	Identify influential land use-social systems decision connections. Identify relationships between farm types and social force influence. Identify reasons for participation in PES programs.

*Original target numbers in proposal: 10-15 expert interview; 15-30 farmer interviews; 200 farmer interview surveys.

Table 2: Table of experts.

Experts	Category	Interview location	Focus/specialty
1	Expert NGO ***Member check***	Puerto Viejo	PES, trees
2	Expert agency	Puerto Viejo	Cattle, Palmito
3	Expert agency	Puerto Viejo	Watershed, PES
4	Expert agency	La Virgen	Small farmer, cattle, pina, ornamentals
5	Expert agency	Puerto Viejo	Small farmer, colonies, cattle
6	Expert agency	Puerto Viejo	Small farmer, cattle, reforestation, black pepper
7	Expert agency	Puerto Viejo	Trees
8	Expert Company	San Carlos	PES, trees
9	Expert agency	San Carlos	Cattle, pina, tourism
10	Expert agency	San Jose	PES
11	Expert company	Horquetas	Palmito
12	Expert NGO	Earth	Tourism, conservation
13	Expert company	San Jose	Cattle, dairy
14	Expert NGO	San Jose	Tourism, development
15	Expert company	San Carlos	Black pepper
16	Expert agencies ***Member check-2***	Pital	Pina, yucca, cattle
17	Expert agency ***Member check***	Puerto Viejo	Cattle, Palmito
18	Expert Asociación	Pital	Development, conservation

Table 3: Quality control of qualitative data.

Mixed Methods Inference Quality:	Definition	Techniques proposed to increase quality
Design Quality	Best practices in design and methodological procedures	Multiple sources of evidence Chain of evidence Control of researcher effects
Interpretative Rigor	Accuracy or authenticity of the interpretations or conclusions	Triangulation of methods and sources Member checks Peer debriefing
Inference Transferability	Ability to generalize beyond the particular study	There are no plans to infer beyond the general case study at hand.

Table 4: Quality control of quantitative data.

Mixed Methods Inference Quality:	Definition	Techniques proposed to increase quality
Design Quality	Best practices in design and methodological procedures	Adequate definitions of variables Control of researcher effects
Interpretative Rigor	Accuracy or authenticity of the interpretations or conclusions	Procedures, treatments or change in participants
Inference Transferability	Ability to generalize beyond the particular study	Random assignment of individuals

APPENDIX 3

Conservation Multiplier Effect

An unexplored alternative result to leakage is a conservation multiplier effect of PES payments. Multiplier effects may be considered across farms or within a farm. Across farms landholders may see positive results or develop positive attitudes toward maintaining forest cover from neighbors who are participants in the PES program. Within the farm, landowners who receive PES may manage the rest of the forest cover on their farm in a manner that increases forest cover. For example, PES payments often go to landowners with diverse livelihood strategies and multiple farm production systems (Wunder, 2006). These landowners may have a block of forest that is under a PES contract for protection while planting crops and/or cattle ranching, managing plantation forestry, or even harvesting timber on adjacent lands (Pagiola, Arcenas, & Platais, 2005). These lands often include riparian buffers of forest, remnant trees in pasture, live fences, and recovering or abandoned lands. If participation in PES programs lead to more sustainable management of these other tree resources, a multiplier effect of the payments could be considered.

The possibility that there could be positive impacts on other tree resources through participation in the PES program was examined. Comparisons between ownership of different forest covers including natural forest, reforestation, riparian forests, remnant pasture trees, live fences and charral were made between participants and non-participants. Additional comparisons were made about the motivations to maintain each forest cover type, how each impacted production on their farm, and their future plans for these production systems. It was reasoned that if there were significant differences between participants and non-participants along these lines it could be interpreted as influenced by the PES program and should be considered as part of the additionality of the PES program.

There were significant differences in the ownership of all of forest types addressed (Table D). As expected the percentage of those in PES with natural forest was much more common for PES participants as it is a requirement for participation in the Protection and Sustainable Management programs. Additionally, the reforestation programs were expected to be more common as it is one of the modes of PES that was specifically targeted. While significant numbers of both groups have riparian forest, significantly more non-participants have remnant pasture trees and live fences. This is likely due to the fact that a large number of farms under PES are purely forest and have no pasture to have remnant trees or live fences. There were significantly more landowners with charral in the PES program which may indicate that more participants are abandoning their land. This finding would be consistent with those found with participants in the Osa peninsula (Sierra & Russman, 2005). However, the total number of those with charral is minimal and the amount of hectares under charral were not extensive with over 90% under 10 has in size.

Though there were significant differences in possession of different tree systems, the motivation for maintaining all of these systems were very similar among participants and non-participants. Both groups also viewed impacts of the different tree systems on the productivity of their farm in a similar manner and had similar future intents. While there was little difference between the groups, some of the results are initiative of regional attitudes and trends and are outlined. As natural forest and reforestation have been discussed extensively, the following refers specifically to the other tree systems.

Key motivations for maintaining riparian forests are largely environmental with water conservation, the protection of biodiversity and aesthetics occupying the three most important motivations for each group. Both groups viewed the impact of riparian forests on their production systems overwhelming as positive or having no impact. Importantly, 28% of participants and 39% of non-participants intended to replant deforested areas or increase the size of their riparian forests. Conservation attitudes toward riparian forests appear to be strong and growing and riparian forest would be expected to increase.

Trees in pastures were largely remnants or from natural regeneration. However, active reforesting was observed in pastures. Nearly 16% of each group indicated that they had planted trees in pasture and over 80% of each group selected for specific species of naturally regenerating trees. The motivations to leave and plant trees in pasture were primarily for the future use of the wood, but also for shade for cattle and to conserve water. Less than 10% of both groups reported pasture trees to have a negative impact on their production system with the rest positive or no impact. Nearly half of each group plans to use some of the trees for wood on their farm, while over a quarter of each group plans to sell some of them. The majority of both groups reported that they planned to leave some of the trees there or to plant even more. This data indicates that trees in pasture are generally viewed as a productive part of the overall farm production system and are actively managed to that end.

Live fences were reported to have a larger positive impact on the farm production systems than any of the forest systems. Motivation for their use was driven by their shade potential, use for forage, soil improving abilities and as a windbreak. However, the most often reported motivation was the fact that they cost less than other fence posts. They were also reported to be motivated by the durability of live fences and the fact that there weren't a lot of trees left for fence posts. Low cost, high durability and positive production impacts have led to the adoption of live fences throughout much of the Corridor.

Charalles were not widespread across this landscape. This forest type received the most respondents indicating negative impacts on their farm system with nearly 25% of non-participants citing this. While nearly three quarters of non-participants reported that they were interested in clearing the charral for pasture or crops, half of the participants indicated that they planned to leave this forest type as it was. Motivations to have land in charrales varied from conservation, to future use of the wood, to insufficient funds to clear the land. This region of the country did not have great amounts of abandoned pasture as in other parts of the country (Arroyo-Mora, Sanchez-Azofeifa, Rivard, Calvo, & Janzen, 2004) and much of it returned to non-traditional agriculture crops or reforestation. This forest type was not common in the region and the sample size is small and should be interpreted carefully.

In summary, most of these forest systems are seen as productive elements of farming systems. Motivations for their maintenance involve a mix of economic and environmental values and represent elements of the coveted win-win situation of conservation and development. While there may be a region-wide appreciation for the conservation of these forest systems, attitudes do not appear to be related to participation in the PES programs. Therefore, we find no evidence for a multiplier effect to be considered with Costa Rica's PES program.

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Tables

Table 1: Tree systems on farms.

Tree systems	PES participant N=99	Non-participant N=108
Natural forest	**91 % of total PES 53% with forest are in protection)	44% of total NP 34% of those with forest are NP
Reforestation	*38% of PES 59% of reforest are PES	24% of NP 41% of reforest are NP
Riparian forest	**90% have	82%
Remnant pasture trees	*46%	83%
Live fences	*46%	72%
Charral	*19%	7%

*Non parametric test for independence significant at .05

**Non parametric test for independence significant at .01

APPENDIX 4

Livelihood Assets Analysis

Livelihood Strategies

Livelihood strategies are the activities and choices that people make about the different ways of combining their livelihood assets to meet their own goals and objectives that can vary within geographic areas, across sectors, and even within households over time (R. Chambers & Conway, 1992). Livelihood assets include; human, social, financial, physical, and natural capital (DFID, 2003). Individual farm households are different in terms of livelihood assets in that they have varied production goals, skills and knowledge, resource endowments, and incorporate different combinations of factors of production in their livelihood strategy (Leach, Mearns, & Scoones, 1999). Power is associated with proximate control over, or the capability to access and use rules and resources (Giddens, 1984). The five livelihood assets are integrated under structuration theory and linked to a similar construct of entitlement analysis (Bebbington, 1999; Leach, Mearns, & Scoones, 1999). Because different actors begin with different initial endowments of livelihood assets, development can be measured in terms of capital assets (Bebbington, 1999). We will follow their insights for this model, and use livelihood assets as a measure of an agent's capability to exert power. Both social and human capital will be used to identify the concept of authoritative resources and means for access to and integration of social structures into an agents' internal structure. The capital assets financial, physical, and natural were used to assess the allocative resources and the 'material levers' that actors can combine with their internal structure to perform and action and exert power.

Methodology

Data for this analysis were collected in 2004 by conducting a survey of 208 participants and non-participants in the PES program. A FONAFIFO database of all PES participants (n=510) within the San Juan-La Selva portion of the MBC was used to randomly select a sample of 99 households. Those receiving reforestation incentives from previous programs were included as participants because their payment contracts were continued under the 1996 Forestry Law. A sample of 108 non-participants were selected from the Ministry of Agriculture's 2000 Costa Rican Cattle Census and paired spatially with those in the participant sample. Spatial matching was done to provide control for similar biophysical land use opportunities and socioeconomic conditions. Further pairing was done based on program requirements for entry into the PES programs (Zbinden & Lee, 2005). Sample sizes provided a sampling error of ±9% for participants with only 6 refusals (Salant and Dillman 1994). The unit of analysis was the household, and a research team administered questionnaires via face-to-face survey interviews averaging one hour per household.

There were 72 participants identified with contracts under the protection modality. Non-participants who met the minimum protection program requirements of two hectares of forest were selected from the total list of non-participants for comparison (N=37). These two groups are compared for the protection modality of PES. There were 38 participants who received payments under the reforestation modality of the PES program. There were 96 non-participants who did not have any reforestation, but met minimum requirements for the reforestation program of more than 1 hectare available for reforestation. Twenty-six individuals were identified that had reforestation on their lands but did not receive PES payments. Both non-participant groups were independently compared with participants in the PES reforestation modality.

Livelihoods Assets Analysis

Participants and non-participants were compared across twenty livelihood assets. The assets fall within the five livelihood asset categories as outlined by the livelihood analysis framework; human, social, financial, natural and physical (Carney, 2002; DFID, 2003).

Human Assets

- Age (continuous)
- University education (binary)
- Number of household dependents (continuous)
- Number of family members working on the farm as primary occupation (continuous)

Social Assets

- Number of social and producer organizations to which a household belonged (continuous)
- Number of training courses they had attended in the last five years (continuous)
- Length of time they owned the farm[1] (continuous)

Financial Assets

- Banded income[2] (continuous)
- Percentage of income from agriculture (continuous)
- Use of credit (binary)
- Land title (binary)

Natural Assets

- Farm size (continuous)

- Area of natural forest (continuous)
- Pasture size (continuous)
- Number of cattle (continuous)
- Land value[3] (continuous)

Physical Assets

- Absentee land ownership (binary)
- Availability of electricity (binary)
- Road access (binary)
- Potable water on the farm (binary)

1. The length of time a household owned a farm was used as a proxy to indicate an increased opportunity and interest in forming social networks in the region.
2. The income variable was banded into quintiles due to the wide variation in regional incomes and to facilitate comparison within the region.
3. Land value was used as proxy (hedonic price) to indicate land quality (degradation, slope, etc.) and location (road access, distance to market, etc) as factors that would likely have influenced land use decisions. The indicator for land value was determined by asking landowners how much it would cost to buy a hectare of pasture next to their farm.

Step 1: Paired Comparisons

Summary statistics of paired comparisons are presented in Table 1 for protection and Table 4 for reforestation. One-at-a-time comparisons were made using T-tests for variables under human and social assets and chi-square tests are provided for the remaining variables. The results are strictly descriptive and are used as a diagnosis for multivariate analysis. Significant differences between participants and non participants were found for variables across all five of the livelihood categories and for both programs. Identification of differences in livelihood assets illustrates potential poverty alleviation and rural development impacts of the PES program. Analysis of livelihood asset combinations also allow for investigation of livelihood strategies that are conducive to PES program participation. Furthermore, this analysis may explain some differences reported in the effectiveness of PES at providing additional conservation in other regions of Costa Rica as both the ability and desire to participate in PES programs is, in part, dependent on livelihood strategies. Finally, understanding who is willing and able to participate is useful information for others interested in developing a PES program similar to the one Costa Rica has implemented.

Protection (see Table 1)

Human Assets

Variables measured within the human assets livelihood category included age, university education, the total number of household dependents, and the number of family members who work on the farm as their primary occupation. The mean age for both participants and non-participants were similar and in the low 50s. Box plots indicate that there is not a wide variation for either group regarding age. The mean age for protection was slightly, but significantly (P>.01) higher than that of their corresponding non-participants. These results indicate a slightly older population of established landowners for the whole region and have implications about the stage of their lifecycle of landholders (e.g. they would not likely have very young children and many of their children would be in their 20s).

The percentage of participants who had at least some university education was much higher for participants than non-participants. Nearly one-third of protection participants had some university education which contrasts significantly (P>.005) with the percentages of non-participants with the same level of education (8%). However, the percentages of those with university education for both of these groups are much higher than that of all non-participants (3%).

The total number of household dependents was similar for both those participants and non-participants in the protection program with between 3 and 4 dependents. However, the number of household members working on the farm was significantly (P>.005) higher for non-participants than for households in the protection program with closer to two family members working full time on the farm. Consequently, those in the protection program were more likely to have some university education and have fewer individuals dedicated to working on the farm.

Social Assets

Three social assets were measured including the number of social and producer organizations a household belonged to, the number of training courses they had attended in the last five years, and the length of time they owned the farm. There were no differences in membership in producer and social organizations for the protection program. Training courses were most often attended by non-participants with protection participants attending fewer courses and significantly different (P>.005). The length of time households owned their farms did not vary significantly between groups, with average length of ownership around 20 years suggesting a fairly stable region without large turnovers of property. It also suggests that most of the landholders have owned their farms since the mid 1980s to early 1990s, well after the original colonization of the region. These results indicate that non-participants may be more actively trying to develop or improve a working farm through training.

Financial Assets

Financial assets were evaluated using the indicators of total gross income, percentage of income from agriculture, the use of credit and land title. Both groups with forest had relatively high incomes. The income variable was banded into quintiles due to the wide variation in sample incomes and to facilitate relative comparison across the sample (Table 2). Agriculture as a percentage of income was significantly different between the groups (P>.005). The percentage of income that households obtained from their farm had a bi-modal distribution with over half of participants in the protection program earning no production income from their farm (PES payments excluded), while over half of non-participants earned near 100% of their income from their farm. This indicates a big discrepancy between participants and non-participants regarding the ownership of farms not specifically used for generating income. Credit was used by large percentages of both participants and non-participants. Nearly half of non-participants and 35% of protection participants indicated that lack of finances was one of the two most important factors limiting production on their farm. Land titles were held by the majority of all groups and indicate a closed frontier with property rights largely established. The relatively high income levels and non-income generating use of farms by PES participants significantly differentiates participants from their farm-dependent counterparts.

Natural Assets

Natural assets included farm size, area of natural forest, pasture size, the number of cattle and land value. Farm size and forest size were significantly larger for participants when compared to non-participants (P>.005). A reverse trend was identified in the area allocated to pasture and number of cattle, with significantly more land dedicated to pasture and associated larger herds owned by non-participants (P>.005). The land value result presents another interesting trend indicating that the value of a hectare of pasture on their farm is significantly lower for participants than for their corresponding non-participants (P>.005). 10% of both participants and non-participants indicated that poor soils were a major limitation to activities on their farm (Table 3). These results correspond with earlier speculation about working farms. The distribution of natural assets indicates that non-participants are much more likely to have more valuable and working pastures than non-participants.

Physical Assets

Several indicators of physical assets were explored to understand how they were associated with participation in the protection program. Non-participants in the protection programs are more likely to live on their farm than non-participants. Households of non-participants were significantly more likely to have both connection to electricity and access to potable water on their farm (P>.005). However, year around road access to their farms was not different among the groups. Thirty-five percent of both participants and non-participants indicated that road access was one of the two most important limitations to production options on their farm (Table 3). However, while 12% identified distance to markets as a farm limitation, none of them listed that factor as one of the most important limitations for production on their farm. Though distance to market has been cited as a major limitation for production potentials, it is not currently a major factor in the region (Bouman, Jansen, Schipper, Hengsdijk, & Nieuwenhuyse, 2000; Chomitz & Gray, 1996; Sierra & Russman, 2005). These results imply that having facilities such as access to potable water and electricity correspond with living on the farm. However, as shown, the overwhelmingly majority of those who have forest and those non-participants who could be enrolled in the PES protection program do not live on their farm.

Conclusion for Protection:

Human assets tell us that participants are more likely to be university educated and have less family dedicated full time to their farm. Financial indicators inform us that participants are not dependent on their farm and have higher incomes. Analysis of respondents' natural assets indicates that participants have larger farms and more forests and that they are less likely to be high land value or working farms. The distributions of landowners physical assets suggest that most do not live on farm, but those that do are more likely to have electricity and potable water on their farm. The paired comparison between participants and non-participants in the protection program indicate that though participants have larger farms and more forest, they are less likely to use those farms to generate income. Protection participants are largely absentee landowners who generate their income form other urban sources and are more likely to have a university education. In summary, non-participants are more farm-dependent in their livelihood strategy than participants.

Reforestation (see Table 4)

Participants in the reforestation modality of PES (38) were compared to non-participants without reforestation (96) and with those who had planted reforestation without incentives (26).

Human Assets

All three groups reported similar mean ages. Box plots demonstrate that 95% of participants in all groups fall within 50 and 60 years of age. Both groups with reforestation have a large number of participants with some university education (29%). Non-participants without reforestation have a significantly (P>.005) lower percentage with university education than participants (3%). All groups have similar number of dependents with reforestation participants having slightly, but not significantly lower number of dependents. The number of family members dedicated full time to farm labor is significantly (P>.005) different between reforestation participants and both non-participants with and without reforestation. This suggests that participants both groups of non-participants are more likely to be working their own farm than participants.

Social Assets

Membership in producer associations or organizations was low for all groups. There was a significant (P>.005) difference between participants and non-participants without reforestation with participants more likely to participate. Non-participants without reforestation were also more likely to have attended agricultural production training workshops in the last 5 years than the other groups, but not significantly. The mean length of ownership of farm for all groups was just under 20 years with 95% of farms owned between 15-25 years by all groups. This means that most of the landowners have owned their farms since the mid 1980s to early 1990s, after the original frontier period.

Financial Assets

Income levels for both the reforestation participants and non-participants with reforestation had similar and high income. Non-participants with reforestation had similar gross income as participants. Banded income showed non-participants averaging income in the 20-40% relative income bracket while both reforestation groups averaged in the 60-80% relative income group. Distribution of income by groups shows that non-participants without reforestation are heavily loaded in the lowest income groups while those with reforestation are heavily loaded in the relatively higher income groups and significantly (P>.005) different. However, both groups with reforestation did have individuals in the lowest income groups (Table 5). Participants had significantly different percentages of their income from the farm than non-participants (P>.005). The data demonstrate a bi-modal distribution with over half of all participants receiving none of their income from the farm while over half of all non-participants received all of their income from the farm. Non-participants with reforestation were evenly distributed across the spectrum with both mean and median percentages of income from the farm identified near 50%. Credit use was the highest among non-participants with reforestation and lowest among non-participants without reforestation with participants landing in the middle. There was a significant difference between participants and non-participants without reforestation in credit use (P>.005). Non-participants without forest had the lowest percentage of landowners with title; however, there were no significant differences between groups. Nearly half of all groups felt that lack of finances was the major limitation for developing their farm (Table 3).

Natural Assets

Reforestation participants (136 ha median) had significantly (P>.01) larger farm size than non-participants (16 ha median) with non-participants with their own reforestation falling in the middle (65 ha median) and also significantly (P>.01) different than participants. There were also significant differences in forest area owned by the groups (P>.01). Reforestation participants owned a median of 63 hectares of forest while over half of non-participants without reforestation did not own any forest and significantly different (P>.01). Non-participants with their own reforestation owned a median of 15 hectares of forest, a median amount between the other two groups and also significantly different for participants (P>.01). The amount of pasture and cattle owned by the groups also showed significant differences. Both groups of non-participants owned significantly more pasture and cattle than reforestation participants (P>.005). Both non-participant groups had significantly (P>.005) higher land values than participants with median values nearly double that of participants.

Reforestation participants have the lowest value of land suggesting that forest plantations are being established with incentives on land that has lower productive value. Results indicate that when compared to participants; both groups of non-participants were more likely to have cattle as a production system on their farm on pasture land that was valued higher.

Physical Assets

Significant differences were identified between participants and non-participants for a number of physical assets. Participants in the reforestation program were largely absentee landowners with only 18% living on their farm. This result was significantly ($P>.005$) different from both non-participants without reforestation (67%) and an intermediate result for non-participants with reforestation with 46% living on their farm. These results indicate that there are a large number of landowners across the region that do not live on their farm. Non-participants without reforestation are significantly ($p>.005$) more likely to have electricity and potable water on their farm. Non-participants with reforestation were significantly ($P>.005$) more likely to have electricity than participants and also significantly more likely to have road access ($P>.01$). However, all three groups were very likely to have road access to their farm all year long with participants having the lowest percentage. All of the non-participants with reforestation had year round road access. Nearly a quarter of non-participants without reforestation identified poor access as a major limitation for farm production (Table 3). However, nearly 60% of non-participants with reforestation felt that poor access was a major limitation on their farm production (Table 3). It is unclear if lack of infrastructure in the form of electricity, water, and some road led to landowners leaving the region for larger cities or if landowners were more likely to purchase a farm without infrastructure if they already lived elsewhere.

Conclusions for Reforestation

Human assets show that having some university education is common for the involvement in reforestation for both participants and non-participants. Age and family size do not appear to be factors in determining participation while both non-participant groups are more likely to have an additional family member dedicated to working on the farm. Social assets appeared to be fairly consistent across the three groups with non-participants without reforestation the least likely to be members in producer associations. Both groups with reforestation had higher income and were more likely to use credit than non-participants without reforestation. The biggest discrepancy between the groups was in the percentage of income from agriculture with most reforestation participants receiving very little or none of their current income from the farm. Non-participants with reforestation appear to be evenly distributed regarding percentage of income from agriculture. Analysis of natural assets indicates that participants in reforestation had larger farms and more forest, but had less pasture and cattle than both groups of non-participants. Non-participants with their own reforestation occupied the middle ground on farm size and forest, but had more pasture land and cattle than the other two groups. Land value comparisons indicate that reforestation participants had the lowest land value for pasture on their property. These results indicate that non-participants with reforestation have working farms, but larger working farms than other non-participants. Those with reforestation are better educated, have higher income, larger farms and forest, and are not farm-dependent for their income.

Step 2: Multivariate Analysis Using Decision Trees

Decision Tree Analysis

Decision trees are developed through machine learning systems that derive decision rules from existing data (Berk, 2006). It is an exploratory method that uses algorithms to develop a classification system used to predict or classify observations (SPSS, 1998). Multiple predictor variables are analyzed to identify statistically significant splits that best categorize the dependent variable (Huba, 2006). The CHAID (chi-squared automatic interaction detector) was used for this research and is a highly efficient technique that uses the chi-squared statistic to identify optimal splits in the data (Kass, 1980). The original method was designed for analysis of categorical data but has been extended to allow for analysis of nominal, ordinal, and continuous data (SPSS, 1999). CHIAD uses a stepwise selection process which stops when a variable has a p value of > .05 (SPSS, 1998) and adjusted to "correct for the number of different ways a predictor variable can be split" using the Bonferroni method (Biggs, de Ville, & Suen, 1991; Huba, 2006). Splits are based on the most significant or lowest P value, with subsequent splits identified within each of the newly formed subgroups sequentially forming branches on the tree (Huba, 2006).

This method was selected because of its ability to use multiple measurement levels of predictor variables (nominal, ordinal and categorical), multicolinearity among the predictor variables, and a high number of predictor variables and small sample size which are problematic for other methods such as logistic regression (Tabachnick & Fidell, 2001). Additionally, the ability of decision trees to identify 'split levels' in continuous variables gives information not provided using other methods. Finally, the visual representation of the data provides an ease of interpretation for both researchers and professionals. However, because of the stepwise nature of the CHAID decision tree analysis, breaks in the data are dependent on prior splits. This means that there are potentially alternative decision tree models with powerful classification abilities. For this reason, multiple decision trees were run for each program. The first tree was run with all the variables, and the second tree excluded the 'most important' variable identified in the first branch in the first tree. Two decision trees were obtained for the protection program and for the reforestation program. Trees were run for reforestation comparing reforestation participants with non-participants without reforestation and non-participants with reforestation that they planted without incentives. This provided additional information on alternative decision tree classification models. For general reading on decision trees, and multiple decision trees as compared to logistic regression analyses see Berk 2006, Lim, Loh and Shih 2000, and Perlich, Provost and Siminoff 2003 (Berk, 2006; Lim, Loh, & Shih, 2000; Perlich, Provost, & Siminoff, 2003).

Protection (Figures 1 & 2)

The CHAID analysis for protection indicated that the first and most significant variable selected was the percentage of income a household gained from agriculture (Figure 1). This could be expected because of the largely bimodal nature of the data identified in the summary data. Few of those who obtained all of their income from the farm were participants in the protection program. The few who were almost completely dependent on their farm all had over 20 hectares of natural forest. The majority of the sample (57%) and three quarters of all protection participants had less then 54% if their income from the farm. However, only 16% of non-participants fall into this category. Of those households, participants were more likely to have at lease 45 hectares of natural forest. One quarter of the sample received between 54-99% of their income from their farm. Of this group, living on or off of their farm was the best indicator of participation. While participants were near evenly split between living on or off of their farm, a larger percentage of non-participants within this category lived off of their farm. This suggests that while living off of the farm was predominantly a trait of protection participants as identified in the paired comparison, non-participants with forest who obtained at least half of their income from the farm were much more likely to be absentee landowners than live on their farm. The decision tree analysis classified the groups correctly (risk estimate) 85% of the time with the protection category correctly classified 92% of the time.

A second decision tree was run for the protection program that excluded the variable agriculture as a percentage of total income (Figure 2). The most important variable identified in this tree was the amount of primary forest on a farm. Very few farms that have less than 8 hectares of forest were in the protection program while almost all of the farms with over 80 hectares of forest had their land in protection. For those that had between 8 and 80 hectares of forest, participants in the protection program were much more likely to have less than 45 hectares of pasture on their farm than non-participants. This decision tree correctly classifies 84% of the total population. This tree is not as successful at classifying protections participants (86%) as the previous one that included agriculture as a percentage of income, but the tree is more accurate at classifying non-participants. This suggests that non-participants may be better identified using natural assets of forest cover and pasture lands while identifying participants is most efficient by combining farm-dependence for income with forest cover.

Reforestation Participants and Non-Participants without Reforestation (Figures 3 & 4)

Participants in the reforestation modality of the PES were compared to non-participants who do not have any reforestation of their own (Figure 3). Decision tree analysis running all of the livelihood variables indicates that the amount of pasture is the most important variable differentiating participants from non-participants. Nearly 50% of all participants have no pasture after reforesting their land while only 3% of non-participants have no pasture lands. Of those that do have pasture, the amount of natural forest on a farm is the best classifier of participants and non-participants. The majority of non-participants have less than 4 hectares of forest on their farm. Another quarter of non-participants had between 4-100 hectares of forest land. Of the few landholders that had over 100 hectares of forest (9) all but one had reforestation. This tree correctly classified 88% of the sample correctly. However, it only classified 68% of the reforestation participants correctly.

A second decision tree was run without the variable pasture land (Figure 4). This analysis found agriculture as a percentage of total income as the most important classification variable. This tree identified the majority of the reforestation participants (66%) as having less than 9% of their income from the farm. Of those with very low income from the farm, almost all of them did not live on their farm. On the other extreme, almost all of those that obtained 100% of their income from the farm did not have reforestation with PES. Of the remaining sample (35%) with intermediate income from agriculture, the majority of non-participants had less than 26 hectares of total farm land. This indicates that a minimum of 26 hectares of farm is important for those who are marginally dependent on their farm for income and plan to reforest with incentives. This tree correctly classified 85% of the sample correctly with 87% of reforestation participants classified correctly. As previously noted for protection, natural assets were more successful at identifying non-participants, but participants were better classified by a combination of financial and natural assets.

Reforestation Participants and Non-Participants with Reforestation (Figures 5 & 6)

Additional decision trees were run contrasting reforestation participants with non-participants who had their own reforestation (Figure 5). The value of pasture land was the most important variable distinguishing between these groups. Sixty percent of the participants had a land value for pasture below $1,095 per hectare while only 12% if the non-participants did. Of this group with low land values, almost all of them had less than 6 hectares of pasture. For those who had a higher land value, absentee ownership was the next best classifier. While nearly half of the non-participants with reforestation lived on their farm, almost all of the participants were absentee landowners. From this group that lived on their farm, almost all participants had less than 40 head of cattle. This data does suggest that absentee landowner participants are taking advantage of low value land to plant reforestation plots. Non-participants with reforestation tend to have higher value land, to live on their farm, and to have more cattle. This decision tree correctly classified the sample 83% of the time, but correctly classified reforestation participants 92% of the time.

A second decision tree was run without the land value variable (Figure 6). This tree identifies the number of people working on the farm as the best classifier. Non-participants with reforestation are more likely to have more than one family member dedicated full time to the farm. Of those with less than one family member dedicated to the farm, reforestation participants were more likely not to have electricity on their farm. The lack of electricity on the farm corresponds with the high rate of absentee ownership. This also supports the interpretation that non-participants with reforestation are more likely to have a working farm with substantial amounts of their income generated on the farm than participants. This decision tree correctly classified 75% of the total sample, with 84% of the reforestation participants correctly classified.

Step 3: Multivariate Analysis Using Factor Analysis and Logistic Regression

Livelihood assets are grouped under five major asset variables; human, social, financial, physical and natural. Each of these variables has a number of different indicators that can be used to understand the asset base. Assets are understood to be used and combined in numerous ways by different agents to develop their livelihood strategy (Carney, 2002). The asset groupings and indicators are not intended to be mutually exclusive and correlation is expected. Therefore, to understand livelihood strategies it is critical to see how the different asset combinations are associated with each other or, how they move together. Analysis was done on livelihood asset combinations using factor analysis to identify how the asset combinations ‘moved together’ in a study of participation in Costa Rica’s program of payments for environmental services.

Factor analysis is a data reduction technique that is used to explain the relationship between correlated variables (Kleinbaum, Kupper, & Muller, 1988). It is used to capture combinations of variables that account for patterns of correlations by analyzing shared variance. Factor analysis is useful for reducing a large number of variables into a more manageable number for use in multiple regression analysis (Kleinbaum, Kupper, & Muller, 1988). Exploratory factor analysis was used to identify the correlations between the livelihood assets indicators to capture the underlying meaning of the correlated data. The groups of correlated indicators, or ‘factors’, that were created from the factor analysis were then used in a logistic regression.

Logistic regression was used to test the ability of the factors to predict participation in Costa Rica’s PES program. This analysis gives insight into the livelihood strategies that influence the ability or willingness to participate in the PES programs. Logistic regression allows for the prediction of categorical outcomes such as participants versus non-participants. Logistic regression also is capable of using different levels of variables from continuous to categorical as used in this study.

Protection: Factor Analysis

The number of factors was determined by using Kaiser's criterion where only values with eigenvalues of greater than 1 are used for analysis. Factor analysis was run with one more and one less variable than identified by the Kaiser criterion to see if improvements could be made on the factor loadings. No improvements were identified. Varimax rotation was used to minimize the number of high loading variables. Eight factors were selected with eigenvalues greater than 1 for the factor analysis of participation in the protection program. These factors explained 74% of the total variation among the indicators (Figure 8).

Factors Definitions:

Factor 1: Working farm (includes the indicators: cattle herd size, family members working on the farm, pasture size, family size, and farm income as a percentage of total income.)

Factor 2: Natural asset extent (includes the indicators: farm and forest size)

Factor 3: Farm infrastructure (includes the indicators: electricity, potable water, and the negative association with living on their farm)

Factor 4: Education and Income (includes the indicators: education and income)

Factor 5: Long term resident (includes the indicators: years of farm ownership and head of household age)

Factor 6: Farm ownership (includes the indicators: title and credit use)

Factor 7: Isolation (includes the indicators: negative relationship between number of training courses and road access)

Factor 8: Organizational membership (includes the indicators: membership in producer organizations and the value of their land)

Factor loadings were strong; however, there were a few substantial cross factor loadings. Specifically, the variables agriculture as a percentage of total income primarily loaded on factor 1 (working farm) and to a lesser degree on factor 3 (farm infrastructure). Other cross loadings included living on farm primary association with factor 3 (farm infrastructure) but also being closely associated with factor 4 (education and income). The final cross loaded indicator was land value which primarily loaded on factor 8 (organizational membership) but was nearly as related to factor 3 (farm infrastructure).

Protection: Logistic Regression

Decision to participate = B_0 + B_1 * Working farm + B_2 * Natural asset extent + B_3 * Farm infrastructure + B_4 * Education and income + B_5 * Long term resident + B_6 * Farm ownership + B_7 * Isolation + B_8 * Organizational membership

Logistic regression was run on the eight factors to identify whether the grouped indicators had predictive power for classifying participation in the protection modality of the PES program (Figure 7). A 66% cutoff was used to adjust for the number of participants and non-participants in the program. The Omnibus Test of Model Coefficients examines the goodness of fit of the regression model with a chi-square value of 49.06 with 8 degrees of freedom with significance level of .000. The pseudo R-square statistics presented in the Model Summary indicate that the model explains between 36% - 50% of the variation in the model. The Classification Table shows that nearly 79% of the overall cases were correctly classified with nearly equal amounts of participants and non-participants classified correctly. Overall, three factors were found to have statistically significant relationships with participation. Factors 1 (working farm), Factor 2 (Natural asset extent), and Factor 3 (farm infrastructure) were all significant at the p-value <.05. The B values should not be used to assess probability of a case falling into a specific category because the indicators were a combination of continuous indicators using different scales and binomial variables. However, the direction of the relationship can be interpreted. In this case, participation has a negative relationship with Factor 1 which represents aspects of a working farm. Factor 2 represents the extent of a landowner's natural assets and is positively associated with participation. Factor 3 represents farm infrastructure and living on the farm which is also negatively associated with participation in the protection program.

Reforestation: Factor Analysis

The number of factors was determined by using Kaiser's criterion where only values with eigenvalues of greater than 1 are used for analysis. Factor analysis was run with one more and one less variable than identified by the Kaiser criterion to see if improvements could be made on the factor loadings. No improvements were identified. Varimax rotation was used to minimize the number of high loading variables. Seven factors were selected with eigenvalues greater than 1 for the factor analysis of participation in the reforestation program. These factors explained 75% of the total variation among the indicators (Figure 9).

Factors Definitions:

Factor 1: Working farm (includes the indicators: cattle herd size, farm income as a percentage of total income, pasture size, and number of family members working on the farm)

Factor 2: Natural asset extent (includes the indicators: farm and forest size)

Factor 3: Farm stability (includes the indicators: title, live on farm, and years owned farm)

Factor 4: Income and education (includes the indicators: income, a negative relation to use of credit, and university education)

Factor 5: Farm infrastructure (includes the indicators: potable water and electricity)

Factor 6: Developing farm (includes the indicators: family size, number of training courses, a negative relationship to age, and a negative relationship to road access)

Factor 7: Organizational membership (includes the indicators: membership in producer organizations and the value of their land)

Factor loadings were strong; however, there were a few substantial cross factor loadings. Specifically, the variable total pasture primarily loaded on factor 1 (working farm) and to a lesser degree on factor 2 (natural asset extent). Other cross loadings included electricity on the farm primary association with factor 5 (farm infrastructure) but also being closely associated with factor 1 (working farm). Interview age primarily loaded on factor 6 (developing farm) but also loaded on factor 3 (farm stability). The final cross loaded indicator was years of farm ownership which primarily loaded on factor 3 (farm stability) but was also loaded on factor 5 (farm infrastructure).

Reforestation: Logistic Regression

Decision to participate = B_0 + B_1 * Working farm + B_2 * Natural asset extent + B_3 * Farm stability + B_4 * Income and education + B_5 * Farm infrastructure + B_6 * Developing farm + B_7 * Organizational membership

Logistic regression was run on the seven factors to identify whether the grouped indicators had predictive power for classifying participation in the reforestation modality of the PES program (Figure 10). A 28% cutoff was used to adjust for the number of participants and non-participants in the program. The Omnibus Test of Model Coefficients examines the goodness of fit of the regression model with a chi-square value of 68.31 with 7 degrees of freedom with significance level of .000. The pseudo R-square statistics presented in the Model Summary indicate that the model explains between 40% - 57% of the variation in the model. The Classification Table shows that nearly 87% of the overall cases were correctly classified with nearly equal amounts of participants and non-participants classified correctly. Overall, four factors were found to have statistically significant relationships with participation. Factors 1 (working farm), Factor 2 (Natural asset extent), Factor 3 (farm stability), and Factor 5 (farm infrastructure) were all significant at the p-value <.05. The B values should not be used to assess probability of a case falling into a specific category in this case because the indicators were a combination of continuous indicators using different scales and binomial variables. However, the direction of the relationship can be interpreted. In this case, participation in reforestation has a negative relationship with Factor 1 which represents aspects of a working farm. Factor 2 represents the extent of a landowner's natural assets and is positively associated with participation. Factor 3 represents farm stability and living on the farm which is positively associated with participation in the reforestation program. That Factor 3 is positively associated with participation is a bit confusing since title was positively associated with reforestation participation in the paired comparisons and decision trees and living on the farm was often negatively associated with participation and years of farm ownership was neutral. Factor 5 represented farm infrastructure and was negatively associated with participation in the reforestation program.

Conclusion

The paired comparison identified the actual population make-up (percentages of who live on farm, median land values, etc.) that were not provided in the other analyses. Decision trees identified the 'best' classifying indicators and provided insight to split or break points (the percentage of income from farm sources, the amount of hectares, etc.).With factor analysis, each of the factors represents a combination a number of indicators to measure an underlying characteristic that explains participation. Understanding how these indicators move together in factors gives insight to the relationship between livelihood assets and adds another dimension to the analysis provided by the paired comparisons and decision trees. Multiple analyses provide a more complete picture of the livelihood strategies that influence the ability/willingness to participate in the PES programs.

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Tables

Table 1: Livelihood paired comparisons for protection participants versus non-participants with over 2 hectares of forest.

Livelihood category	**Variable**	**Protection participants** N=72	**Protection non-participants** N=37
Human	**Age** [A] (mean years)	*55.7	51.1
	University education [B] (% with some university education)	**29%	8%
	Total dependents [A] (mean # individuals)	3.13	3.46
	Family on-farm labor [A] (mean # individuals)	**1.07	1.92
Social	**Organization membership** [A] (# memberships)	.82	.87
	Training courses [A] (# attended in last 5 years)	**.18	.87
	Years owned farm [A] (# years)	21.2	19
Financial	**Income (**Banded) [1]	4 median 3.40 mean	3 median 2.94 mean
	Agricultural Income [B] (% of total income)	**0% (Mean=24%)	100% (Mean=79%)
	Credit use [B] (% who have used)	79%	68%
	Title [B] (% with title)	97%	89%
Natural	**Farm size** [B] (median hectares)	** 137 (Mean=209)	79 (Mean=138)
	Forest area [B] (median hectares)	**70 (Mean=122)	9 (Mean=28)
	Pasture area [B] (median hectares)	**8 (Mean=31)	32 (Mean=67)
	Cattle [B] (median # head)	**0 (Mean=28)	25 (Mean=75)
	Land value per ha pasture [B] (median value)	**$1,712 (Mean=$2,206)	$2,283 (Mean=$3,207)
Physical	**Live on farm** [B] (% who live on farm)	29%	43%
	Electricity on farm [B] (% with electricity)	**39%	68%
	Road access all year [B] (% with access)	80%	89%
	Water on farm [B] (% with piped or well water)	**56%	84%

- ** Indicates significance at α = .05
- * Indicates significance at α =.10
- [A] = Independent T-Tests.
- [B] = Non-Parametric tests for independence used for non-normal data and small sample size.
- [1] = Income was banded into quintiles due to non-normal distribution of data.

Table 2: Protection banded income.

Relative income	0-20%	20-40%	40-60%	60-80%	80-100%
Participant	10	8	12	21	17
	15%	12%	18%	31%	25%
Non-participant	8	6	6	8	6
	23%	18%	18%	23%	18%

Table 3: Top two major factors limiting farm production activities (% of total participants).

Farm limitation	Protection Participant N=72	Protection non-participant N=37	Reforestation participant N=38	Reforestation non-participant without reforestation N=96	Reforestation non-participant with reforestation N=26
Finances lacking	35%	49%	32%	52%	46%
Access to farm	35%	35%	37%	23%	58%
Market for goods	5%	8%	10%	10%	15%
Poor soils	10%	5%	3%	7%	15%
No limitations	29%	24%	29%	35%	42%

Table 4: Livelihood paired comparisons for protection participants versus non-participants with over 2 hectares of forest.

Livelihood category	**Variable**	**Non-participants without reforestation** N=96	**Reforestation participants** N=38	**Non-participants with own reforestation** N=26
Human	**Age** [A] (mean years)	55	53.1	53.5
	University education [B] (% with some university education)	**3%	29%	29%
	Total dependents [A] (mean # individuals)	3.42	2.84	3.35
	Family on-farm labor [A] (mean # individuals)	**1.87	1.13	**1.8
Social	**Organization membership** [A] (# memberships)	**.59	1.02	.84
	Training courses [A] (# attended in last 5 years)	.86	.65	.36
	Years owned farm [A] (# years)	18.1	18.9	19.5
Financial	**Income (**Banded) [1]	**2 median **2.56 mean	4 median 3.64 mean	4 median 3.46 mean
	Agricultural Income [B] (% of total income)	**100% med **75mean	0% med (Mean=21%)	**44% median **50% mean
	Credit use [B] (% who have used)	**60.4%	82%	92% (not sig)
	Title [B] (% with title)	80%	92%	100%
Natural	**Farm size** [B] (median hectares)	*16 median **64 mean	136 median 244 mean	*65 median 154 mean (not sig T)
	Forest area [B] (median hectares)	*0 median **12 mean	63 median 134 mean	*15 median **56 mean
	Pasture area [B] (median hectares)	**11 median 37 mean	1 med 22 mean	**16 median 38 mean (Not sig. T)
	Cattle [B] (median # head)	**14 median 40 mean	** 0 med 25 mean	**19 median *56 mean
	Land value per ha pasture [B] (median value)	**2,739 median **4,193 mean	**$1,096 med $1,478 mean	**2,740 median **4,940 mean
Physical	**Live on farm** [B] (% who live on farm)	**67%	**18%	**46%
	Electricity on farm [B] (% with electricity)	**83%	**40%	**77%
	Road access all year [B] (% with access)	93%	84%	*100%
	Water on farm [B] (% with piped or well water)	**87%	61%	81%

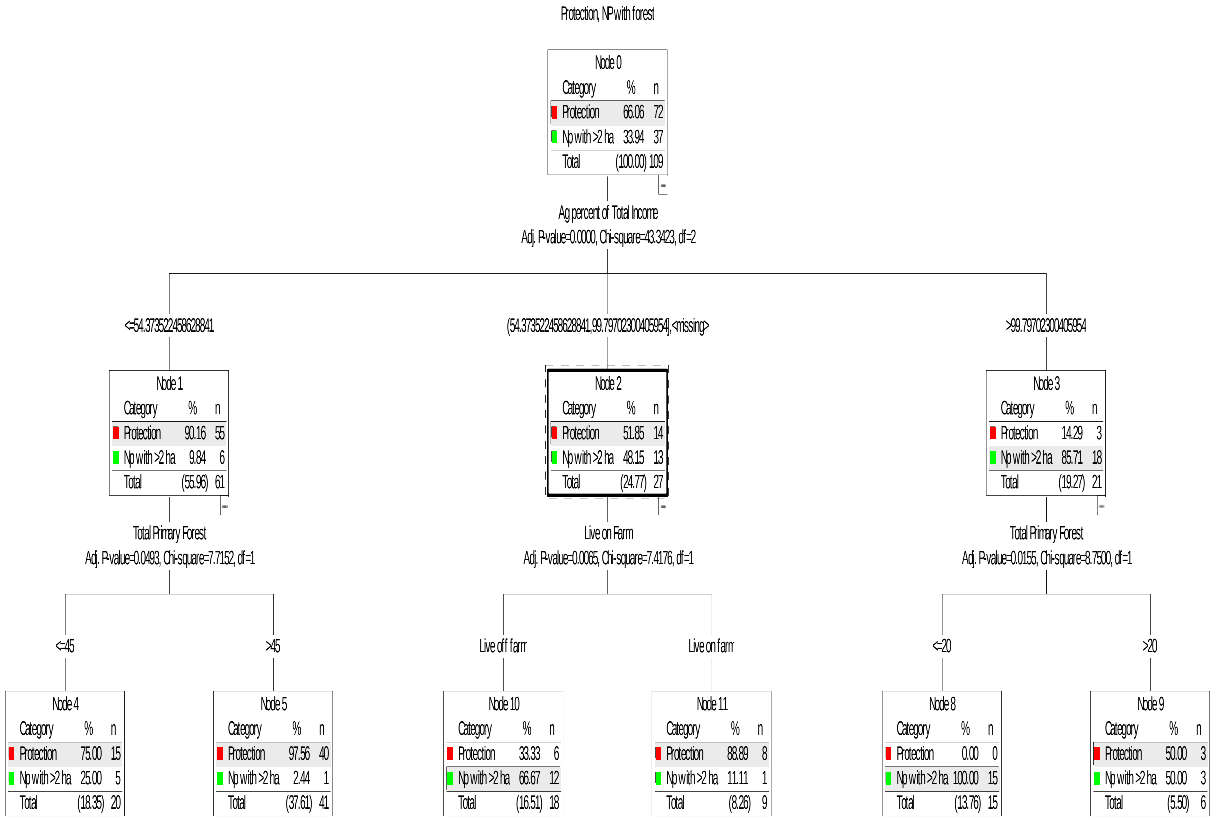
- ** Indicates significance at $\alpha = .05$
- * Indicates significance at $\alpha = .10$
- [A] = Independent T-Tests.
- [B] = Non-Parametric tests for independence used for non-normal data and small sample size.
- [1] = Income was banded into quintiles due to non-normal distribution of data.

Table 5: Reforestation banded income.

Relative income	0-20%	20-40%	40-60%	60-80%	80-100%
Non-participant	23	26	17	11	11
without forest	25%	30%	19%	13%	13%
Participant	3	4	6	13	10
	8%	11%	17%	36%	28%
Non-participant	6	0	6	4	10
with forest	23%	0%	23%	15%	38%

Figures

Figure 1: Protection CHIAD.



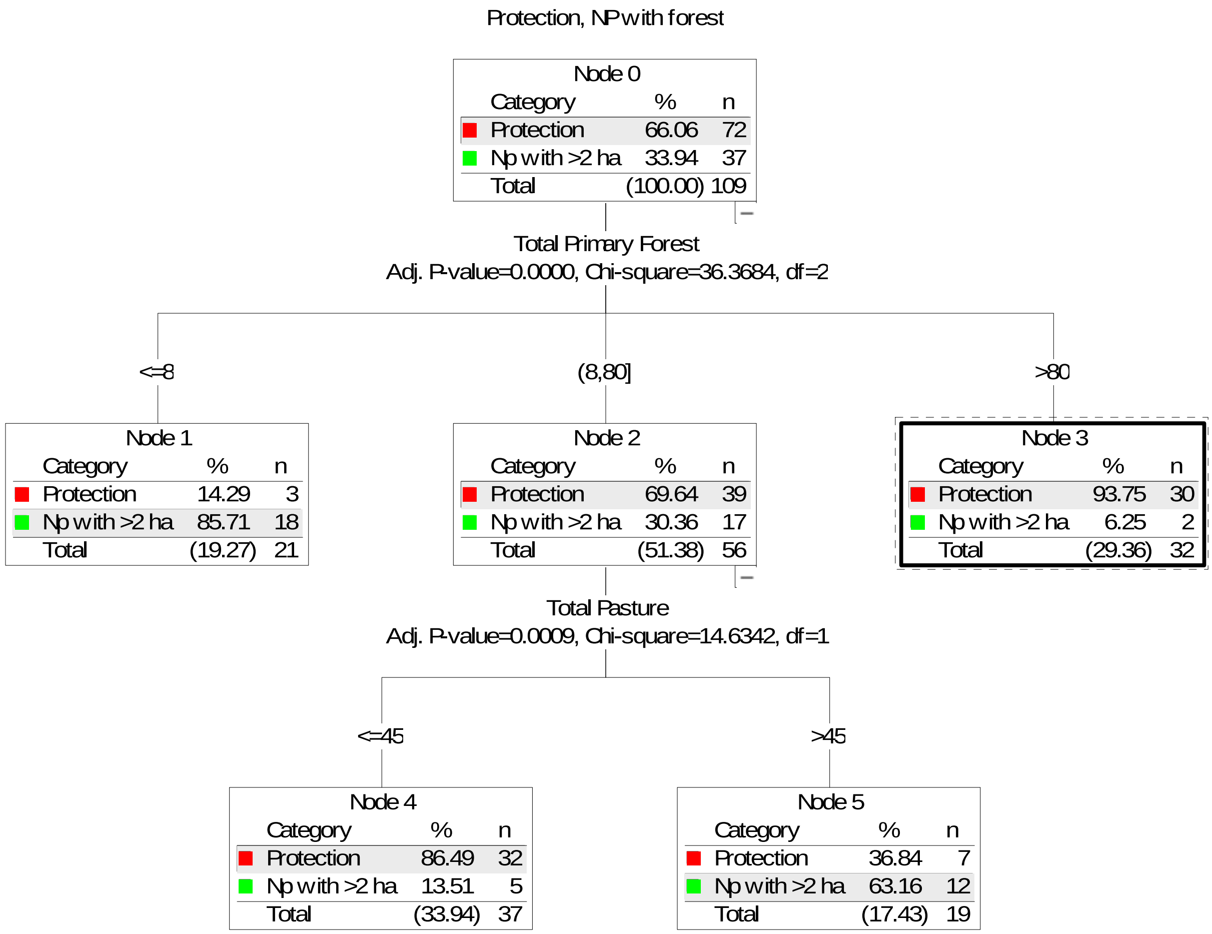
Misclassification Matrix

		Actual Category		
		Protection	Np with >2 ha	Total
Predicted Category	Protection	66	10	76
	Np with >2 ha	6	27	33
	Total	72	37	109

Risk Statistics

Risk Estimate	0.146789
SE of Risk Estimate	0.033897

Figure 2: Protection CHIAD: Without the variable agriculture as a percentage of income.



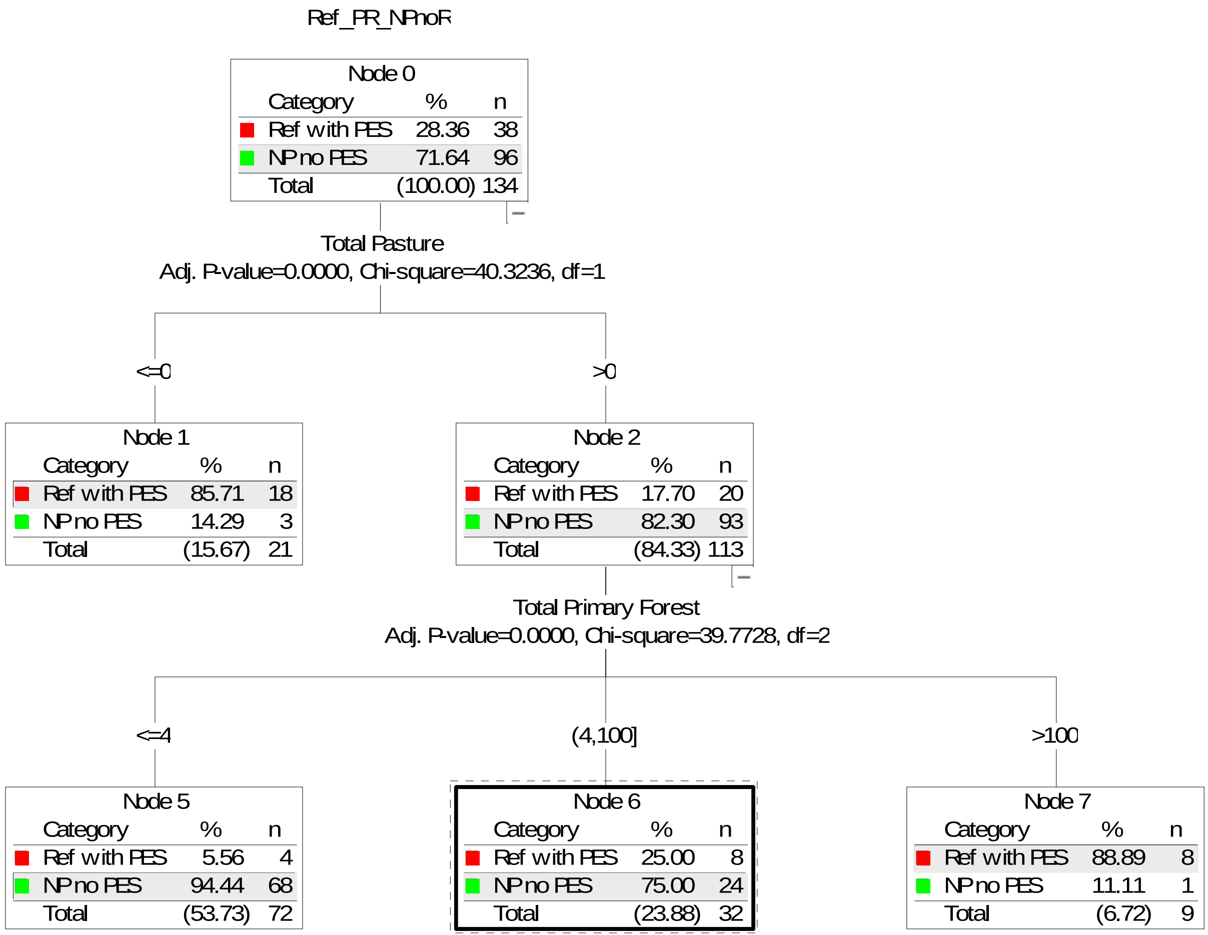
Misclassification Matrix

		Actual Category		
		Protection	Np with >2 ha	Total
Predicted Category	Protection	62	7	69
	Np with >2 ha	10	30	40
	Total	72	37	109

Risk Statistics

Risk Estimate	0.155963
SE of Risk Estimate	0.0347519

Figure 3: Reforestation CHIAD.
(participants and non-participants without own reforestation)



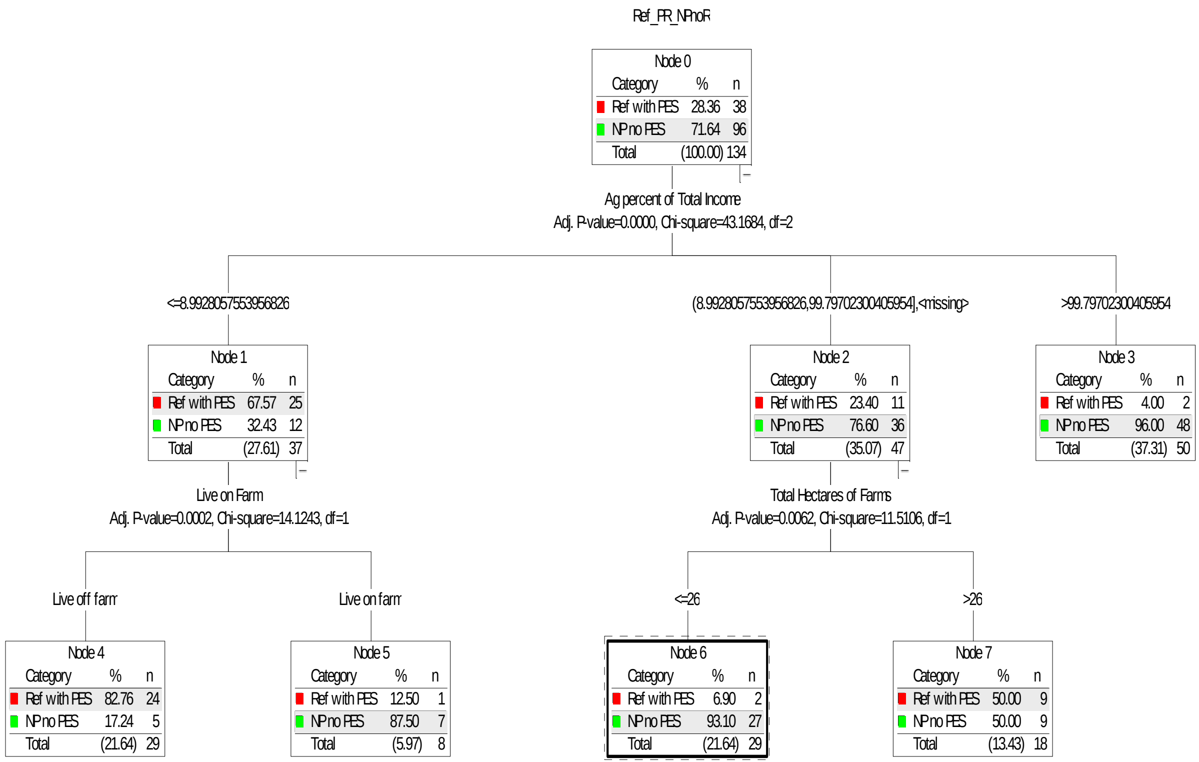
Misclassification Matrix

		Actual Category		
		Ref with PES	NP no PES	Total
Predicted Category	Ref with PES	26	4	30
	NP no PES	12	92	104
	Total	38	96	134

Risk Statistics

Risk Estimate	0.119403
SE of Risk Estimate	0.028012

Figure 4: Reforestation CHIAD: Without the variable pasture.
(participants and non-participants without own reforestation)



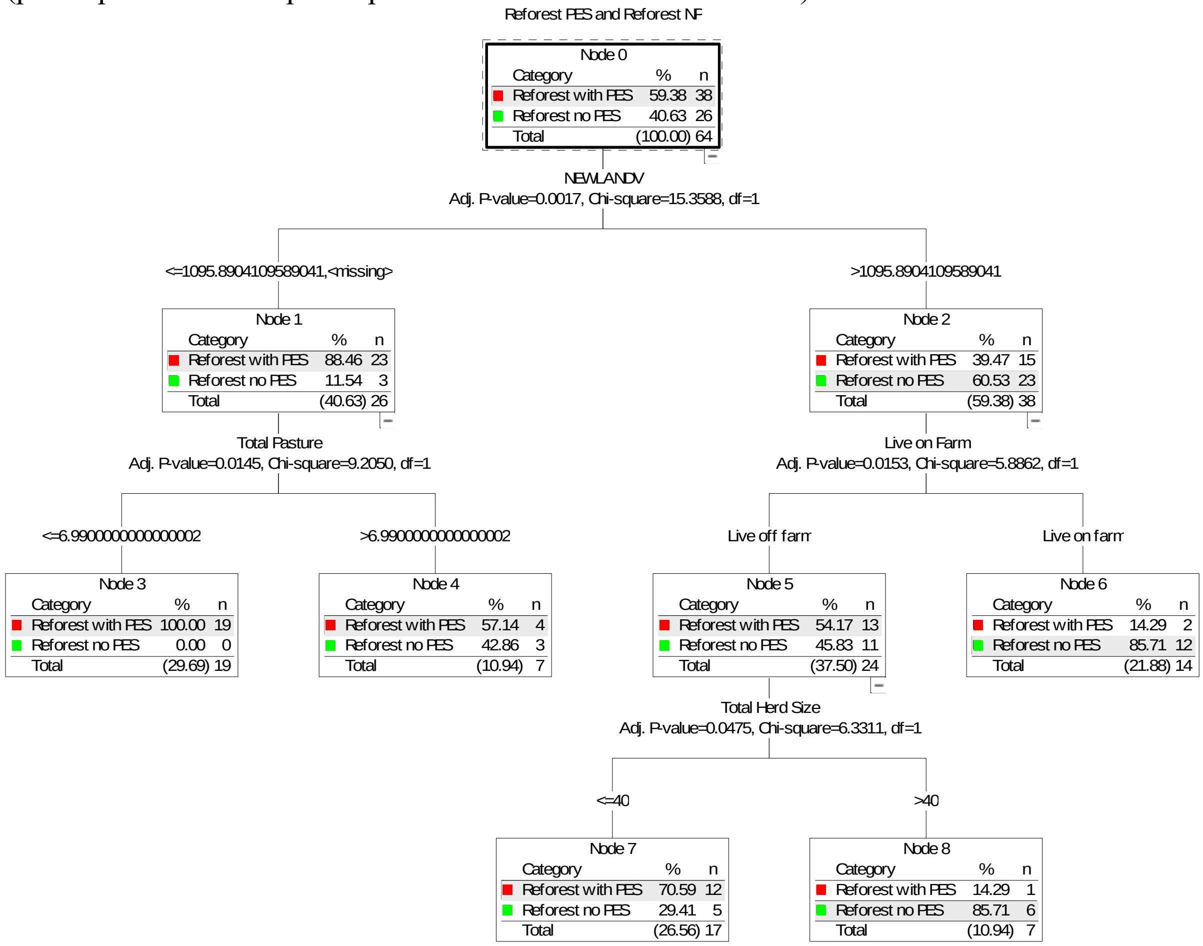
Misclassification Matrix

		Actual Category		
		Ref with PES	NP no PES	Total
Predicted Category	Ref with PES	33	14	47
	NP no PES	5	82	87
	Total	38	96	134

Risk Statistics

Risk Estimate	0.141791
SE of Risk Estimate	0.0301348

Figure 5: Reforestation CHIAD.
(participants and non-participants with their own reforestation)

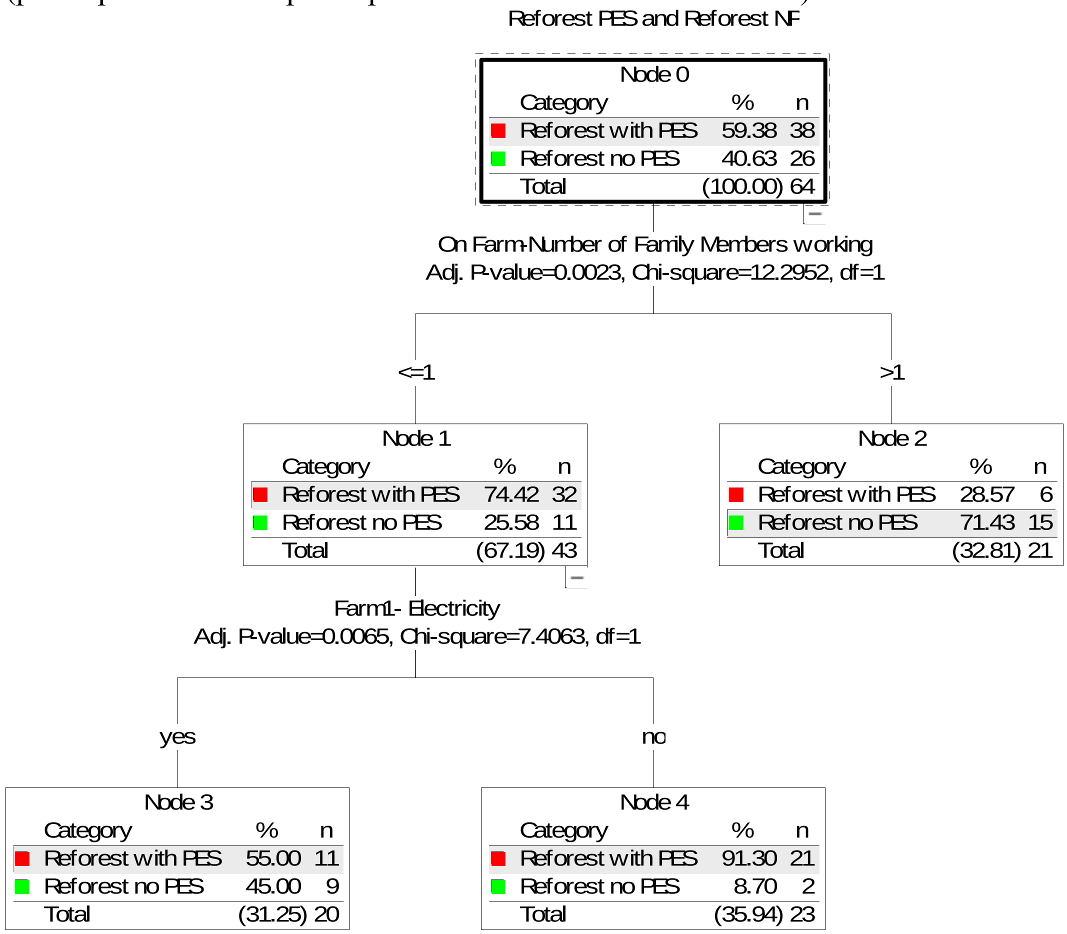


Misclassification Matrix

		Actual Category		
		Reforest with PES	Reforest no PES	Total
Predicted Category	Reforest with PES	35	8	43
	Reforest no PES	3	18	21
	Total	38	26	64

Risk Statistics	
Risk Estimate	0.171875
SE of Risk Estimate	0.047159

Figure 6: Reforestation CHIAD: Without the variable land value.
(participants and non-participants with their own reforestation)



Misclassification Matrix

		Actual Category		
		Reforest with PES	Reforest no PES	Total
Predicted Category	Reforest with PES	32	11	43
	Reforest no PES	6	15	21
	Total	38	26	64

Risk Statistics

Risk Estimate	0.265625
SE of Risk Estimate	0.0552082

Figure 7: Protection: Factor analysis.

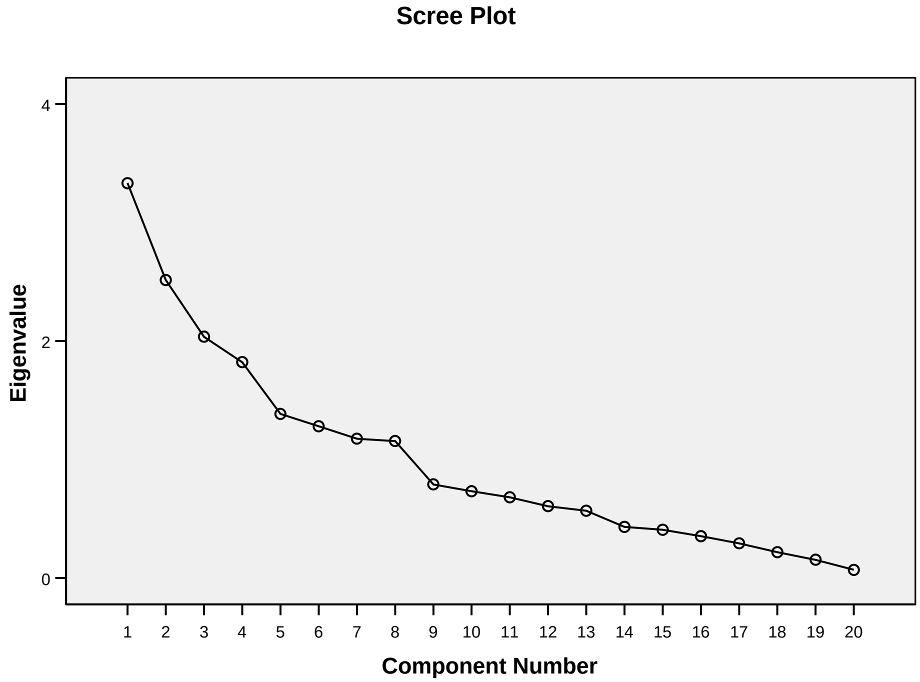
Rotated Component Matrix[a,b]

	Component							
	1	2	3	4	5	6	7	8
Total Herd Size	.789	.130	.158	.291	.073	.011	.109	-.071
On Farm-Number of Family Members work	.699	-.030	.317	-.223	.123	.033	.051	.300
Total Pasture	.621	.252	.074	.397	.226	.101	.196	-.338
Total number of Dependents	.619	-.045	-.027	-.118	-.177	.029	-.396	.147
Ag percent of Total Income	.534	-.192	.505	-.224	-.204	-.055	.183	-.114
Total Hectares of Farr	.118	.958	.008	.109	.022	.061	.041	.020
Total Primary Forest	-.058	.935	-.086	-.018	.021	-.021	-.019	.074
Farm1- Electricity	.152	-.072	.717	.097	.200	.104	.164	.013
Farm1- Water	.133	.018	.708	.094	.001	.033	.004	.046
Live on Farm	-.116	-.123	-.539	.427	.003	.343	.264	.178
Education Groups Universtiy Binomial	-.065	-.066	.096	.805	.034	.119	.055	.003
Mid-point income in U	.252	.382	.036	.698	-.121	-.045	-.171	.126
year owned farm	.025	.131	.096	-.148	.844	.096	-.035	-.159
Interviewee-age	.019	-.081	.058	.112	.844	-.151	.177	.103
Farm1- Title	.155	-.027	-.065	-.063	.071	.868	-.007	.193
Credit	-.090	.084	.181	.258	-.135	.682	.018	-.189
Number of Training Courses	-.175	.017	.126	.062	-.217	.189	-.718	-.173
Farm1-Yearly Access road	-.084	.029	.341	.042	-.093	.258	.716	.052
Total of Producer and social-political organizations	.074	.169	-.018	.041	-.099	.032	.178	.799
NewLandValue	-.078	-.192	.471	.219	.339	.077	-.067	.495

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 10 iterations.

b. Only cases for which Protection, NP with forest = Protection are used in the analysis phase.



Total Variance Explained[a]

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.332	16.661	16.661	3.332	16.661	16.661
2	2.514	12.571	29.232	2.514	12.571	29.232
3	2.036	10.182	39.414	2.036	10.182	39.414
4	1.821	9.106	48.520	1.821	9.106	48.520
5	1.385	6.924	55.444	1.385	6.924	55.444
6	1.280	6.400	61.844	1.280	6.400	61.844
7	1.176	5.878	67.722	1.176	5.878	67.722
8	1.155	5.777	73.499	1.155	5.777	73.499
9	.790	3.948	77.447			
10	.732	3.658	81.105			
11	.681	3.407	84.512			
12	.606	3.031	87.543			
13	.568	2.840	90.383			
14	.431	2.154	92.536			
15	.407	2.035	94.571			
16	.353	1.763	96.334			
17	.293	1.463	97.797			
18	.218	1.091	98.888			
19	.154	.770	99.658			
20	.068	.342	100.000			

Extraction Method: Principal Component Analysis.

a. Only cases for which Protection and NP with no-psa = Protection are used in the analysis phase.

Figure 8: Protection: Logistic regression.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	49.056	8	.000
	Block	49.056	8	.000
	Model	49.056	8	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	90.610[a]	.362	.502

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Classification Table[a]

			Predicted		
			Protection and NP with no-psa		
	Observed		NP for protection	Protection	Percentage Correct
Step 1	Protection and NP with no-psa	NP for protection	29	8	78.4
		Protection	15	57	79.2
	Overall Percentage				78.9

a. The cut value is .660

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	Upper
Step 1[a]	FAC1_1	-1.058	.293	13.049	1	.000	.347	.195	.616
	FAC2_1	1.704	.614	7.706	1	.006	5.494	1.650	18.293
	FAC3_1	-.801	.257	9.684	1	.002	.449	.271	.744
	FAC4_1	.114	.260	.190	1	.663	1.120	.673	1.866
	FAC5_1	.335	.322	1.081	1	.299	1.398	.744	2.627
	FAC6_1	.307	.231	1.767	1	.184	1.360	.864	2.139
	FAC7_1	.321	.255	1.583	1	.208	1.378	.836	2.273
	FAC8_1	.472	.314	2.251	1	.134	1.603	.865	2.968
	Constant	2.219	.468	22.507	1	.000	9.195		

a. Variable(s) entered on step 1: FAC1_1, FAC2_1, FAC3_1, FAC4_1, FAC5_1, FAC6_1, FAC7_1, FA

Figure 9: Reforestation: Factor analysis.

KMO and Bartlett's Test[a]

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.485
Bartlett's Test of Sphericity	Approx. Chi-Square	233.431
	df	190
	Sig.	.017

a. Only cases for which Ref_PR_NPnoR = Ref with PES are used in the analysis phase.

Rotated Component Matrix[a,b]

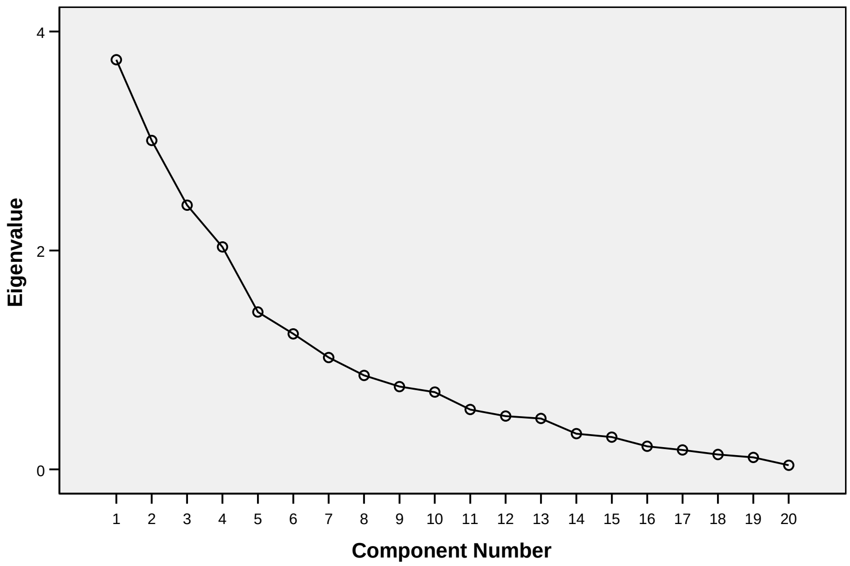
	Component						
	1	2	3	4	5	6	7
Total Herd Size	.875	.067	.118	-.025	.000	-.023	-.084
Ag percent of Total Income	.719	-.266	-.156	-.023	.340	.131	.027
Total Pasture	.698	.505	.085	.017	-.047	-.004	.016
On Farm-Number of Family Members working	.664	.022	-.318	-.087	.151	.176	.310
Total Hectares of Farms	.046	.954	.113	-.011	-.001	.041	.129
Total Primary Forest	-.052	.909	.096	-.034	.045	-.039	.048
Farm1- Title	.000	.185	.845	.030	-.108	-.011	-.159
Live on Farm	-.326	.175	.721	-.134	-.240	-.158	.092
year owned farm	.121	-.048	.646	-.344	.493	-.119	-.019
Mid-point income in USD	.258	.391	-.002	.739	.091	.173	.163
Credit	.198	.227	.151	-.688	-.250	.211	.292
Education Groups Universtiy Binomial	-.218	-.202	-.032	.617	-.415	-.113	.152
Farm1- Water	.077	.084	-.082	.019	.766	.083	.037
Farm1- Electricity	.475	-.181	-.133	.097	.476	-.185	.085
Total number of Dependents	.205	.112	-.177	-.037	-.208	.781	.121
Number of Training Courses	-.025	-.197	-.031	.048	.329	.753	.073
Interviewee-age	.136	-.390	.494	.283	.103	-.510	.051
Farm1-Yearly Access by road	.340	-.078	-.073	.338	-.106	-.370	.269
Total of Producer and social-political organizations	-.032	.168	-.102	-.078	-.092	.017	.861
NewLandValue	.174	-.001	.043	.310	.396	.162	.692

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 9 iterations.

b. Only cases for which Ref_PR_NPnoR = Ref with PES are used in the analysis phase.

Scree Plot



Total Variance Explained[a]

Compone	Initial Eigenvalues			traction Sums of Squared Loadi			tation Sums of Squared Loading		
	Total	of Varianc	umulative %	Total	of Varianc	umulative %	Total	of Varianc	umulative %
1	3.742	18.712	18.712	3.742	18.712	18.712	2.928	14.642	14.642
2	3.004	15.022	33.734	3.004	15.022	33.734	2.658	13.289	27.931
3	2.414	12.068	45.802	2.414	12.068	45.802	2.162	10.810	38.741
4	2.032	10.162	55.964	2.032	10.162	55.964	1.858	9.290	48.031
5	1.437	7.187	63.151	1.437	7.187	63.151	1.849	9.247	57.278
6	1.238	6.192	69.343	1.238	6.192	69.343	1.820	9.098	66.376
7	1.022	5.111	74.453	1.022	5.111	74.453	1.616	8.078	74.453
8	.858	4.292	78.745						
9	.756	3.781	82.526						
10	.706	3.531	86.057						
11	.547	2.735	88.792						
12	.487	2.433	91.225						
13	.464	2.322	93.547						
14	.326	1.630	95.177						
15	.295	1.475	96.651						
16	.210	1.050	97.702						
17	.177	.885	98.586						
18	.136	.680	99.266						
19	.109	.546	99.812						
20	.038	.188	100.000						

Extraction Method: Principal Component Analysis.

a. Only cases for which Ref_PR_NPnoR = Ref with PES are used in the analysis phase.

Figure 10: Reforestation: Logistic regression.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	68.306	7	.000
	Block	68.306	7	.000
	Model	68.306	7	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	91.504[a]	.399	.573

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Classification Table[a]

Observed			Predicted: Ref_PR_NPnoR: NP no PES	Predicted: Ref_PR_NPnoR: Ref with PES	Predicted: Percentage Correct
Step 1	Ref_PR_NPnoR	NP no PES	84	12	87.5
		Ref with PES	6	32	84.2
	Overall Percentage				86.6

a. The cut value is .280

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	95.0% C.I.for EXP(B) Upper
Step 1[a]	FAC1_1	-1.265	.298	17.963	1	.000	.282	.157	.507
	FAC2_1	1.225	.510	5.756	1	.016	3.403	1.251	9.253
	FAC3_1	.721	.273	6.971	1	.008	2.057	1.204	3.513
	FAC4_1	.082	.299	.076	1	.783	1.086	.605	1.950
	FAC5_1	-.911	.300	9.198	1	.002	.402	.223	.724
	FAC6_1	-.108	.314	.118	1	.731	.898	.485	1.661
	FAC7_1	-.078	.260	.090	1	.765	.925	.556	1.539
	Constant	.793	.376	4.449	1	.035	2.209		

a. Variable(s) entered on step 1: FAC1_1, FAC2_1, FAC3_1, FAC4_1, FAC5_1, FAC6_1, FAC7_1.

Appendix 5

Bridges and Barriers to Developing and Conducting Integrated Team Research: Lessons Learned from a NSF IGERT Experience

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Abstract

Understanding complex socio-environmental problems require specialists from multiple disciplines to integrate research efforts. Integration, in this context, is the coordination, collaboration and synthesis of research across disciplines and among researchers. Programs such as the National Science Foundation's (NSF) Integrative Graduate Education and Research Traineeship (IGERT) facilitate integrated research efforts and change the way academic institutions train future leaders and scientists. The University of Idaho (UI) and the Tropical Agriculture Research and Higher Education Center (CATIE) in Costa Rica collaborate on a joint IGERT program focusing on biodiversity conservation and sustainable production in fragmented landscapes. We describe our experiences and lessons learned conducting interdisciplinary team research. We present a spectrum of integration ranging from disciplinary to transdisciplinary across seven aspects of research. The spectrum differentiates types of integration across seven aspects of research and distinguishes the type of integration within the UI-CATIE IGERT program. Using case study illustrations from our UI-CATIE IGERT, we examine the individual, disciplinary, and programmatic bridges and barriers to conducting interdisciplinary research. We conclude with a set of recommendations for exploiting the bridges and overcoming the barriers to conducting integrated research.

Introduction

The need for an interdisciplinary education to train future managers, scientists, and leaders to solve complex socio-environmental problems is recognized by many academic and scientific institutions (Ewel, 2001). Understanding complex interactions needs to be at the forefront of programs training future managers, scientists, and leaders (National Academy of Sciences, 2005). An increasing number of universities have added programs that support cross-disciplinary perspectives. However, the majority of academic institutions address critical topic areas such as the complexity of conservation through discipline-bound approaches. As Wilson 1998 notes, the ongoing fragmentation of knowledge into disciplinary specializations "are not reflections of the real world but artifacts of scholarship" (Wilson, 1998).

Barriers to expanding beyond traditional disciplinary research structures include: lack of funding for interdisciplinary research, lack of historical inter-departmental or cross-disciplinary cooperation, extended time requirements, differences in methodologies and disciplinary norms, turfism, and egos (Golde & Gallagher, 1999; Lele, 1991; Younglove-Webb, Gray, Abdalla, & Thurow, 1999). These institutional barriers generate trained incapacities (E. A. Rosa & Mahlis, 2002) in professionals who are not prepared to collaborate across disciplines in an integrated manner and who lack the capacity to address increasingly complex scientific dilemmas (Brewer, 1999; Zarin, Kainer, Putz, Schmink, & Jacobson, 2003) Thus, while disciplinary specialization has lead to great advancements in science, it may not create knowledge that is capable of answering complex problems (Brewer, 1999; Zarin, Kainer, Putz, Schmink, & Jacobson, 2003).

The National Science Foundation (NSF) designed the Integrative Graduate Education and Research Traineeship (IGERT) program to train doctoral students for a future that will overcome these institutional barriers. NSF describes the goal of the IGERT program as "[To produce graduate students] with the interdisciplinary backgrounds, deep knowledge in chosen disciplines, and technical, professional, and personal skills to become in their own careers the leaders and creative agents for change. The program is intended to catalyze a cultural change in graduate education for students, faculty, and institutions, by establishing innovative new models for graduate education…for collaborative research that transcends traditional disciplinary boundaries" (NSF, 2004).

With its financial support of the IGERT program, the NSF is attempting to foster the institutional capacity for interdisciplinary research and education programs within US universities.

Our objective in this paper is to share our lessons learned about integrated research and education at the midpoint in an IGERT program at the University of Idaho (UI) and the Tropical Agriculture Research and Higher Education Center (CATIE) in Costa Rica. We present a typology that defines interdisciplinary research in relation to other types of integration. We then share a set of lessons learned about interdisciplinary research and education from an IGERT program at the University of Idaho (UI) and the Tropical Agriculture Research and Higher Education Center (CATIE) in Costa Rica. We explain the individual, disciplinary, and programmatic bridges and barriers to conducting integrated research as identified by program participants during a mid-project evaluation workshop. While bridges and barriers have traditionally been conceived as distinct issues, we find they are not mutually exclusive. Instead, depending on context, an issue can become either a bridge or a barrier to successfully achieving interdisciplinary objectives. Finally, we offer a set of recommendations for exploiting bridges and overcoming barriers in order to further awareness and understanding of the challenges of interdisciplinary research.

Interdisciplinarity in a Spectrum of Integration

Integration of research commonly refers to a process of coordinated, collaborative, or combined inquiry into a common problem with sharing, creation, and synthesis of knowledge among disciplines and researchers (Clark et al., 1999). Previous conceptualizations offer a research integration typology that includes disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary research (Jakobsen, Hels, & McLaughlin, 2002; Jantsch, 1970; Pickett, Burch, & Grove, 1999; Rosenfield, 1992). Building on this literature, Table 1 differentiates these four types of integration across seven research concepts that help to illustrate important progressions across the spectrum: 1) level of interaction; 2) problem definition; 3) epistemology; 4) design, research, questions, methods, theory; 5) knowledge generation; 6) academic programs; and 7) research products.

Table 1 serves as a heuristic tool to summarize relative differences across the spectrum of integrated research. The spectrum does not imply that different points on the continuum constitute right or wrong approaches. Instead, the critical point that emerges from

Table 1 is that the different levels of integration provide the ability to address fundamentally different problems as a result of combining or coordinating the research concepts, methods, and results. Table 1 establishes a contextual point of departure for understanding the challenges and strategies to overcome when conducting integrated research.

Disciplinary Research

Disciplinary research defines one endpoint within the integration spectrum. We include disciplinary research in the integration spectrum to emphasize the importance of maintaining standards of rigorous disciplinary methods, theory, and knowledge (Daily & Ehrlich, 1999). Researchers generally work independently and the choice of research topic emerges from within the discipline (Janssen & Goldsworthy, 1996). Disciplinary research remains within its own epistemological boundaries. Disciplines maintain and reinforce themselves through their own professional standards, publications, and education programs (Janssen & Goldsworthy, 1996). This disciplinary infrastructure helps communicate new concepts, theories, and methods as they develop within the field. Disciplinary knowledge has been the cornerstone of knowledge generation since the creation of universities as an institution (Daily & Ehrlich, 1999).

Multidisciplinary Research

Multidisciplinary research is defined by collaboration among researchers from more than one discipline. Multidisciplinary researchers bring their own disciplinary theories, methods, and skills to address a common theme (Golde & Gallagher, 1999). Multidisciplinary team members generally don’t discuss or challenge the epistemological beliefs of other team members, even though varied beliefs about what constitutes truth, knowledge, and science may exist. Multidisciplinary team members define and frame research problems from within each of the participating disciplinary perspectives. Although the researchers constitute a team, they tend to work independently with intermittent interaction giving updates on progress and recent activities (Clark et al., 1999). At this level of integration researchers continue to use their own research designs, methods, and theories (Rosenfield, 1992). With limited interactions and strong reliance on disciplinary epistemologies and traditional research protocols, multidisciplinary research produces only limited potential for synthesis and creation of new interdisciplinary knowledge (Jakobsen, Hels, & McLaughlin, 2002). Multidisciplinary research does offer important cross-disciplinary learning opportunities and new directions to disciplinary researchers (Pickett, Burch, & Grove, 1999). Disciplinary manuscripts are generally published separately, and summary manuscripts tie the effort together (Rosenfield, 1992).

Interdisciplinary Research

Interdisciplinary research differentiates itself from multidisciplinary research by the degree of coordination that must occur throughout the research process. Interdisciplinary research addresses a common problem – one that has been defined with the input of all the participating researchers. Interdisciplinary team members must clarify epistemological beliefs to develop mutual understanding of the interdisciplinary problem, coordinate the research design, and define what constitutes valid interdisciplinary knowledge. Interdisciplinary teams with a wide breadth of disciplines require increased recognition of the importance of developing mutual understanding of epistemological differences (Kelly, 1996). The interdisciplinary team must organize and coordinate research to provide information, data, and results that facilitate the team's common goals. Interdisciplinary teams often use a conceptual map to design and depict the interfaces between researchers (Heemskerk, Wilson, & Pavo-Zuckerman, 2003). Integration in the interdisciplinary setting focuses analyses on the interactions between variables across the disciplines (Janssen & Goldsworthy, 1996). Interdisciplinary research requires regular communication and interaction of team members. Matching spatial and temporal scales, and working on complimentary methods and analyses are also hallmarks of interdisciplinary research, especially in the environmental and natural resource sciences (Golde & Gallagher, 1999). Interdisciplinary research tends to synthesize data, theories and ideas rather than report on the disciplinary perspectives (Jakobsen, Hels, & McLaughlin, 2002)4; see also (Richards, 1996) for further discussion on the concept of synthesis). Within universities interdisciplinary research is often conducted outside of the structures of disciplinary academic departments, such as programs that draw on perspectives from multiple disciplines.

Transdisciplinary Research

Research groups conduct transdisciplinary research when they jointly formulate research problems and use non-traditional methods to integrate research and theory that transforms disciplinary knowledge into new knowledge structures (Somerville & Rapport, 2000). Accordingly, transdisciplinary research must operate under a common or transcendent epistemology. Researchers pool theoretical and conceptual knowledge to jointly develop a common conceptual framework that also transcends disciplines (Rosenfield, 1992). Teams work together through all phases of research, from problem definition to data collection to analysis (USGS, 1998). Theories, research design, and even methods are shared as collaborators plan, decide, think, and act jointly (USGS, 1998). New knowledge is created and disciplinary knowledge may be restructured as a result of the research (Jakobsen, Hels, & McLaughlin, 2002).

Transdisciplinarity has emergent properties that enable researchers to ask questions through a new knowledge structure that reframes traditional disciplinary foundations. Transdisciplinary research promotes "theoretical, conceptual, and methodological reorientations with respect to core concepts of the participating disciplines" (McMichael, 2000), p. 218). Synthesis manuscripts are created in transdisciplinary research. Products can include new integrative conceptual frameworks, new theories, novel methodological approaches (Stokols et al., 2003), and even new disciplines with their own assumptions, principles and methods (Janssen & Goldsworthy, 1996). Two books of conference proceedings and submissions have been published on this topic and are excellent references for this category of research which is at times less then clear (Julie Thompson Klein et al., 2001; Somerville & Rapport, 2000).

Case Study: The UI-CATIE IGERT Program

In 2001, the NSF awarded a collaborative UI-CATIE faculty team an IGERT grant for an international, interdisciplinary graduate research and education program with a theme of "biodiversity conservation and sustainable production in anthropogenically fragmented landscapes" (Bosque-Perez, 2001). The objectives of the UI-CATIE IGERT program are to prepare students to contribute to interdisciplinary thinking, work effectively in interdisciplinary research teams, and integrate theoretical knowledge with practical experience and problem solving.

Eighteen doctoral students (four cohorts recruited over two years) participate in the project. Student enrollment spans departments in the UI College of Natural Resources, College of Agricultural and Life Sciences, the UI Environmental Science Program, and CATIE through an institutionalized joint doctoral program. The UI-CATIE IGERT project provides students with international experience, multi-institutional perspectives, and diverse resources for coursework and mentoring not conventional to disciplinary doctoral programs. Research teams operate in agricultural and forested landscapes in Costa Rica and Idaho, USA.

A central and innovative element to the program's structure has students conduct research as part of an interdisciplinary team and include in their dissertation at least one co-authored interdisciplinary chapter resulting from their collaborative work. Students represent a wide range of disciplines including: botany, economics, entomology, forest ecology, wildlife and plant genetics, hydrology, remote sensing, rural sociology, soil sciences, and wildlife biology. Five teams of students and faculty mentors have formed – three conducting research in Costa Rica and two in northern Idaho. All five teams are comprised of members from at least three disciplines.

The academic program structure (Table 2) was designed by the UI-CATIE project faculty to help institutionalize interdisciplinary research within the two institutions (UI-CATIE, 2001). These programmatic components combined with students' disciplinary programs enhance the rigor of the disciplinary training in individual departments with interdisciplinary learning. The program design supports the NSF IGERT program goals to transcend disciplinary boundaries and facilitate research at the interdisciplinary level.

Methodology

Interdisciplinary Integration Workshop

There are few studies that formally examine the factors that facilitate or encumber a functioning interdisciplinary research team in academia (Bruce, 2004; Golde & Gallagher, 1999; Jakobsen, Hels, & McLaughlin, 2002; Younglove-Webb, Gray, Abdalla, & Thurow, 1999). To document and reflect on our experience with interdisciplinary integration, we conducted a series of workshop exercises during an annual project meeting in Moscow, Idaho May 17-21, 2004. All students, most faculty, and three external advisory panel members participated in the workshops. We facilitated group dialogue, separate faculty and student sessions, and individual program evaluations to document the perceptions of the integration processes underway. We coded and organized data from each session into themes to facilitate in-depth discussion on each specific theme. At the end of the meeting, we presented a synthesis of the results to validate the findings with participants. The synthesis was reviewed in a panel discussion at the International Symposium on Society and Natural

Resources in June 2004 (Nielsen-Pincus, 2004). The process generated a framework for continued dialogue on effective means for conducting interdisciplinary research within our program consistent with participatory social science methodologies that engage respondents for review of data and results (Creswell, Clark, Gutmann, & Hanson, 2003). Identifying and understanding the factors that help and hinder integration on interdisciplinary research teams offers us the opportunity to utilize bridges more effectively and overcome the barriers.

Workshop Results

Bridges and Barriers to Integration

Identifying and understanding the factors facilitating (bridges) and encumbering (barriers) integration on interdisciplinary research teams offers us the opportunity to utilize bridges more effectively and overcome the barriers. Our analysis of the workshop materials and experience in the IGERT program characterizes these factors along a continuum (i.e., the factor becomes a bridge when taken to one extreme or a barrier on the other). Three themes of bridges and barriers emerged from the workshop: individual, disciplinary, and programmatic. The following sections present our findings in the context of these three themes.

Individual Bridges and Barriers

Our experience suggests that bridges and barriers to conducting integrated research can begin at the individual or personal level. Three categories of personal characteristics represent the individual theme of bridges and barriers in interdisciplinary research: vision, dedication, and problem solving (Table 3). An individual's vision factors in elements of risk, flexibility, a common vision, creativity, and cross-disciplinary thinking. For example, individual aversion or affinity for risk taking (i.e., trying something new, innovative, and challenging) can paralyze or catalyze an interdisciplinary research project. Similarly, a researcher's willingness to craft her disciplinary focus around a complex, common problem signifies a level of flexibility necessary to mutual problem definition. Creativity and the ability to think across disciplines also constitute vision characteristics that can facilitate team-based problem definition, research design, and analyses.

Dedication to the interdisciplinary process emerged as a second important category of individual components in the interdisciplinary process. Dedication factors in elements of a researcher's commitment, professionalism/accountability, and patience. Interdisciplinary work requires team members to be committed to providing data and results to other team members to advance group objectives in addition to those of the individual. However, the pull between one's disciplinary and interdisciplinary activities may become a tension in many routine research activities. Thus, individual accountability to team commitments and professionalism in the balance between disciplinary and interdisciplinary is vital to the capacity of a team to complete interdisciplinary projects. Often a team member's completion of a specific task depends on another team member completing specific data analysis or other research tasks. In this context, team members' patience level with the progress of the interdisciplinary project becomes a valuable asset to create bridges or prevent barriers toward accomplishment of interdisciplinary objectives.

Problem-solving orientation constituted a third category of individual bridges and barriers to the interdisciplinary process. Problem-solving includes factors of conflict management, communication strategies, and experience. Conflict left unaddressed lingers and eventually deteriorates functional group dynamics. Similar to group dynamics elsewhere, proactive communication when problems arise can avert the conflicts and challenges associated with the interdisciplinary design. During the workshop, many individuals reflected on team members with prior integration and team experiences as those most able to facilitate interdisciplinary success in coordinating problem definition and research designs. In some cases a *de facto* leader may emerge who manages the inevitable conflicts that arise.

Disciplinary Bridges and Barriers

We identified four categories of factors associated with disciplines that create challenges in interdisciplinary research: disciplinary idiosyncrasies, scales and units, models and frameworks, and focal themes (Table 4). Factors of idiosyncrasies among disciplines include language and paradigms. The lack of a common vocabulary, or the uses of common vocabulary with different meanings, may stand as disciplinary barriers to effective interdisciplinary research. Researchers who learn the common language and the scientific paradigms of other team members can be assets to interdisciplinary knowledge generation. Additionally, mutual understanding of team paradigms may develop into critical epistemological foundations for the successful interdisciplinary project.

A particular challenge to many interdisciplinary projects is integration across various scales using different measurement units. Our teams have biophysical scientists that range from conservation geneticists working at the molecular level to landscape ecologists working across hundreds of square kilometers, who must integrate with rural sociologists working at the county or community scale. Identifying spatial and temporal scales and variables that can be coordinated, measured and integrated across scales and disciplines has challenged all students and faculty due to little guidance available in the disciplinary literatures. Tools such as Geographic Information Systems (GIS) and statistical modeling techniques that can integrate data at different scales have emerged as possible bridges to successful interdisciplinary knowledge generation. Temporal challenges to coordinating the interdisciplinary research design as data collection in some disciplines requires several field seasons while others may require one intensive data collection period.

Disciplinary bridges and barriers highlight the challenge associated with having the 'right' disciplines involved to address particular interdisciplinary research questions. In our IGERT project, teams formed around geographic areas of interest, resulting in some teams identifying an interdisciplinary problem that 'fit' the disciplinary make-up of the team, and others that lacked the full range of disciplines ideally needed to address the problem. As a result of this type of coordination some areas of inquiry in the interdisciplinary research problem remain unfulfilled. Our project has mitigated some of these limitations from 'missing disciplines' through interdisciplinary internships designed to fulfill needs of another interdisciplinary team, and by providing short-term fellowships for additional masters and doctoral students to fill gaps in the interdisciplinary framework.

Finally, we found that a focal theme that highlights factors relating to the problem application, the topical system, the unifying analysis, and the research audience can help facilitate interdisciplinary interaction, knowledge generation, and products. Focal themes served as an important communication device for our teams to frame complex interdisciplinary problems. For instance, applied management and conservation problems such as agricultural regimes or social and ecological policy impacts helped frame our integrated activities. We found that interdisciplinary integration is facilitated when focal theme factors are easily communicated and simply described, i.e., when the application is clear, when a coherent single system is studied, when the analysis method is specified, and when there is a common research audience. On the other hand multiple research applications, topics, analytic methods, and audiences challenge the interdisciplinary project and process.

Programmatic Bridges and Barriers

During the workshop, programmatic level bridges and barriers also emerged that comprised three categories: framework, mentoring, and training and resources (Table 5). The broad ranging UI-CATIE IGERT framework — biodiversity conservation and sustainable production in fragmented landscapes — allowed teams to have flexibility in their research design. While this flexibility was a bridge for some teams' creativity in the problem definition and research design phase, it also became a barrier for others due to the lack of specific questions and research topics. While the jointly-authored chapters are an innovative part of our program framework, in some cases it may create tradeoffs between disciplinary and interdisciplinary responsibilities. We found evidence of bridges when disciplinary and interdisciplinary projects compliment one another. An additional key factor within the programmatic framework highlighted the concern to balance depth and breadth. Interdisciplinary researchers must be able to frame their work in terms of both depth (mechanisms) and breadth (systems) to identify the internal and emergent properties of the research setting. The tension between depth and breadth presented a barrier to some team members who alluded to the practical constraints of operating within a traditional degree granting department, and a bridge to others who noted that it helped them better understand the larger systems to which their work may connect.

Workshop participants suggested that the mentors' prior experience with interdisciplinary research affects the commitment to assist students in the negotiation of challenges within the interdisciplinary graduate education. The degree of involvement of advisors in developing interdisciplinary proposals can also symbolize the paradox of bridges and barriers to team research. Program requirements for international experience and cross-disciplinary mentorship across the involved colleges and institutions created logistical barriers, but also facilitated new collaborative research approaches.

Interdisciplinary research programs require some training and resources for researchers. We found four training and resource factors that caused bridges and barriers including: technical training, funding, time requirements, and doctoral preliminary exams.

Technical training in integrated frameworks, joint proposal writing, and analytic tools can significantly affect the timely completion of research tasks outlined in the interdisciplinary research framework. Many participants considered the time requirement as a fundamental challenge throughout the program; in graduate education interdisciplinary work exacerbates the disciplinary degree timeframe.

Similarly, just as funding remains a critical resource for all graduate students, integrated research in graduate education may present additional financial challenges. While our IGERT program offered competitive multi-year graduate stipends, funding for professional travel, and a limited research operations budget, garnering additional financial support for interdisciplinary operations presents further coordination and proposal writing challenges. However, team-based proposals for additional funding can greatly facilitate the establishment of team objectives, and accountability to the project throughout the stages of research.

Recommendations for Successful Integrated Research

Based on our IGERT project experiences and related literature on integrated research, we offer nine recommendations to exploit the bridges and overcome the barriers to interdisciplinary integration. We believe most of our recommendations apply to interdisciplinary team research efforts in general and facilitate the bridge-building processes for integrated research projects.

1) Develop an accountability protocol

Individual accountability is a necessary feature of integrated work and the means by which researchers depend on one another. The team-developed proposal becomes a living social contract between team members. Developing an interdisciplinary proposal and the protocols for problem solving helps team members articulate their own expectations and individual characteristics, and better understand those of other team members. In the face of shifting individual priorities and deadlines, an accountability strategy clarifying interdisciplinary team deadlines and requirements is essential (Clark et al., 1999; Younglove-Webb, Gray, Abdalla, & Thurow, 1999).

2) Develop formal and informal communication strategies

Success with integrated research requires developing a formal communication strategy of how, when, and what researchers need to communicate as well as plans to complete analyses and written products. At greater degrees of integration across the spectrum, team members must engage in continual interaction as an essential part of mutual learning. Team meetings should include activity updates when appropriate, but moreover serve as opportunities for ongoing dialogue about the research problem, design, methods, analysis, and conclusions, as well as disciplinary level differences in paradigms, scales, frameworks, etc. Communication should not simply remain formal. Regular informal interaction can facilitate many of the bonds and relationships necessary for effective teamwork at the individual and programmatic levels.

3) Select team members thoughtfully and strategically

Bridges for integrated research can form with thoughtful and strategic selection of the disciplines needed and individual participants able to fill those positions. Interdisciplinary team members must cooperate, share leadership, and demonstrate responsibility (Naiman, 1999). Researchers who operate successfully in creative, flexible, and risk-adaptive settings may thrive when conducting interdisciplinary work. Selecting team members with vision, dedication, and problem-solving characteristics can set the team on a trajectory toward success from the start. Janssen and Goldsworthy (1996, p. 268) summarize these qualities well: “Synthetic research will require team members who are good at brainstorming, who are able to overcome their own disciplinary limitations in creative interaction” and prepared to ensure their research addresses the team defined problem (Janssen & Goldsworthy, 1996).

4) Address temporal and spatial scale issues first

Clearly defining a problem becomes essential in order for each team member to conduct research within the range of temporal and spatial scales inherent to the problem definition (Pickett, Burch, & Grove, 1999). Scale decisions determine the extent and hierarchy of the system under investigation (Ahl & Allen, 1996). Outlining different disciplinary scales and scale theories (Allen & Hoekstra, 1992; Gunderson & Holling, 2002) facilitates understanding of the interdisciplinary challenges of the research project, exposes researchers to the paradigms of colleagues from other disciplines, and fosters problem-solving strategies. Interdisciplinary teams can be challenged by choosing a scale for interdisciplinary work because individual disciplines have cultural norms of appropriate scales that may not match the integrated problem (Benda et al., 2002; Folke, Holling, & Perrings, 1996; James, Ashley, & Evans, 2000; Norton, 1995; Poiani, Richter, Anderson, &

Richter, 2000). However, our cumulative experience reveals that creativity in methods and research design (thinking outside the box while remaining rigorous) can overcome many of the scale issues in interdisciplinary research, a critical process for addressing complex problems.

5) Recognize and respect timing issues

As researchers move from doing disciplinary to transdisciplinary research, the research process may take longer and will require greater degrees of coordination. Additionally, different disciplines require different amounts of time to complete research. Developing a timeline and a research framework that outlines each team members' responsibilities becomes critical in the early stages of the team formation. The framework and associated timeline should reflect the time necessary to develop a common language (Wear, 1999), research activities to build trust and relationships (Younglove-Webb, Gray, Abdalla, & Thurow, 1999), and mutual understanding of the problem and the conceptual model (Rosenfield, 1992). The proposal timeline is especially salient because the "speed" at which variables can be measured (short, medium, or long time frame) may differ among disciplines (Gunderson & Holling, 2002), causing temporal problems for data collection, field research, and data analysis. The research timeline should focus on the sequencing and responsibilities for research activities so that synthesis of data, analysis, and writing of results may occur in a coordinated and timely manner.

6) Define focal themes and research questions jointly and clearly

Integrated research teams should create a focal theme that ties each individual component of the research to the common team vision through a description of the research application, topical and analytic themes, and desired research products. We found that focal themes generally aided integration potential and became clearer through field visits, discussions with academic and community stakeholders, and team brainstorming. In our IGERT project the overarching research program assisted in framing the development of a team's focal theme, helped in finding integrated team funding opportunities, and generally assisted in the development of a common team vision.

7) Emphasize problem definition and team proposal writing

Research problems must be orientated toward the disciplines represented in the team. Interdisciplinary proposal writing requires intensive time. Interdisciplinary research programs should be designed to provide significant time to coordinate thorough and detailed proposals with specific attention given to the integrating elements. Integration strategies must build from a base of collaboration, mutual learning, and understanding of epistemological boundaries. Research objectives must evolve through all participating team members. Developing the integrated proposal helps to foster common vision and dedication to the project, exposes members to the team's problem-solving approach, highlights the epistemological traditions, and develops the integrated theme. A variety of methods exist to develop conceptual frameworks and to define problems in an integrated setting; many stress creativity in the process (Heemskerk, Wilson, & Pavo-Zuckerman, 2003). We recommend, especially for natural resource and environmental problems, team members spend time with stakeholders in the field prior to proposal writing for sensitivity to the contexts and boundaries across which they may work.

8) Target interdisciplinary training

Interdisciplinary training and/or cross-disciplinary coursework can help mitigate differences in research methods, disciplinary jargon, and paradigms among team members. In our project, participants also identified exposure to fields that already cross disciplinary boundaries such as landscape ecology, ecological economics, and conservation biology as valuable in this regard. Seminars that cover interdisciplinary topics provide students with additional capacity to understand other disciplinary models, frameworks, and paradigms. Training in interdisciplinarity can assist team members in overcoming disciplinary constraints, fostering creativity, and generating commitment to interdisciplinary work.

9) Identify mentors to focus on team integration issues

Team mentorship in addition to individual mentorship stands as an effective tool for facilitating integrated team research. A team mentor can provide oversight on the progress of the team as a whole and can query individual team members' progress toward the team research goals. The mentor also can provide an accountability structure for the team. Furthermore, the mentor can help define team objectives, take an active role in guiding teams through conflicts, and help resolve technical integration problems (Young, 2000).

Conclusions

In conclusion, we offer three main points from our experience in the UI-CATIE IGERT program. First, the demands of disciplinary knowledge within interdisciplinary research remain substantial and incumbent on the participants to link their specialization to the team project. Each researcher must justify and explain their disciplinary work, including the research theories, design, and methods and the integration of it into the integrated research project to their interdisciplinary team and mentors from other disciplines. This educational dialogue is essential to the integration process and for developing mutual understanding. The focus on systemic interactions (interdisciplinary breadth) must be considered equally important as the focus on fundamental mechanisms (disciplinary depth) in interdisciplinary research.

Second, we conclude that the different degrees of integration, from disciplinary to transdisciplinary, offer different advantages and drawbacks to integrated teams. It is important for teams, as well as research programs, to identify the type(s) of integration they will pursue, and understand the challenges to the research process inherent in each. Many teams and programs can not attempt transdisciplinary integration, nor should they (Somerville & Rapport, 2000). Problem definition and pragmatism will help to define which degree of integration fits best.

Third, interdisciplinary research can be enabled or challenged by individual personalities, disciplinary distinctions, and programmatic design. We suggest that others involved in interdisciplinary research document their activities and share their experiences. Journaling by students (and faculty), intermittent reports focused specifically on problems and successes of integration, and program overviews such as this one, are potential methods to achieve this goal.

It is not possible to place the bridges and barriers to successful integration in any particular order of importance. Our experience does not provide a *roadmap* for conducting integration – as we have found that there is no single best way to achieve integration – but rather we hope that our experience can offer some key *signs* to assist others in navigating the integration process.

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Tables

Table 1. Spectrum of disciplinary integration in scientific research

	Disciplinary	Multidisciplinary	Interdisciplinary	Transdisciplinary
Integration vocabulary	Independent: Self-reliant and autonomous	Collaborative: work together, join forces, team up, pool resources, and cooperate	Coordinated: organized, synchronized, harmonized, corresponding, matched, and mutual	Combined: joint, shared, collective, and transcending
Level of Interaction	Team members may conduct independent, collaborative, coordinated, or combined research	Team members cooperatively conduct research in parallel to each other.	Team members coordinate frequently and consistently throughout the life project.	Team members act, plan, and think as a collective.
Problem Definition	Problem definition is guided by disciplinary paradigm.	Problem definition is usually guided by disciplinary paradigm, and often adopted from or framed by one lead discipline.	Problem defined mutually by researchers from multiple disciplines. Problem definition interrelates different disciplines.	Problem is jointly defined and developed through mutual understanding of team members. Problem definition transcends disciplinary boundaries.
Epistemology	Team members rely on disciplinary epistemology.	Team members rely on disciplinary epistemology, but of differing paradigms.	Team members may rely on disciplinary epistemology, but must accept the validity of different paradigms.	Team members rely on a transcendent or common paradigm that reflects the nature of the problem definition
Design, Research Questions, Methods, & Theory	Team members utilize traditional approaches to disciplinary research design, questions, methods, and theory.	Team members utilize traditional approaches to disciplinary research design, methods, and theory. Research questions may be framed by the discipline that defined the problem.	Team members coordinate research design, questions, methods, and data collection. Temporal and spatial scales and conceptual frameworks are synchronized to integrate disciplinary work.	Team members combine theories to develop a new common conceptual framework that transcends disciplinary boundaries. Research design, questions, methods, and scales are mutually developed.
Knowledge Generation	Knowledge is created within disciplinary boundaries and	Knowledge is created within disciplines, but conclusions may	Knowledge is created that may impact knowledge structures in all	Knowledge is restructured through the creation of new

	conclusions may spark new disciplinary questions.	generate problems, research questions, and hypotheses that are applicable to other disciplines.	disciplines. Conclusions generate new types of interdisciplinary research problems.	shared knowledge structures, and theories. Conclusions drive new theoretical frameworks and areas of research.
Products	Products are disciplinary manuscripts targeted to disciplinary journals.	Products are disciplinary manuscripts that may contain summary of multidisciplinary findings. Summary analyses may also be published in disciplinary journals.	Products are joint synthesis manuscripts or multiple coordinated manuscripts that focus on specific interdisciplinary findings. Manuscripts often targeted to interdisciplinary journals.	Products are joint synthesis manuscripts that transcend and redefine disciplinary orientations. Manuscripts often targeted to interdisciplinary journals.

Developed from: (Clark et al., 1999; Golde & Gallagher, 1999; Jakobsen, Hels, & McLaughlin, 2002; Jantsch, 1970; J. T. Klein, 1996; Rosenfield, 1992; Somerville & Rapport, 2000; Stokols et al., 2003)

Table 2: Academic structure of the UI-CATIE IGERT Program

Programmatic Component	Description
Mentorship	Co-advisors (UI and CATIE) required for students conducting research in Costa Rica. Committee member on all student committees from both the UI CNR and CALS.
Team Research Project	Students training in different disciplinary fields work together to jointly define research problems and conduct interdisciplinary research.
Dissertation Chapters	Students must include at least one co-authored interdisciplinary chapter in their dissertation in addition to departmental dissertation requirements.
Interdisciplinary courses	*Interdisciplinary Research in Biodiversity Conservation and Sustainability* – 3credit course used to develop team proposals; *Current Issues in Biodiversity Conservation and Sustainability* – Semi-annual seminar used to explore the literature across a variety of disciplines and promote interdisciplinary dialogue.
Cross-disciplinary coursework	Two required courses in each of four core areas: 1) social science and ethics, 2) economics, 3) biophysical sciences, and 4) agriculture or forestry.
Preliminary exam	Interdisciplinary component of each student’s qualifying exam.
Internship	3-6 month research internship required for each student to develop breadth of international and/or interdisciplinary experience.
Annual program meeting	Field visits to student research sites, student/faculty symposia focusing on team research, and interdisciplinary training workshops

Source: (UI-CATIE, 2001)

Table 3. Individual bridges and barriers to integrated interdisciplinary research

Barriers		Bridges
	Vision	
Regression to what is 'known' in 'traditional' disciplinary work	*Risk taking*	Willingness to try something new
Rigid adherence to individual disciplinary work	*Flexibility*	Willingness to adjust disciplinary focus to make team project work
Focused on disciplinary work and not on team-defined problem; separate projects	*Problem centered/ Common vision*	Focus on resolving research problem from holistic perspective
Lack of creativity; focus on disciplinary 'depth' as an indicator of rigor	*Creativity*	Creatively designing a project that is integrated and rigorously meets both 'depth' and 'breadth'
Not willing/able to think in terms of other disciplines	*Cross disciplinary thinking*	Ability to think holistically, make connections
	Dedication	
Focused on disciplinary project	*Commitment*	Dedicated to integrated project
Not meeting self-imposed deadlines	*Professionalism/accountability*	Meeting commitments and deadlines
Focus on individual timeline	*Patience*	Acceptance of team-created timelines
	Problem solving	
Avoidance, attitude that problems will all work out or go away if ignored	*Conflict resolution*	Active communication to resolve/overcome barriers
Not frequent, distant, no plan, simple updates	*Communication strategy*	Frequent, personal, dependable, in-depth, professional
Little experience working in teams and across disciplines	*Experience*	Lots of experience working in teams and across disciplines

Table 4. Disciplinary bridges and barriers to integrated interdisciplinary research

Barriers		Bridges
	Idiosyncrasies	
Unique language/jargon, more technical background necessary	*Language*	Common or easy-to-understand language/jargon, less technical background necessary
Lack of understanding of different paradigms or single-paradigm bias	*Paradigm*	Understanding of different paradigms or accepting multiple-paradigms
	Scales and units	
Poor match between extent of variables or processes	*Spatial scale*	Good match between extent of variables or processes
Poor match between 'speed' of variables or processes	*Temporal scale*	Good match between 'speed' of variables or processes
Few common units, standards, measurements	*Metrics*	Common units, standards, measurements
Disjointed data gathering seasons	*Timing*	Synchronized data gathering seasons
	Models and frameworks	
No current models	*Examples of interdisciplinary work*	Existing examples of models that include relevant disciplines and data; predictive or descriptive
Lack of necessary disciplines	*Team make-up*	Good fit to context of local problem
	Focus theme	
Disciplines on team have incommensurabilities that make answering management/ conservation questions difficult	*Problem centered/ Applied results*	Disciplines on team can combine to answer management/ conservation questions
Diverse or multiple systems, policies, programs or process	*Topical/systematic focus*	Single system, crop, policy, program, or process
No unifying theme	*Unifying theme/focus*	Unifying theme, such as spatial (GIS based) or social (management/ conservation), that links research
Different audiences	*Audience*	Same audience

Table 5. Programmatic bridges and barriers to integrated interdisciplinary research

Barriers		Bridges
	Framework	
No focus to guide teams or research	*Broad and flexible research topic*	Flexibility to choose research
Add-on I Interdisciplinary projects seen as "add-ons", primary focus on disciplinary project not associated with team project	*Disciplinary or interdisciplinary focus*	Creative synthesis to make individual disciplinary research part of integrated project
Traditional approaches to framing research	*Depth versus breadth* *Mechanistic and systemic* *Isolation and interaction*	Innovation and freedom to create projects that focus on interactions and systems
	Mentoring	
Less integration experience or support	*Advisor experience/ Commitment*	More integrated experience and support
Integrated portions of proposal not supported by disciplinary advisors	*Proposal writing*	Integrated portions of proposal supported by disciplinary advisors
Programmatic/bureaucratic details for two institutions	*CATIE partnership*	Local expertise and contacts
Language, logistics, access are more difficult.	*International research*	CATIE expertise, local agency/NGO contacts
	Training and resources	
Not experts in all aspects of own discipline	*Technical training*	Training in interdisciplinary models/frameworks
Insufficient funding	*Funding*	Sufficient funding
Disciplinary work may take less time	*Timing*	Integrated work may take longer
Exams focus narrowly on discipline	*Preliminary Exams*	Exams are comprehensive of interdisciplinary topic

APPENDIX 6

Human Assurances Form

University of Idaho
University Research Office
Institutional Review Board
P.O. Box 443043
Moscow, Idaho 83844-3043
Phone: 208-310-9877
Fax: 208-885-7710

Federalwide Assurance: FWA00005639
Federal Assigned IRB #: 00000843
UI Assigned Number: 03-086

MEMORANDUM

TO: Steve Hollenhorst & Wayde Morse
Conservation Social Sciences - 1139

FROM: Steve Meier, Chair
Human Assurances Committee

DATE: August 27, 2003

SUBJECT: Approval of "Social Forces Driving Land Use Choices and their Spatial Characteristics"

- -

On behalf of the Human Assurances Committee at the University of Idaho, I am pleased to inform you that the above-named proposal is approved as offering no significant risk to human subjects. This approval is valid for **one year** from the date of this memo. Should there be a significant change in your proposal, it will be necessary for you to resubmit it for review. Thank you for submitting your proposal to the Human Assurances Committee.

Steven E. Meier EAD

Steve E. Meier
SEM/ed