MANGROVES, SHRIMP AQUACULTURE AND COASTAL LIVELIHOODS IN THE ESTERO REAL, GULF OF FONSECA, NICARAGUA

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Abstract

In the Gulf of Fonseca, shared by El Salvador, Honduras and Nicaragua, shrimp farming initiated in the 1980s provided much needed regional economic investments; it also was identified as a main threat to mangrove ecosystems and dependent livelihoods. A dichotomy was drawn, between the shrimp farming industry and coastal people, which does not reflect the diversity of shrimp farming developments ranging from small-scale farmers to large industries. It also fails to assess the multiple dynamic interactions of shrimp aquaculture with other coastal livelihoods. Using an approach which integrates several methodologies and scales, this research leads to a deeper and more nuanced understanding of the relationship between environmental change, coastal livelihoods and small-scale shrimp farming development, using the community of Puerto Morazán, in the Estero Real as a case study. The various methodologies integrated included remote-sensing, GIS mapping, household surveys, and participant observation. The study shows first, that aquaculture encroached primarily on salt and mud flats; however the activity led to significant indirect changes in mangrove plant communities. Second, in the community, small-scale shrimp producers were found to be better off in terms of incomes, assets and livelihood opportunities. This was especially evident in the case of seasonal lagoon fisheries where access is ultimately controlled by a local elite formed by small-scale shrimp producers. Third, aquaculture brought wealth to the community but also lead to a privatization of former estuary commons and the consolidation of social inequality among community members. At the regional scale, small scale shrimp producers were found to be increasingly vulnerable to market and natural disturbances, thus raising concern over the long term impacts of this privatization. This thesis greatly advances the debate regarding shrimp aquaculture, rural development and mangrove ecosystems by illustrating the active role played by local actors and the nuanced dynamics - including land tenure, demographic, biophysical and technological changes - generated by the introduction of shrimp aquaculture in the region.

RESUMÉ

L'aquaculture de crevette fut initiée dans les années quatre-vingts dans le Golfe de Fonseca situé entre le Salvador, le Honduras et le Nicaragua, attirant des investissements économiques d'un coté mais posant une menace pour les écosystèmes de palétuviers et les activités économiques qui en dépendent de l'autre. Une dichotomie entre l'industrie de crevette et les populations locales fut établie, ne reflétant pas cependant la diversité de développements d'aquaculture existant dans la région – entre petites coopératives et grands complexes industriels. De plus, les diverses interactions entre l'aquaculture et les autres activités côtières ne sont pas analysées. Cette recherche vise, à travers l'intégration de plusieurs méthodologies et échelles d'analyse, a une compréhension plus nuancée des relations entre changement environnemental, activités côtières et développement local d'aquaculture, utilisant la communauté de Puerto Morazán comme étude de cas. Les différentes méthodologies intègrent des analyses d'images satellitaires, de la cartographie via SIG, des enquêtes statistiques de foyers et une participation directe dans la communauté de choix. L'étude démontre d'abord que l'aquaculture de crevettes affecte, directement, principalement les plages salines, générant cependant des changements indirects important dans l'écosystème côtier de palétuviers. Au niveau de la communauté, l'étude prouve que les acteurs impliqués dans l'aquaculture de crevette sont plus avantagé en termes de revenues, capitaux et opportunités de vie. L'exemple de l'utilisation des lagunes saisonnières démontre ce point étant donné que l'accès à ces sites de pêches privilégiés est contrôlé par une élite formée par les aquaculteurs de crevette locaux. Troisièmement, l'aquaculture a attiré des bénéfices économiques pour la communauté mais a aussi mené à une privatisation de zones côtières anciennement ouvertes à tous; créant un écart socio-économique entre différents groupes. Au niveau régional, l'aquaculture de crevette locale est particulièrement vulnérables aux variations de marchés mondiaux et aux désastres naturels ; ce qui remet en question la durabilité au long terme de cette activité. Cette thèse avance le débat concernant les liens entre aquaculture de crevette, développement rural et écosystèmes de palétuviers en illustrant le rôle actif joué par les acteurs locaux et les dynamiques nuancées- incluant les changements de tenures terriennes, démographies, technologies et paysages biologiques- générée par l'introduction de cette activité dans la région.

ACKNOWLEDGEMENTS

CHAPTER 1: INTRODUCTION

Concern over widespread land cover changes, whose rates and magnitude increased over the past hundred years, has lead international institutions, academia and government to focus on understanding the underlying drivers of these changes (Lambin *et al.* 2006; Lambin *et al.* 2001; Meyer *et al.* 1994). Land cover/use changes have been particularly important in coastal areas where human communities have historically aggregated due to relatively easy access to markets and resources (Visser 2004). Coastal wetlands, including mangrove ecosystems, have been considerably affected by human-driven changes due to the high valuation of alternatives land uses such as agriculture and urban expansion (Barbier *et al.* 2003). Alongi (2002: 341) estimated that one third of the mangrove areas have been lost globally over the past fifty years, mainly due to anthropogenic factors. Aquaculture was identified to affect mangroves considerably due to its direct and indirect impacts, including deforestation to install ponds and associated infrastructure as well as changes in hydrology and sediment regime (Lambin *et al.* 2006; Lambin *et al.* 2003; Alongi 2002; Barbier *et al.* 2002; Lacerda 2002; Paez-Osuna 2001b; Paez-Osuna 2001a; Hogarth 1999; Stonich *et al.* 1997). Other potential drivers of change include increased human populations, natural disturbances (hurricanes and floods), changes in urban/rural infrastructure, pollution etc (Lambin *et al.* 2003). Among the drivers of change, there is a debate concerning the link between environmental degradation and wealth (in terms of lack of or abundance of) (Swinton *et al.* 2003; Ellis 2000; Reardon *et al.* 1995). The livelihood approach shows that the environment-poverty link is complex and relative to the specific context of each case. Identifying and analyzing change in human-environment interactions requires an understanding of how different drivers are related across different scales (MEA 2005).While a global focus highlights large scale processes and patterns, it is important also to look at the local scale as a "systematic analysis of local scale land-use change studies, conducted over a range of time-scales, helps to uncover general principles to provide an explanation and prediction of new land-use changes" (Lambin *et al.* 2003: 231).

This study aims at understanding the relationship between environmental change, coastal livelihoods and shrimp farming development in the Gulf of Fonseca, a gulf shared by Honduras, Nicaragua and El Salvador (see Map 1). Environmental change is embodied here by the degradation of mangrove ecosystems in the region. Nicaragua, Honduras and El Salvador are amongst the poorest countries of Central America, and the Gulf of Fonseca is one of the most densely populated and poor area of the region (IUCN 1996; Stonich 1992). Shrimp farming development started in the late 1970s[1] and provided much needed employment and investments in the region (Stanley 2003; Alduvin 2002); it was also identified as one of the main threats for mangrove ecosystems and their dependent livelihoods[2] (Alduvin 2002; Varela 2000; Stonich *et al.* 1997; Dewalt *et al.* 1996; Vergne 1993). A dichotomy between the shrimp farming industry on one hand and coastal people on the other was drawn that did not identify the diversity of the shrimp farming development, ranging from small-scale farmers to large industries, and its interactions with also diverse coastal communities. Local coastal communities are important actors in the land use change caused by shrimp farming and it is therefore important to identify the role that local shrimp farming has played in local households' livelihood and in the wider estuarine environment.

1. 1 Purpose and objectives

The overall purpose of this thesis is to understand human-environment interactions in the Estero Real, Gulf of Fonseca, Nicaragua from the 1980s to the present. The study seeks to assess the environmental and social changes brought about by small-scale, locally-driven, shrimp aquaculture in the community of Puerto Morazán, Estero Real, Gulf of Fonseca, Nicaragua. Specifically, the objectives of the study are:

1) to examine spatial and temporal changes in land cover/land use from the 1980s to the present in the Gulf of Fonseca, Nicaragua, focusing on shrimp aquaculture development and coastal wetlands change (Chapter Two); and,
2) to analyze the direct and indirect implications of small-scale shrimp aquaculture development for local livelihoods (Chapters Three and Four)

[1] Shrimp aquaculture started in Honduras in the late 1970s and in Nicaragua and Salvador in the late 1980s.
[2] Mangrove-dependent livelihoods include artisanal fisheries, wood collection, tourism and collection of non-timber forest products (medicines, fruits etc).

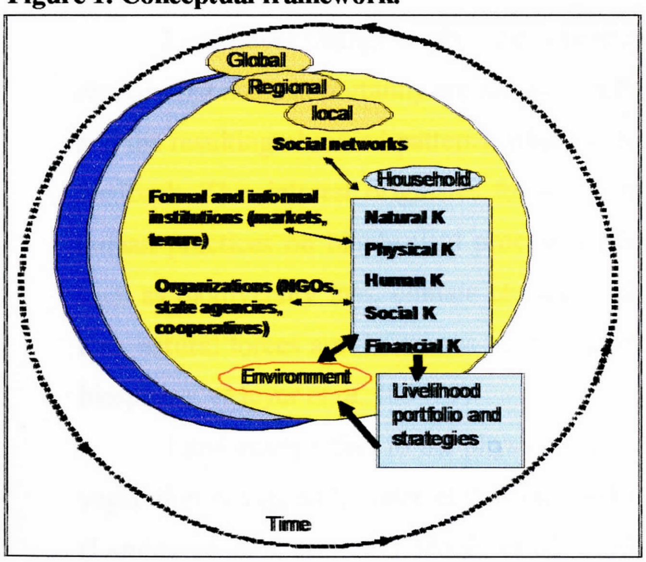
1.2 Literature review

1.2.1 Conceptual framework

The study will integrate the land use and cover change (LUCC) framework, focused on drivers of change and feedback at different scales, to the livelihood approach that focuses on household livelihood portfolios and strategies across time and space (Fox *et al.* 2003; Ellis 2000; Liverman *et al.* 1998). Changes in land use at the household and community level will constitute the link between observed patterns of land cover/use change and changes in household livelihoods. It can be summarized by the following diagram (Figure 1) inspired by work by Allison *et al.* (2001), Geist and Lambin (2002) and MEA (2005):

The LUCC framework focuses on the drivers and patterns of landscape change while the (sustainable) livelihood framework analyses the household context, which gives rise to local environmental changes; both form part of the wider socio-ecological context of an area (Berkes *et al.* 2005; Berkes *et al.* 2003).

Figure 1. Conceptual framework.



The thesis will start by focusing on changes in the environment and then compare these to local household's portfolios and strategies in order to understand the relationship between the environment and local peoples, especially small-scale shrimp farmers. There is an important difference in how small-scale shrimp farming will be conceptualized depending on the starting point: environment or household. Indeed, from an environment standpoint, small-scale shrimp farming refers to a small ecological footprint for each household (i.e., small and medium ponds), independently of aggregate effects, whereas from a household approach, small-scale refers to local actors. Often small-scale ponds are managed by small-scale shrimp farmers, however it is important to note that rural poor sometimes pool their resources to hold and manage bigger areas (i.e. cooperatives). Changes in livelihood strategies include, in my case study, switches from sea-based uses to land based ones. LULC studies have tended to be biased towards land-based analyses of change, due to the difficulties involved with detecting changes in sea-use. In coastal areas however, changes in sea-use if they involve a switch to land-based activities has an observed effect on land use; thus highlighting the interdependencies of sea and land based activities.

1.2.2 Land use and cover change (LUCC)

Land cover change studies are concerned with understanding how the world around us changes but more importantly are focused on the underlying processes leading to those changes and the resulting observed patterns, which in turn affect the processes in a positive or negative feedback. This interest originates from a growing concern with the global consequences of human practices on biophysical processes (the environment) as manifested by global issues such as biodiversity loss, climate change, and pollution. It seems that "human actions rather than natural forces are the source of most contemporary change in the states and flows of the biosphere" (Meyer *et al.* 1994: 3).

Land cover refers to the physical state of the Earth's surface (i.e., quantity and type of vegetation cover, soil, water etc) while land use refers to "human employment of the land" (Lambin *et al.* 2003: 207; Meyer *et al.* 1994: 5). The relationship between the two can be conceptualized as one of structure (land cover) and function (land use); while a change in function is likely to change the structure, a change in structure may happen without changing its function for human beings (Meyer *et al.* 1994).

Land cover and land use are related by what has been called "proximate sources" of change (or direct drivers of change), that is "those human actions that directly alter the physical environment" (Meyer *et al.* 1994: 6). These alterations of the physical environment can be either conversions (shift from one land cover type to another) or modifications (changes in the character of the land cover type) (Lambin *et al.* 2006; Lambin *et al.* 2003; Meyer *et al.* 1994). Proximate sources of change (or direct drivers of change) are influenced by broader indirect underlying causes (or indirect drivers of change) (Lambin *et al.* 2006; Lambin *et al.* 2003; Geist *et al.* 2002; Lambin *et al.* 2001; Veldkamp *et al.* 2001; Meyer *et al.* 1994). These indirect drivers of change include natural variability, economic, technological, demographics, institutional and cultural factors operating at various time and spatial scales. There seems to be no overriding factor explaining land cover/use change but "synergetic factor combinations of resource scarcity leading to an increase in the pressure of production on resources, changing opportunities created by markets, outside policy intervention, loss of adaptive capacity, and changes in social organization and attitudes" that alter ecological processes and in turn feed back to alter the drivers of change through complex and uncertain interdependencies (Lambin *et al.* 2001: 205). Separating the influence of each of the drivers is extremely difficult given that changes are usually the result of a combination of factors operating, independently or not, at various spatial and time-scales (Geist *et al.* 2002; Lambin *et al.* 2001; Scoones 1999).

Land cover change has traditionally been associated with disciplines in the natural and physical science while land use has been the object of studies by more social oriented disciplines (Meyer *et al.* 1994). While this divide no longer applies in land cover/use studies, issues are still associated with linking different disciplines and methodologies. Efforts have been made to relate remote sensing techniques with community or household based analyses or linking "people and pixels" (Fox *et al.* 2003; Liverman *et al.* 1998). The rationale has been that land cover/use studies using remote sensing can provide global, regional and even local information about spatial and temporal processes of change that would be otherwise extremely difficult to obtain. On the other hand, studies originating from the social sciences (economics, geography, sociology etc.) have rich accounts of underlying factors at various scales. The main challenge lies in linking phenomena that are not necessarily spatially grounded to observed spatial and temporal changes. A common theme linking different disciplines has been to emphasize multiplicity in order to understand human-environment interactions through the land use and cover change framework. Indeed, "multiple responses to social change, multiple levels of analysis and multiple aspects of the life course of individuals, households, and land parcels, multiple connections in social and geographical space, and multiple ties between people and land" (Fox *et al.* 2003: 3). Decision-making by individuals constitutes the finer level of analysis for LUCC studies but requires considerable amounts of data to be collected, most studies therefore focus on households based on the assumption that they function as a unit in terms of decision-making; Fox (Fox *et al.*: 2) highlights this view by stating that "households decision-making is critical to the understanding of the change in LUCC". This assumption can be flawed due to existing power struggles within households i.e. between gender, generations etc. (Deere 1995; Carney 1993). Conceptualizing household boundaries and continuity is also problematic given that households are dynamic entities that change as individuals' life histories evolve (Fox *et al.* 2003; Ellis 2000). Incorporating the views of both men and women in the household surveys conducted in this study partly addressed the first issue (see Methods section), while the second was addressed mostly by unraveling household histories. The next section presents the sustainable livelihood framework, which provides lenses to examine holistically the way people make a living.

1.2.3 The livelihood approach: definitions and applications

The analytical concept of livelihood was developed to provide a more holistic understanding of how households, especially rural households in developing areas, make a living, beyond commonly used measures such as income or consumption (Ellis 2000; Ellis 1998). "Livelihood" is understood as the means of living of individuals or households, and "comprises the assets (natural, physical, human, financial and social), the activities and the access to these (mediated by institutions and social relations) that together determine the living gained by [a given] individual or household" (Ellis 2000:10). Natural capital represents the resource base used by the individual/household (i.e. the environment), physical capital refers to material and infrastructural tools (farm equipment, boats etc), financial capital is related to the liquid assets and credit available, human capital includes labor, education, health while social capital reflects existing social networks, kin groups associated with a given individual/household that mediate its access to other types of capital (Allison *et al.* 2001; Ellis 2000; Ellis 1998; Scoones 1998). Access is defined by "rules and social norms that determine the differential ability [of individuals/households] to own, control, use resources" (Scoones 1998: 8). Access seems to be highly related to social capital and the difference between the two is sometimes uncertain. These assets categories are by no means independent from one another; for example increase in education (human capital) might be dependent on available social capital while increase in financial capital is sometimes related to a decreased in another type of asset (Reardon and Vosti 1995; Ellis 2000).

The livelihood framework focused particularly on livelihood diversity and diversification. The first term refers to "the existence at one point in time of many sources of incomes [for a given individual/household]" while the second term relates to "the process by which rural households construct an increasingly diverse portfolio of activities and assets in order to survive and improve their standard of living" (Ellis 2000:14-15). Livelihoods can be derived from farm and/or non farm incomes and often times non farm incomes play an important role in rural livelihoods (Bebbington 1999). Migration whether seasonal, cyclical or even permanent constitutes a frequent diversification strategy whereby some household members leave their home base to support the remaining household through remittances (Adger *et al.* 2002; Ellis 2000; Stonich 1991c).

There is an assumption that household portfolios are necessarily increasing in time; however rather than increasing *per se* household portfolios seem to be fluctuating based on external and internal events that improve or not households' economic condition (Dercon 2002; Ellis 2000). The ability of individuals/households to improve their condition is highly dependent on the relationship between the type of assets they control and the ease with which these assets are converted from one type to another (i.e., usually to cash income) (Reardon *et al.* 1995). Livelihood diversification can be considered as a strategy adopted by households to maximize returns from different assets across time and space. It allows households to deal with low returns from certain type of activities during certain periods of the year (i.e., seasonality involved in farm cycle) (Ellis 2000; Ellis 1998). It can be seen as a pro-active choice to reduce potential risks associated with changing environmental and social conditions (risk management) or a response to stresses or shocks that pushes households to diversify by necessity (coping strategies) (Dercon 2002; Ellis 2000; Ellis 1998).

Livelihoods can only be understood as part of a dynamic space and time continuum: available assets mediated by external global and local environmental, economic and social conditions-at one point in time/space- facilitate/hinder the adoption of a set of livelihood strategies. In turn, these strategies determine available assets, mediated by a set of conditions that influence the well-being of a household (Angelsen 2003; Allison *et al.* 2001; Ellis 2000). Reardon and Vosti (1995) emphasize the need to distinguish between welfare poor-households that do not have enough to survive in the immediate present- and investment poor-households that can cope with present needs but cannot invest for the future. This inability to re-invest can have profound implications for the long-term sustainability of these households' livelihoods and has implications for environmental conservation. Indeed, an inability to reinvest in natural capital will impact the use of natural resources. Similarly inability to invest in education or equipment can have important implications for future well-being of that household. Coomes *et al.* (2004) explain the failure of conservation initiatives in the Peruvian Amazon to a limited understanding of the micro-economic factors that influence livelihood heterogeneity among forest dwellers, namely how households assets and demographics influence forest resource use. That example and many others show the importance of understanding and situating micro-scale household livelihood strategies (Coomes *et al.* 2004; Angelsen 2003; Fox *et al.* 2003; Allison *et al.* 2001; Liverman *et al.* 1998).

1.2.4 Wetlands: threats and importance to livelihoods

In the tropics, coastal wetlands encompass lowland river floodplains, inland swamps, mangroves and lagoons, whose extent and nature varies spatially and temporally. Hogarth (1999) defines mangroves as ecosystems, uniquely adapted to saline conditions, existing in the transition zone between saltwater and freshwater systems in tropical coastlines. The term "mangrove" refers both to the ecosystem and those plant species (of different families and genera) that have common adaptations which allow them to cope with salty and oxygen-depleted (anaerobic) substrates (Ramsar 1971). Developmental decisions are causing an extensive loss of mangroves globally through conversions to urban lands, aquaculture, and intensive agriculture (FAO 2007b; Chhabra *et al.* 2006; Singh 2005; Alongi 2002; Neiland *et al.* 2001; Paez-Osuna 2001b; Valiela *et al.* 2001; Barbier 1993). These developmental decisions often overlook the considerable ecosystem services essential to human well-being that are provided by wetlands directly, in the form of subsistence agriculture, provision of fuel, construction material, fishing, food resources, medicinal plants and household material, and indirectly through existing ecological processes such as erosion control, water purification, carbon dioxide sink, biodiversity and genetic resource maintenance etc. (FAO 2007b; MEA 2005; Dorenbosch *et al.* 2004; Moberg *et al.* 2003; Lacerda 2002; Neiland *et al.* 2001; Nagelkerken *et al.*

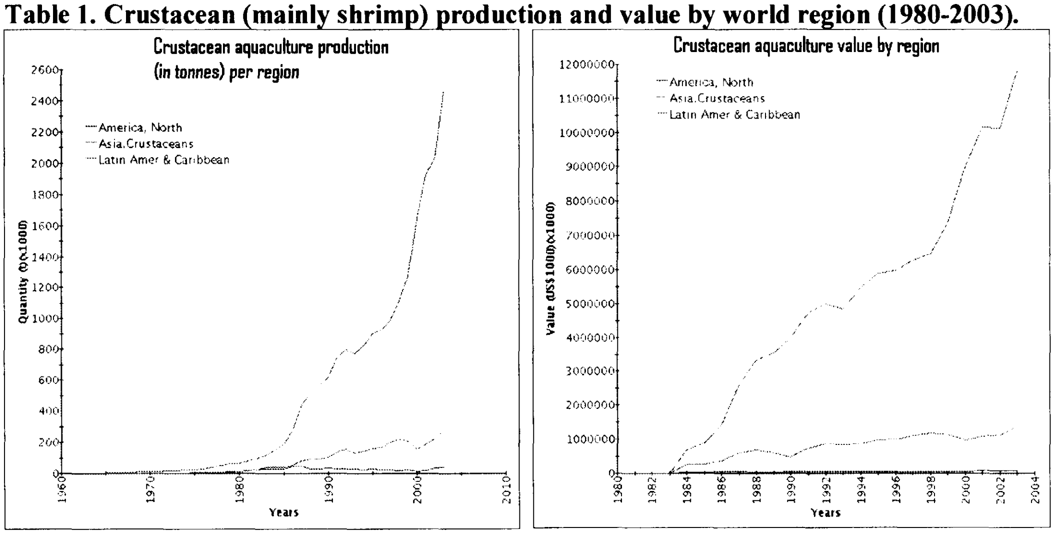
2000; Hogarth 1999; Ronnback 1999). Wetlands tend to be undervalued for a variety of reasons including their public good features, discounting, uncertainties and lack of knowledge of existing ecological processes and their tie to human well-being (Berkes 2006; Barbier *et al.* 2003; Berkes *et al.* 2003; Ostrom 2002; Adger *et al.* 2000; Ostrom *et al.* 1999; Barbier 1993; Hardin 1968). The FAO (2007b: 12) estimates that "the world has lost some 3.6 million hectares of mangroves over the last 25 years, or 20 percent of the extent found in 1980" due mostly -in Asia, Latin America and the Caribbean- to large aquaculture and tourism land use conversions.

There also is a strong environmental justice element to this considerable loss in wetland area. Indeed, wetlands were often used 'traditionally' by marginal groups (ethnic minorities, women, rural poor), with little political power, that were displaced when 'new' highly profitable economic options such as shrimp farming or intensive rice cultivation became associated with former marginalized lands (Hoanh *et al.* 2006; Luttrell 2006; Martinez-Alier 2001; Stonich *et al.* 1997; Dewalt *et al.* 1996; Stanley 1996; Barbier 1993; Carney 1993). Wetland loss or degradation is also associated with overexploitation of natural resources (i.e fuelwood & timber extraction, plants and fauna collection) and alteration of essential ecological processes (i.e changes in hydrology, erosion/sedimentation etc) due to human land use changes (Lambin *et al.* 2006; Lacerda 2002). Changes causing gradual change through landscape modifications rather than direct conversions are harder to measure but can still cause fundamental changes in the flow and stocks of ecosystem services provided; thus affecting livelihoods (Lambin *et al.* 2006; MEA 2005).

1. 2.5 Shrimp aquaculture: global and regional assessments

The Food and Agricultural Organization (FAO) reports a decline in global wild fisheries stocks since 1974 and considers aquaculture to be a key alternative to counter wild fisheries decline while supporting global fisheries demand (FAO 2007a). Aquaculture's growth averages at 8.8 percent per year since 1950, more than seven times the growth rate for capture fisheries and three times that of terrestrial farmed and meat production systems over the same period (FAO 2007a: 16). Shrimp production represented in 2004 only 7.4 percent of the total aquaculture production but 16.3 percent of the total aquaculture trade value, reflecting its high value as a commodity compared to other aquaculture resources such as fin fishes and mollusks (FAO 2007a: 20). The share of shrimp in total fish trade is diminishing compared to a 21 percent peak in 1994, due mainly to an increase in value of other aquaculture products, but nonetheless shrimp increased by 18% in value and 69% in quantity during 1994-2004 with farmed shrimp representing 41 percent of total shrimp traded in 2004 (FAO 2007a: 47). Tables 1a and 1b present shrimp aquaculture production and value from 1980 to 2003 for different regions of the world. The exponential increase in quantity of shrimp produced is linked with rapid expansion of shrimp aquaculture worldwide, first in Asia followed by Latin America (FAO 2007a; FAO 2006a; Tobey *et al.* 1998) and was partly driven by technological advances in shrimp pond management (FAO 2006a), a phenomenon nicknamed the 'blue revolution' (Stonich *et al.* 2000).

Table 1. Crustacean (mainly shrimp) production and value by world region (1980-2003).



1a. Crustacean production 1b. Crustacean value

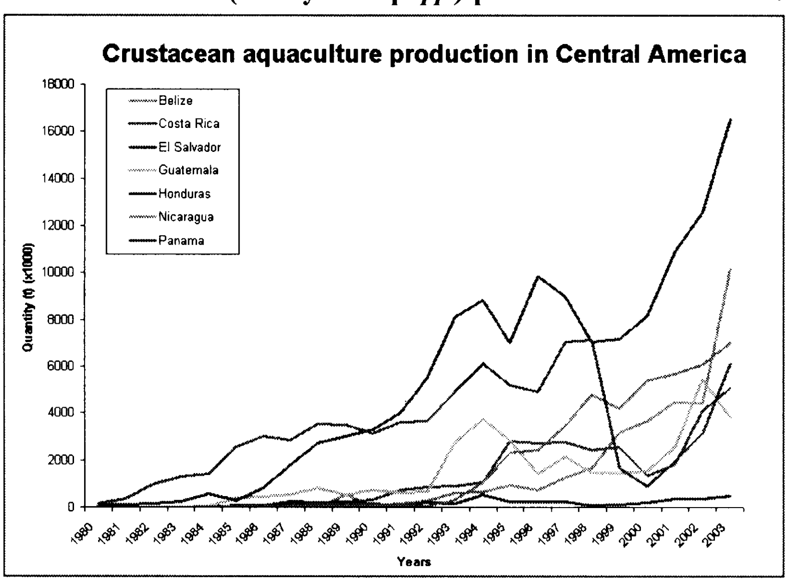
Adapted from the FAO (2005) fisheries database (1950-2005).

Latin America started developing its aquaculture potential in the 1970-1980s, as opposed to a much earlier development in Asia, and has the highest aquaculture annual growth rate at 21.3 percent (FAO 2006b: 6-7). Table 3 illustrates growth rates of the shrimp industry in Central America specifically from 1980 to 2003 (FAO 2005). All Central American countries, with the exception of El Salvador, show important increases in shrimp production during that time. Main producer countries such as Panama and

Honduras show production reductions during 1994-1995, due to the Taura disease, and 1999 due to the combined effects of hurricane Mitch (mainly Honduras and Nicaragua) and the White spot shrimp disease (FAO 2006a; Tobey *et al.* 1998). Nicaragua was affected to a lesser extent but shows signs of reduced production as well and is positioned in third position in 2003 after Honduras and Belize (*ibid*), outweighing Panama that was a leader in shrimp aquaculture development in the 1990s.

The globalization of shrimp markets created a "shrimp fever" in the late 1970-mid 1980s attracting investments in high value shrimp production initially in Ecuador followed by Chile, Brazil in South America and Honduras, Nicaragua in Central America (FAO 2006b; FAO 2006a). The 'Shrimp fever' held the promise of increased national gross domestic products (GDP) while simultaneously contributing to rural poverty alleviation and increased food security (FAO 2006a).

Table 2. Crustacean (mainly shrimp *spp.)* production in Central America 1980-2003.



Adapted from the FAO (2005) fisheries database (1950-2005).

Rapid (and mostly unorganized) growth led however to considerable environmental consequences for coastal and inland water ecosystems globally as well as in Latin America (FAO 2007b; Alongi 2002; Martinez-Alier 2001; Paez-Osuna 2001b; Paez-Osuna 2001a; Stonich *et al.* 2000; Tobey *et al.* 1998; Stonich *et al.* 1997). Alongi (2002: 341) estimates that 1/3 of mangrove areas where lost worldwide since the 1950s while the FAO (2007b: 12) accounts for a loss of 20 percent of the 1980 mangrove extent globally; pond aquaculture was identified as a major cause of direct (pond establishment) and indirect (changes in hydrology, pollution, sedimentation) loss of coastal ecosystems (FAO 2007b; Alongi 2002; Paez-Osuna 2001b; Paez-Osuna 2001a). A study done by the Network of Aquaculture Centers in Asia-Pacific in 1994, reported by Tobey *et al.* (1998: 19) for a regional assessment of Latin America, estimates that between 20 to 50 percent of mangrove destruction since the 1980s is due to shrimp aquaculture.

1.3 Methods

This section presents and discusses briefly the methods employed to conduct this research; each chapter elaborates more on the specific methods used to collect and analyze the chapter's specific data.

The study involved the integration of multiple sources of information and the use of several different methodologies including remote sensing/GIS, participant observation, household semi-structured interviews, 'participatory GIS mapping' and literature/archival based reviews. This interdisciplinary methodological approach had a two-fold purpose. First, it allows the research to gain insight into different sources of knowledge operating sometimes at different scales (regional versus local). Second, it results in triangulation of the information. Triangulation refers to the use of several sources of data and methods, in order to strengthen the validity of the findings (Hay 2005; Baxter *et al.* 1997). It constitutes a guiding principle for documenting the human side of land-use and land cover changes. Indeed, Fox (2003: 5) encourages a "push for data collection strategies that incorporate the myriads aspects of the individual and the land", which often requires long and intensive data collection strategies.

Succinctly, participant observation involves "getting close to people and record information about their lives" (Bernard 2006: 323). The method is more of a guiding principle widely used in ethnographic research. It aims at reducing the issue of reactivity, which refers to people changing their attitudes through the eyes of an outside researcher, while also requiring the researcher to invest time in building a rapport. On the negative side, it can also lead researchers to 'go native', whereby experiences of informants become part of the researchers' lives- a normal process- and excessively shadow researchers' perceptions.

The community of Puerto Morazán, in the department of Chinandega, Nicaragua was chosen for a case study. This community was selected for two reasons. First, this community was among the first to engage in shrimp farming in Nicaragua, with initial efforts in the early 1980s, and remains today dependent on estuary extraction and shrimp aquaculture for its livelihood. It constituted, therefore, an ideal case to analyze the dynamics brought about by shrimp farming in a coastal community. Additionally, the '*Centro de Investigación de Ecosistemas Acuáticos*' (CIDEA), the partner institution in Nicaragua, has had a base in that community since 1990 with essential resources such as access to equipment (car, boat), knowledgeable personnel, and well-documented archives regarding the Gulf of Fonseca.

Household surveys were conducted in the community of Puerto Morazán during January to May 2006.The sample universe was determined by mapping all the households in the community and identifying their occupants with the help of two local informants. Seventy five randomly chosen households, stratified amongst shrimp farming and non shrimp farming producers, were interviewed using a combination of structured and semi-structured approaches. Structured interviews follow a predetermined and standardized list of questions while semi-structured interviews allows greater flexibility by focusing on a more generic thematic content and allowing informants to respond selectively to the questions asked (Hay 2005: 81). The household surveys combined structured discussion items that required specific information content for quantitative data collection (demographics, livelihood activities, incomes and assets). Additional semi-structured questions were asked as well regarding household histories, livelihood activities in the past and present, environmental change, shrimp farming as well as concerns and preoccupations. These more open ended answers informed the quantitative data and were analyzed later on by coding the entries in ac qualitative analysis software. The results of this analysis are present throughout the thesis but more specifically in Chapter Three and Four. Spatial information was also collected, by overlaying transparencies, on a map during household interviews regarding fishing spots, camps and lagoon areas as well as other landmarks of interest. These were digitized in a GIS database and are used mostly in Chapter Four to show lagoon extents.

The remote sensing analysis aimed at identifying land cover changes in the Estero Real estuary from the 1980s to the present. More specifically, it focused on quantitative and qualitative changes of mangrove and shrimp aquaculture land covers. To do so, a post-classification change analysis was performed by comparing supervised classifications of Landsat and Spot satellite images for 1987, 1993, 1999 and 2006. The land cover classes generated include primary mangroves, transitional mangroves, wetlands, salt and mud flats, dry vegetation and water. Shrimp farms were digitized for 1987 and 1993 and identified using government databases and field-based GPS points for the later years. In order to compare across time, each image was first radiometrically corrected before being compared in a cross-tabulation matrix (Mather 2004). The 2006 image was validated using GPS points collected in the field during the fall of 2006. Past images could not be validated spatially due to lack of available data; however they were validated through more generic regional land cover estimates. Chapter Two discusses in more detail the methodology employed for the remote sensing analysis.

The household survey instrument and the university ethics review approval required for research that involves human participants are found in Appendix 1 and 2, respectively.

1.4 Context

This section provides a brief overview of the context within which each of the subsequent chapters is embedded. The information is based on the open-ended section of the household surveys conducted in the community of Puerto Morazán, which focused on household's decadal calendars, informal interviews conducted with other community members as well as reports from the Nicaraguan government, academics and NGOs.

1.4.1. Study area

The Estero Real is a Nicaraguan estuary belonging to a wider estuarine complex, the Gulf of Fonseca, which is shared by Honduras, El Salvador and Nicaragua. A total of

81,700 hectares were designated as a RAMSAR site in 2000[3], including an estimated 70,000 ha of interdependent patches of mangroves, salt flats, marshes and lagoons (Núñez-Ferrera 2003; Ramsar 2000). In 2005, the Estero Real supported about 13,752 ha of shrimp aquaculture ponds that replaced mostly salt flats, mangroves and lagoons, causing concerns related to the environmental effects of this industry (IUCN March, 1996; MARENA 2006; Núñez-Ferrera 2003).

The Gulf of Fonseca is located in the subtropical climatic zone, where dry and wet seasons alternate. During the rainy season, rainfall occurs in an unpredictable pattern, in short and intense bursts. This makes the area prone to erosion, especially if the soils are without vegetation cover (Dewalt *et al.* 1996; Stonich 1992). The Nicaraguan side of the Gulf is located in primarily rural municipalities located in the department of Chinandega, with high population densities of 71 people / km^2 (twice the national average) (PROARCA/COSTAS 2001: 11). This population distribution is in part explained by historical legacies of social and environmental change brought by the cotton boom in the 1950-60s and the cattle boom in the 1970-80s, followed by the latest boom in shrimp development in the 1980s-90s (Stonich 1991b; Stonich 1989; Williams 1986). The cotton and to a lesser extent the cattle boom radically changed the structure of rural society by transforming tenants into seasonally needed wage labor (Williams 1986). This caused important migrations to 'marginal areas' such as highlands and mangrove edges (Dewalt *et al.* 1996; Williams 1986). Issues of environmental degradation due to these past legacies, including deforestation and pollution, have been identified in the Gulf (Southworth *et al.* 2004; Boyd 2000).

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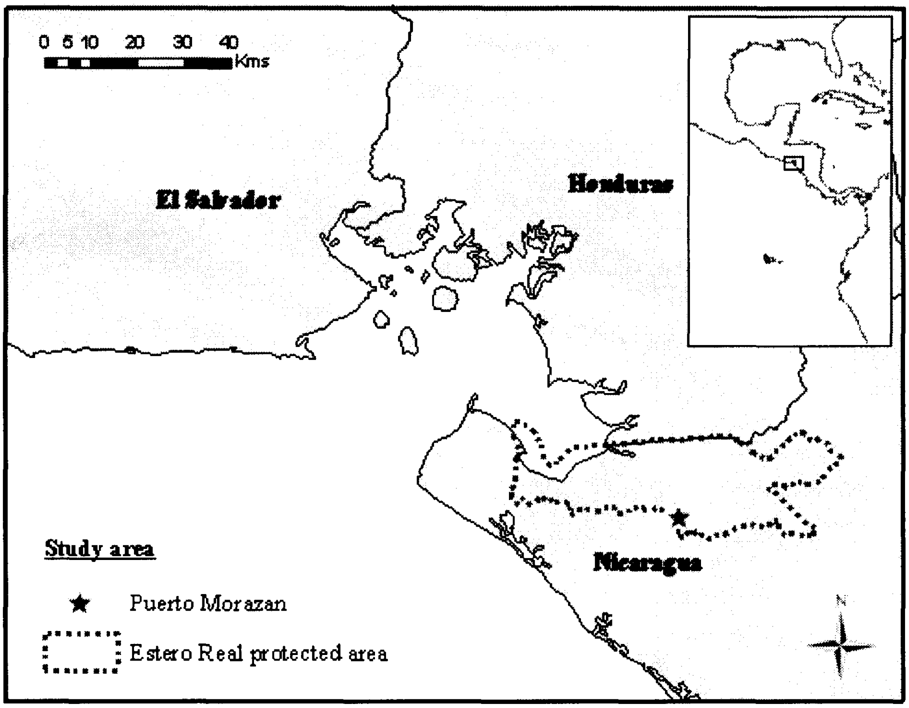
[3] The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resource (Ramsar 1996)

Map 1. Gulf of Fonseca, Central America



1.4.2 Land tenure

1.4.2.1 Legal context

The estuary deltas of the Estero Real are legally characterized as state lands and officially managed by governmental institutions. However, the estuary coastal lowlands are *de facto* areas where various management regimes coexist, ranging from private to common-property to open access conditions. Private property refers to areas where an individual or a corporation has exclusive rights, determining access and levels of exploitation, while common-property resources refers to areas where control of access is difficult (exclusion costly) and resource are substractable (use by one impacts availability of resource use by another) (Berkes *et al.* 2003; Ostrom 2002; Ostrom *et al.* 1999; Ostrom 1990; Berkes *et al.* 1989). Open access refers to areas where access is free and open to all (Berkes *et al.* 1989), similar to the example given by Hardin (1968) in his famous article on the 'tragedy of the commons'. Regime types observed at the local level depend greatly on the socioeconomic context, the nature of these resources (degree of substitutability and substractability), and the existence of exogenous factors influencing the first two factors (such as laws and international prices) (Ostrom 1990). When the resource becomes hard to exclude and/or substractability increases due to changes in population, technology or in the resource itself for example, common property management schemes tend to collapse (Berkes *et al.* 2005; Kurien 2005; Singh 2005; Seixas *et al.* 2003a; Seixas *et al.* 2003b; Kalikoski *et al.* 2002; Seixas 2000; Kapetsky 1981).

1. 4.2.2 An increasing governmental presence in the Estero Real

The Estero Real in the early 20th century was likely inhabited by small *mestizo* communities, who are descendants of indigenous peoples and Spaniards that occupied the pacific coast of Nicaragua (CIDEA 2006; Squier 1852). At this time, the state had little presence in the area and power was in the hands of local landed elites (Gould 1990). The General Law on the Exploitation of Natural Resources of March 12th 1958 established, for the first time, the basic conditions that determine the exploitation of natural resources on state lands (CIDEA 2006; Núñez-Ferrera 2003); however it was not until the mid 1970s that state presence became more apparent in the Estero Real. In 1976[4], mangrove commercial harvesting was prohibited by the former Institute of Natural Resources and the Environment (IRENA)[5] for mangrove stands greater than 2m of height, thus dampening mangrove harvesting and trade and restricting the activities available to local estuary dwellers; in 1991 mangrove harvesting and trade was entirely prohibited by INRENA (Nunez-Ferrera 2003). Efforts to enhance natural resource protection resulted in the creation of a protected area in the region. In 1983, the wetlands of the "*Deltas del Estero Real y llanos de Apacunca*" were declared officially a protected area under the category of genetic resources reserve[6] by Decree no. 1320 of September 8th 1983 (CIDEA 2006; Núñez-Ferrera 2003). However no legal enforcement mechanisms were effectively set in place to monitor and manage the protected area.

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[4] Emergency Law on the Rational Use of Forests, Decree no. 235 of 1976 (Núñez-Ferrera 2003).

[5] The restriction was reserved for mangrove stands whose height is greater than 2m and the fine was of 50 cordobas (~ 2.94USD) per tree harvested without proper authorization (Núñez-Ferrera 2003).

[6] Conservation area for wild genetic resources in order to obtain selected germ plasma and maintain habitats in conditions necessary to protect and restore certain species, groups of species, biotic communities with genetic resources of commercial and scientific importance. The *Llanos de Apacunca* genetic reserve has the special purpose of protecting a variety of wild maize (*Zea luxurians*) as part of national biodiversity (Ramsar 2000).

At the same time in the mid-1980s, parallel to government efforts for environmental protection, the state encouraged development initiatives in the Estero Real. A *tapos* experiment[7] in the lagoons introduced the idea of developing shrimp aquaculture in order to harness the high biological productivity of the estuary. These efforts were intensified in the 1990s, a decade experiencing favourable local and international conditions for shrimp farming characterized by high international prices for shrimp, low input costs (especially oil) and good environmental quality of the Estero Real estuary (Coze Saborio 2006). This led to exponential population growth in the Estero Real, despite its legal protected status which theoretically prevented extensive development.

Simultaneously, Nicaragua continued to further develop its environmental legal framework. On May 2 1996, the General Law on the Environment and Natural Resources was declared, (re)establishing that the coastal, fluvial and lacustrian beaches and riparian areas are state property (Art. 72).[8] It stated that users need a special permit from MARENA, the natural resources ministry, to sustainably manage mangrove forest and other vegetation in estuary channels and coastal beaches. In 1998 a Supreme Court decision stated that coastal state lands could not be developed, including all lands within 2 km of all oceans, navigable river channels or lakes (Núñez-Ferrera 2003); a decision that posed a dilemma concerning the establishment and growth of the shrimp aquaculture sector. On November 8 2001, the Estero Real was declared a site of international importance under the RAMSAR convention. While the commitments to protect RAMSAR sites are not to be enforced by any international agency, the symbolic gesture showed a desire (at least on paper) to commit to environmental protection of the area.

However, there is an undeniable tension between environmental protection commitments and economic growth imperatives as shrimp farming provides 3.33% of Nicaragua's total exports in 2005 for an aggregated value of 90 million dollars annually; placing aquaculture amongst the four primary sources of income, after coffee, meat and tourism, for the country (Coze Saborio 2006). Thus, despite commitments to sustainably manage the estuary and its biodiversity, the aquaculture sector continues to grow without

[7] *Tapos* refer to a fishing method that uses woody material to create an enclosure in a shallow water area (lagoon, estuary) to retain shrimp. The Nicaraguan fisheries ministry promoted the development of a *tapos* enclosure in Puerto Morazan in the mid-1980s (CIDEA 2006).

[8] Gaceta No152 del 6 de Junio de 1996.

adequate planning (Núñez-Ferrera 2003). This overall disorganization is manifested by a multiplicity of institutions that are responsible for managing the estuary and the multitude of inter-organizational arrangements by which concessions are obtained (no less than 7 different concession arrangements between local producers and governmental institutions (municipalities, environment and/or industrial development ministries)) (Núñez-Ferrera 2003). The government is presently recognizing this weakness and is in the process of elaborating and negotiating a protected area management plan (MARENA 2006). The management plan is discussed in further detail in Chapter Four.

1.4.3 History of livelihoods in Puerto Morazán 1930-2005

During the reign of the Somoza dynasty (1937-1979), estuary forest extraction in the form of timber as well as mangrove bark used for the national and Salvadorian leather tanneries provided the main source of income for estuary dwellers (CIDEA 2006). Fisheries[9] constituted mainly a source of subsistence to local residents and a safety net to smooth consumption during harsh times (Gould 1990). However, given that the population was low (an estimated 150 persons in the community of Puerto Morazán with about 20-25 fishermen), it is assumed that local fisheries were not overexploited (CIDEA 2006). Access to the estuary for collecting firewood and subsistence food, essentially as a source of additional income and as a safety net, was an implied right of the rural poor (households #116, 170, 191). Efforts by the landed elite to restrict access to the estuary, through enclosure of the commons in the estuary edges, were met with a strong resistance on the part of local communities (Gould 1990)[10].

The community of Puerto Morazán is characterized by a series of historic infrastructural changes that greatly affected the local landscapes, economy, and livelihoods. In 1936, the community of Puerto Morazán changed its name from

[9] Whether or not the lagoons were communally managed at that time is unclear, most households mention 1970-1980s, when shrimp became more valuable, as the start date of the communal management of the lagoons. Lagoons were however used at that time.

[10] This resistance to the loss of *ejidal* lands, usually found in marginal areas at the edge of the larger haciendas, during the cotton boom of the 1950s fostered *campesinos* organization and subsequent adherence to the Sandinista movement when reform within the Somoza regime failed to meet their needs and demands (Gould 1990).

Nacascolo[11] to the present denomination (Alcaldía Municipal de Puerto Morazán 2004). The community and the municipality bearing the same name were created by legislative law in 1946 and officially inaugurated for the opening of a new train line. When the train line linking the departmental capital of Chinandega to Puerto Morazán was created, it boosted an era of thriving trade of basic grains and timber/wood products passing through the port of Puerto Morazán to San Salvador and Honduras. The train brought 'progress' and 'prosperity,' as commodities from the fertile interior (maize, rice and cotton) were exported to neighboring Honduras and El Salvador. The train was a direct consequence of the modernization of Nicaragua's primary sector, principally through the cotton boom of the 1950-60s that radically transformed an agricultural sector dominated by haciendas with long-term tenants to a seasonal wage labor-based agricultural economy (Gould 1990; Williams 1986). Inhabitants of present day Puerto Morazán remember the 'train times' when the community had a hotel and a regular port as a time of abundance.

The port was also famous as a transit area for mangrove bark and mangrove wood trade originating from the Estero Real. This trade was mainly occurring in the 1940-60s until an artificial substitute for mangrove bark for tanning was found. In the 1970-mid 1980s, mangrove timber was harvested to support banana trees in neighboring plantations.

In 1960, the train network was destroyed during a flood thus effectively marginalizing Puerto Morazán as a port of national importance and a trade route to Honduras and El Salvador (CIDEA 2006; Gould 1990). The trade route moved eastwards to the (new) Pan-American Highway, completely bypassing the Estero Real. Also, as mentioned previously, in 1976 mangrove commercial harvesting was partially prohibited by IRENA, thus dampening mangrove harvesting and trade and restricting further the activities available to local estuary dwellers; in 1991 mangrove harvesting and trade was entirely prohibited by INRENA (Nunez-Ferrera 2003).

The decline of mangrove and basic grains trade was mirrored by the decline of the town of Puerto Morazán. This was described by one informant as follows: "since the train left, Puerto Morazán died" (household #221). Many households left the community to establish themselves in neighboring communities, such as the community of Palacio

[11] The name of a tree that used to be common in the region.

where lands were arable (Gould 1990). Others moved further away to neighboring Honduras and El Salvador in hopes of a better life in cities. Those that remained focused on subsistence resource harvesting (fish, shrimp, shell fish, firewood), selling marginal amounts to neighboring communities due to high transportation costs. Fishing technologies at the time were dominated by *mangas*[12] in the estuary channels and *atarayas*[13] in the seasonal lagoons where people fished by foot. Boats were mostly paddle or sail-powered and most fishing was done in close proximity to Puerto Morazán waters. These technologies were identified by fishermen as labor intensive.

In the 1970s, Salvadorian traders acted as promoters of local fisheries. They provided credit and equipment in exchange for estuary resources, especially *camaron cocido*[14] that was coming from the winter seasonal lagoons. Many households mentioned the important role played by Salvadorian traders for commercializing their products that were not in demand in national Nicaraguan markets. Consequently, from the 1960 to 1980, there was a shift from trade and wetland forest exploitation to semi-commercial lagoon fisheries' extraction which became very important for remaining local residents' livelihoods.

Shrimp aquaculture radically changed (again) the economic balance of the region; for the first time since the destruction of the railway, Morazan was connected to the international markets and was important to the national government economic development initiatives. First attempts were initiated in 1977 when the Nicaraguan government supported isolated shrimp pond experiment in the area of Puerto Morazán (~ 30 hectares) with the assistance of the Japanese government; the project was abandoned due to political and technical issues with no commercial production reported (FAO 1988 reported in Curie 1994). In 1981, the fisheries department of the Nicaraguan government (the late-INPESCA), financed by the '*Banco Nacional de Desarollo*' (BND) established an extensive shrimp aquaculture operation, cooperatively owned in Puerto Morazán

[12] *Mangas* are gillnets that are set in a small channel inlet during low tide. When the high tide comes, fish enter and get trapped when the tide is low again. According to fishermen interviewed this technology is less harmful to fish population as it "does not scare fish away" as opposed to gillnets that are set across the main estuary channel (*transmallos).* I did not find any research to support or disprove these observations.
[13] Cast net
[14] *Camaron cocido* is shrimp cooked at low temperatures with a salt for conservation. It was mainly purchased by Salvadorians.

(Curie 1994). The project was abandoned in 1983 due again to political disorder but the pond was recuperated by local cooperatives. By 1985 two small groups operated extensive shrimp ponds in Puerto Morazán. In 1987, INPESCA promoted again shrimp production but based on the Mexican *tapos* system[15] with a reported 130 hectares of shrimp ponds.

By the late 1980s, seven cooperatives operated in the area of Puerto Morazán with an estimated 250 members managing between 100-250 hectares of extensive shrimp ponds (see Chapter One regarding shrimp pond evolution) (Coze Saborío 2006; Curie 1994). From the mid-1980s to beginning of 1990s, shrimp aquaculture was reportedly managed only by local cooperatives using mostly extensive production systems. Credit was easily available with the BND, supported mainly by subsidies from the Sandinista government (households # 54, 170, 218). In the 1990s, a change of political regime from the socialist Sandinistas to the more neoliberal Chamorro government created a framework that supported foreign investments in shrimp aquaculture, favoring the entrance of larger scale players in the estuary. Local informants mentioned that credit became increasingly harder to obtain due to a combined change in political regime and a loss of credibility of cooperatives due to issues of mismanagement of funds and increase of debt (households # 54, 170). Additionally Hurricane Mitch in 1998 destroyed most shrimp farming infrastructure leading to a decrease of 25% of the shrimp pond infrastructure in 1999. Many small-scale producers in Puerto Morazán still have high levels of debt dating back from hurricane Mitch, which can reach amounts as high as US$ 100,000 due to accumulated interests. Saborio Coze (2006: 5) reports that "cooperatives initiated the [shrimp aquaculture] activity, representing 100% of the production in the late 1980s, 33% in 1995 and only 5% in 2004". In 2004, there was an estimated 10, 335 hectares of active shrimp ponds with 60% belonging to industries and 40% to cooperatives (CIDEA 2006: 52).

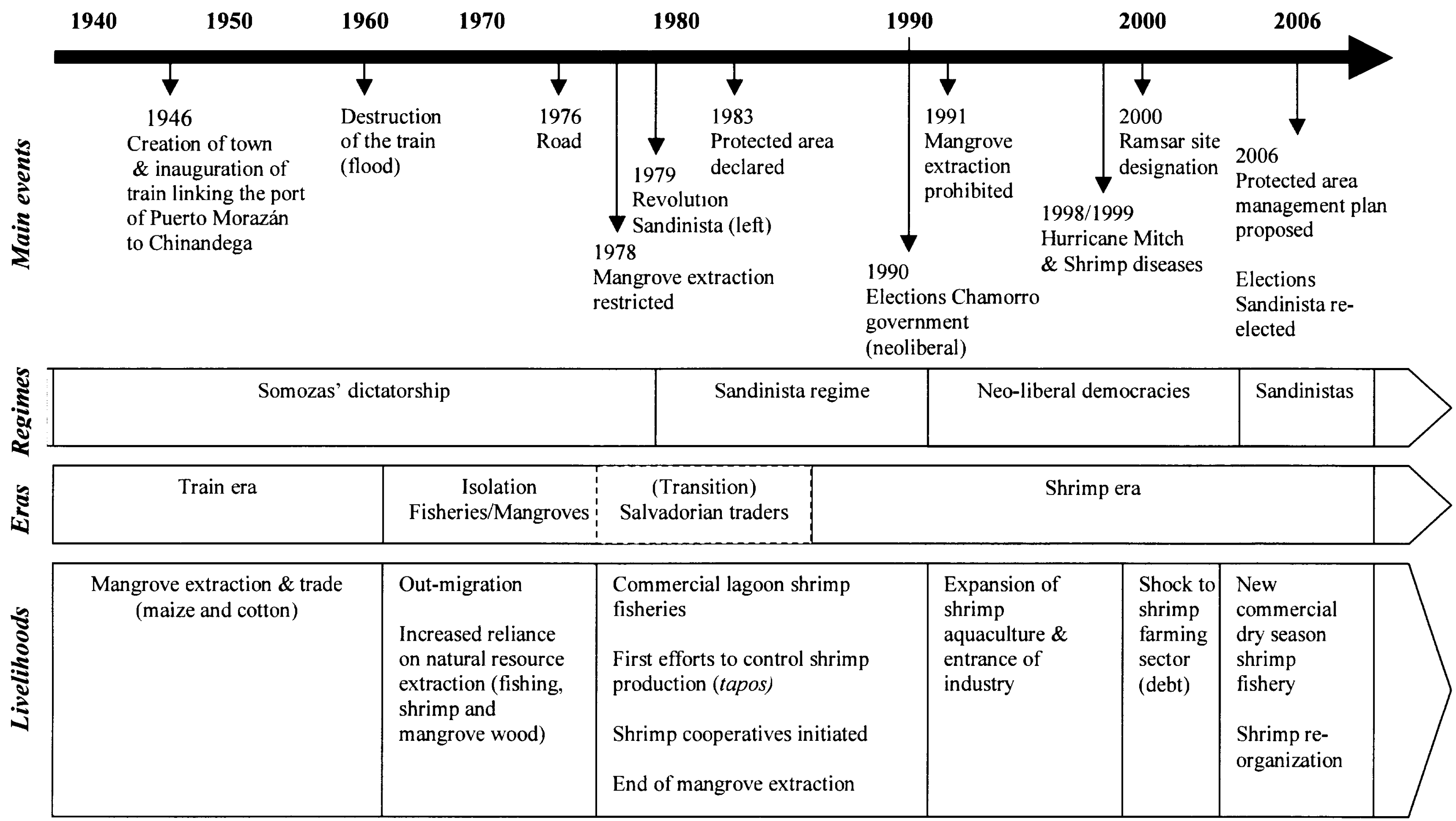
Hurricane Mitch highlighted dramatically the risks associated with an excessive dependency on shrimp aquaculture. Indeed, local informants realized that the market was at the mercy of powers beyond their control including international shrimp and oil prices and natural disasters occurrence. One informant when asked regarding shrimp

[15] see Chapters Two and Four for more details regarding *tapos*

aquaculture risks stated “we cannot control prices; there is a monopoly of the trade system [by others]”. Hurricane Mitch also transformed considerably the estuary’s fisheries according to local inhabitants. Commercial crab collection which was an important source of income for many poor households collapsed entirely post-Mitch, it is today slowly recovering. Overfishing due to population, technological and biophysical changes increased greatly the distances required to catch fish in the estuary. In 2000, a small shrimp (*fievre*) found at the mouth of the estuary started being commercialized with success during the dry season; providing a new source of income for a time of the year where scarcity of livelihood sources is high.

Figure 2 summarizes the main historic events shaping coastal livelihoods from the 1930s to the present, focusing more on the last two decades, as defined by households interviewed and the literature (IUCN March, 1996; CIDEA 2006; MARENA 2006; IUCN 1996; Gould 1990).

Figure 2. Main historic events shaping estuarine livelihoods in Puerto Morazán.



1.5 Thesis structure

An initial review of the literature pertaining to the Gulf of Fonseca presents a situation of acute conflict between local people and shrimp industry, symbolizing the forces of globalization (Horton 2007; Stonich *et al.* 2000; Stonich *et al.* 1997; Stanley 1996). When I first visited the Nicaraguan side of the Gulf of Fonseca, I was therefore greatly surprised to realize that local people were often times engaging actively in shrimp aquaculture, as an integral part of the process of change. This study is about better understanding the active role played by local shrimp producers.

Chapter One presents the thesis' research question and objectives, followed by a review of relevant bodies of literature, a general methods section (supplemented by more detailed sections in each chapter) and a context section which provides the background for the overall study including a description of the study area, its history and present land tenure.. Chapter Two focuses on patterns of land cover/land use change in the Estero Real, Gulf of Fonseca providing an assessment of environmental changes since the emergence of shrimp aquaculture in the region (1980-2006). Chapter Three describes the socioeconomic context of the community of Puerto Morazán and highlights the role of small-scale shrimp farmers in local economy. Chapter Four explores how shrimp farming development has affected estuary land tenure through changes in another important livelihood activity (lagoon fisheries). Chapter Four is in essence an integrative chapter that builds upon findings from chapters Two and Three. The Conclusion briefly summarizes all findings and discusses implications of this thesis for land cover and land use studies and environment-development issues.

CHAPTER 2: LAND COVER/USE CHANGES IN THE ESTERO REAL, GULF OF FONSECA

2. 1 Introduction

The Gulf of Fonseca, shared by El Salvador, Honduras and Nicaragua came under international scrutiny in 1998 when Hurricane Mitch hit its shores impacting greatly coastal livelihoods (Cahoon *et al.* 2002a; Girot 1999). This natural disaster brought attention to existing land uses in the Gulf and prompted a call for sound integrated coastal management in the three member states (Bilio 1999; IUCN 1996; Vergne 1993). Studies, mostly focusing on the Honduran side of the Gulf, called attention to the rapid loss of mangroves, mostly blamed on shrimp farming development, which reportedly increased vulnerability of local people to natural disasters and reduced key livelihood options (especially fishing) for coastal communities (Alduvin 2002; Varela 2000; Stanley 1998; Stonich *et al.* 1997; Dewalt *et al.* 1996; IUCN 1996; Stanley 1996; Stonich 1992; Stonich 1991a). The Gulf of Fonseca was chosen as a key case study for demonstrating rapid environmental change brought by shrimp farming as can be attested by the satellite images posted on the interactive web-based "Atlas of Our Changing World" (Singh 2005) and the National Geographic's special feature on Mangroves in February 2007. Both sources emphasize the negative effects of shrimp farming, notably due to direct encroachment on mangrove ecosystems as illustrated by this quote: "a prime location for shrimp ponds, though, happens to be the shore zone occupied by mangroves, an unhappy conflict of interests that has a predictable outcome: The irresistible force of commerce trumps the all-too-removable mangrove" (Warne 2007: 142).

The FAO (2007b: 12) estimates that "The world has lost some 3.6 million hectares of mangroves over the last 25 years, or 20 percent of the extent found in 1980" which is mostly due in Asia, Latin America and the Caribbean to large aquaculture and tourism land use conversions. The same report mentions that fortunately the rates of net mangrove loss globally show signs of slowing down, a fact that the authors attribute to increased environmental consciousness.

Is that the case in the Gulf of Fonseca? What are the effects of shrimp aquaculture development on the coastal land cover? This study investigates land cover changes in the

Estero Real, Gulf of Fonseca using remote sensing analysis. Most specifically, it documents the effects of shrimp aquaculture development on the estuarine environment from 1987 to 2006 in six year increments. The next section provides definitions of the wetland types found in the study area before reviewing the use of remote sensing in coastal environments.

2. 2 Remote-sensing and coastal resources

2.2.1 Wetlands of the Estero Real: definitions

The Gulf of Fonseca, including the Estero Real in the Nicaraguan side, is a wetland area dominated by an extensive mangrove[16] cover with lagoons, mud/salt flats, marshes patches of dry tropical forests. Hogarth (1999) defines mangroves as ecosystems, uniquely adapted to saline conditions, existing in the transition zone between saltwater and freshwater systems in tropical coastlines. The term "mangrove" refers both to the ecosystem[17] and those plant species (of different families and genera) that have common adaptations which allow them to cope with salty and oxygen-depleted (anaerobic) substrates (Ramsar 1971). While the focus is usually on mangrove communities, it is important to stress that other sub-ecosystems are associated with coastal wetlands. In the tropics these include, mud, sand or salt flats, marshes (salt marshes, salt meadows, freshwater marshes) and coastal freshwater or brackish lagoons (Alongi 1998; Vergne 1993; Ramsar 1971). A clear definition of mud, sand and salt flats seems to be lacking in the literature, and little attention has been given to their ecological roles (Alongi 1998; Dewalt *et al.* 1996). These areas are however potentially affected by shrimp farming development as they are prime sites for pond construction (Vergne 1993). Definitions refer both to intertidal areas as well as areas found further inland influenced only by the highest tides of the month (Vergne 1993: 5; Alongi, 1998). Freshwater or brackish lagoons are transitional wetlands, which are flooded during the rainy season and dry up during the dry season, and constitute important seasonal resources for local communities (Vergne 1993: 6).

[16] Mangroves ecosystems refer both to plants that are resistant to salty and anaerobic environments as well as an ecosystem formed by these plants and accompanying fauna/flora and specific physico-chemical conditions (Hogarth 1999).

[17] This ecosystem is composed of salt-tolerant woody plants with morphological, physiological, and reproductive adaptations that enable them to colonize littoral habitats, and their associated flora, fauna and their physico-chemical environment.

2.2.1 Remote sensing

Remote sensing is frequently used to identify changes in mangrove forest cover and shrimp farming extent (FAO 2007b; Beland *et al.* 2006; Cornejo *et al.* 2005; Muttitanon *et al.* 2005; Krause *et al.* 2004; Tong *et al.* 2004; Alonso-Perez *et al.* 2003; Dahdouh-Guebas *et al.* 2002; Lizano *et al.* 2001; Manson 2001; Gao 1999; Ruiz-Luna *et al.* 1999; Blasco *et al.* 1998; Green *et al.* 1998; Terchunian *et al.* 1986). Different ecosystem structures often produce different spectral reflectances thus enabling detection with optical remote-sensing devices (Kovacs *et al.* 2004; Mather 2004; Kovacs *et al.* 2001; Gibson *et al.* 2000; Green *et al.* 1998). There is an observed zonation in mangrove structure and derived succession patterns that have implications for the identification of mangrove areas with remote-sensing technologies (Lacerda 2002; Hogarth 1999). Challenges encountered included limitations to identify specific land cover types accurately due to issues of image resolution and the dynamic nature of coastal systems (Blasco *et al.* 1998; Green *et al.* 1998). More importantly, it is difficult to determine which driver of change is the most important one for a given observed land cover change. This is especially the case for coastal areas where multiple human and natural processes have synergetic impacts on the landscape (Blasco *et al.* 1998). Despite these limitations, analyses based on remotely-sensed imagery were judged to be extremely useful as they provided a large scale assessment of existing processes and were relatively cost-effective as they limited the amount of extremely detailed ground based studies needed (Manson 2001). The need for field-based studies remains however as the accuracy of the analyses is greatly improved with input from ground-based information, necessitating a balance between ground and 'space' based data (Mather, 2004).

2. 3 Data and Methods

The change analysis was performed based on a post-classification of four multispectral Lansat TM 5 images (January 6th 1987; January 13th 1987; February 7th 1993; February 24th 1999) and one multispectral SPOT 4 image (January 29th 2006), using IDRISI and ArcGIS softwares. The post-classification is based on a comparison of each individually classified satellite image. Additionally, GIS layers (roads, villages, estuary channels, aquaculture ponds from 2000 to 2005), digitized on a SPOT 2004 image[18], were obtained from the '*Centro de Investigación de Ecosistemas Acuáticos'* (CIDEA)[19] and the '*Ministerio de Industria, Fomento y Comercio*' (MIFIC)[20] and were used to geometrically correct each image for the change analysis.

2. 3. 1 Preprocessing

To ensure accuracy of the change analysis, each image was geometrically rectified and registered to a common NAD 27 UTM 16 N projection, based on a SPOT 2004 image (Mather 2004). The geometric correction was done by selecting calibration points estimated to be similar in both images and calculating the residual mean error between the two points. Each reference point was chosen to be a relatively stable and easily identifiable landmark such as a crossroad, a corner of a shrimp pond, etc (McCoy 2005; Mather 2004; Congalton 1991). The resulting RMS for each image was below the ½ pixel resolution threshold, and was therefore deemed acceptable (Eastman 2006a).

Radiometric corrections for all bands of the 1987, 1993, 1999 Landsat TM 5 images and the 2006 SPOT 4 image were also performed to convert the digital numbers (DN) of the raw data into spectral radiances. The images were not atmospherically corrected given that the change analysis focused on a post-classification procedure (Song *et al.* 2001).

Additionally, estuary channels were masked to reduce variability due to differences in tide levels and only the area within the protected area was analyzed for change. This was important due to significant variations in tide levels between the images (see Appendix A). Only the area within the protected area, a total of 91, 651 hectares, was kept for each image and the remainder was masked including the buffer zone, the '*Sabana de Jicaro*' and '*llanos de Apacunca'* reserve[21]. Unfortunately all images did not cover the same area and therefore in the change analysis each image was analyzed based on the area found in common for all images (which corresponds to the 1993 image), which covers 81,116 hectares (about 89% of

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[18] The SPOT 2004 image was used a reference image for the geometric correction but not included in the change analysis since it was a 10m resolution black and white image, very different from the images included in the change analysis.

[19] CIDEA is part of the '*Universidad Centroamericana*' (UCA) in Nicaragua and is specialized in shrimp aquaculture, water quality and integrated coastal management.

[20] *Ministerio de Industria, Fomento y Comercio* (MIFIC), responsible for shrimp farming concessions.

[21] These are other ecosystems included in the protected area but that are more land based (forests and savannas). They are not affected by shrimp farming and not part of the coastal ecosystem directly and were therefore not included in the study.

the entire protected area). The 1987 classified image was a product of a mosaic adjoining two 1987 images from a same month[22]. To minimize errors in classification due to changes in reflectance or atmospheric conditions between the two images, the mosaicking[23] was done only after classifying each 1987 image independently.

2.3.2 Land cover classifications

2.3.2.1 Finding the shrimp ponds

Shrimp ponds have a similar spectral reflectance to salt/mud flats when dry and lagoons or shallow water areas when filled with water. Additionally their shape, especially for small-scale shrimp ponds, is identical to that of natural salt flats. To address this issue, a shrimp pond layer was digitized on each image and subsequently overlaid on the land cover based classifications. This method is the most widely adopted method for identifying shrimp ponds (Dwivedi *et al.* 2005; Alonso-Perez *et al.* 2003; Dahdouh-Guebas *et al.* 2002; Ruiz-Luna *et al.* 1999; Terchunian *et al.* 1986) and ensures the greatest accuracy for the change analysis in a context of shrimp pond heterogeneity[24]. Other methods include chemical soil properties analyses to separate salt pans and shrimp ponds (Sridhar *et al.* 2007) and tasselled capped transformation based classification (Beland *et al.* 2006). The latter study also experienced difficulties separating shallow water and aquaculture; additionally both studies assumed that shrimp ponds were necessarily water filled which is not the case in the Estero Real, Nicaragua during the dry season. Indeed shrimp aquaculture is practiced mostly during the wet season for small-scale shrimp farmers (see Chapter Two) and it is therefore impossible to determine active shrimp ponds versus recently abandoned ones with the digitized layers only. The 1987 and 1993 shrimp pond digitizing is mainly based on visual assessment and is supported in areal extent by the literature. The 1999 and 2006 shrimp pond extents were obtained from the CIDEA and MIFIC GIS databases and supplemented by GPS-based shrimp pond locations generated by our own field data collection in September-October 2006.

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[22] The mosaic was made with the January 13th 1987 image covering the January 6 1987 image. This was a preferred choice due to the drier conditions in the first image as opposed to an extremely wet conditions in the second image that might have introduced distortions in the classification.

[23] Refers to a remote-sensing technique to append different images together.

[24] It is also considerably labor intensive and systematic monitoring would benefit from a systematic method for identifying shrimp ponds regardless of its water level stage.

2.3.2.2 Supervised classifications

Land cover maps of the study area for 1987, 1993, 1999 and 2006 were derived by separate supervised classifications using a maximum likelihood classifier (see Appendix 3). Maximum likelihood classifier is a robust and well accepted hard classifier, and has been used extensively for mapping mangrove areas (Muttitanon *et al.* 2005; Tong *et al.* 2004; Alonso-Perez *et al.* 2003; Dahdouh-Guebas *et al.* 2002; Lizano *et al.* 2001; Manson 2001; Green *et al.* 1998; Terchunian *et al.* 1986). The maximum likelihood method is based on bayesian probabilistic theory that assumes that a class exists *a priori*, in terms of probabilities assessed by computing the means as well as variances and covariances of signature data (Eastman 2006b). Pixels are then assigned to most likely class based on the a priori classes (Eastman 2006b; Mather 2004). An assumption is made that each class is equally likely, which is the 'safe option' when little is known of the extent of each land cover (Mather 2004). It must be noted however that this equal probability of each land cover class might not be reflecting reality.

The training sites were digitized based on visual identification and field based GPS point collection of seven land cover classes (red mangroves, secondary succession, salt flats, marshes, mud flats, water and dry vegetation), clouds and shadows, were added when necessary. Villages and human settlements were not selected as a distinct land cover class, as there were not easily discernable on the composite images and occupy a marginal area in the study area.

After the classification, salt and mud flats were reclassed in one category entitled 'flats' to allow time comparison given differences between the two reflect changes in wetness in the estuary. Similarly clouds and shadows were reclassed as 'clouds'. The final thematic layers were smoothed using a 3x3 mode filter (Alonso-Perez *et al.* 2003; Green *et al.* 1998) to reduce salt-and-pepper random noise (Eastman 2006b), resampled to a common resolution (28.5m pixel size) and the shrimp pond digitized layers were overlaid on the classified maps.

2.3.3 Validation

Field-based validation points, independent from the training sites, were collected in September 2006 to validate the 2006 classification. The SPOT image was taken in January (dry season) while the validation points were collected in wet season when movement in the estuary is made easier due to higher water levels. The main difference between the two time periods is water level and therefore bias is introduced for water level dependent land cover categories such as marshes or water. The other categories remain similar. To ensure an independent sampling scheme, the estuary was divided in 561 grid cells of about $1km^2$ each. A hundred cells were randomly selected subsequently and field visits (boat, car or foot-based) were undertaken. In each randomly selected cell, two sub-locations were purposefully chosen based on land cover/land use difference (i.e. Mangroves, shrimp ponds active or abandoned, dry vegetation etc). In these locations, efforts were made to collect a diversity of land cover types to ensure the collection of sufficient validation points for each land cover class (McCoy 2005). Each points was geographically located using a GPS, photographed and observations on the area (plant community size, type of vegetation, landscape structure, 'what was seen further away', human presence etc.) as well as the weather at the time were recorded in a notebook. A transect of at least 100m perpendicular to the estuary was done at each point in order to capture the different mangrove succession stages from red mangrove at the edge to secondary mangroves *spp.* further inside (usually about 20-40m) and then salt or mud flats (about usually 50-100m) (see Photo 1). A total of 875 points was taken. The points were subsequently converted into 642 polygons to minimize spatial autocorrelation (Congalton 1991). An accuracy matrix was then produced for the 2006 image based on standard accuracy procedures (Congalton 1991). Mangroves and shrimp aquaculture extents are compared for the previous years with study area specific literature.

2.3.4 Land cover/land use change analysis

Each classified image was compared in a post classification procedure, which provides information about land cover types appearing before and after change (from-to) but can generate large errors of commission in case of a classification error in either one of the data pairs resulting in a false indication of change (Beland *et al.* 2006: 1492). The accuracy matrix for 2006 allows us to separate land cover classes that are well estimated to ones that have a high degree of confusion and therefore guides the analysis of the results and discussion regarding change analysis. Figure 3 below summarizes all the methods adopted in this paper, while Table 3 presents all the land cover classes analyzed.

Figure 3. Methods used for the change analysis.

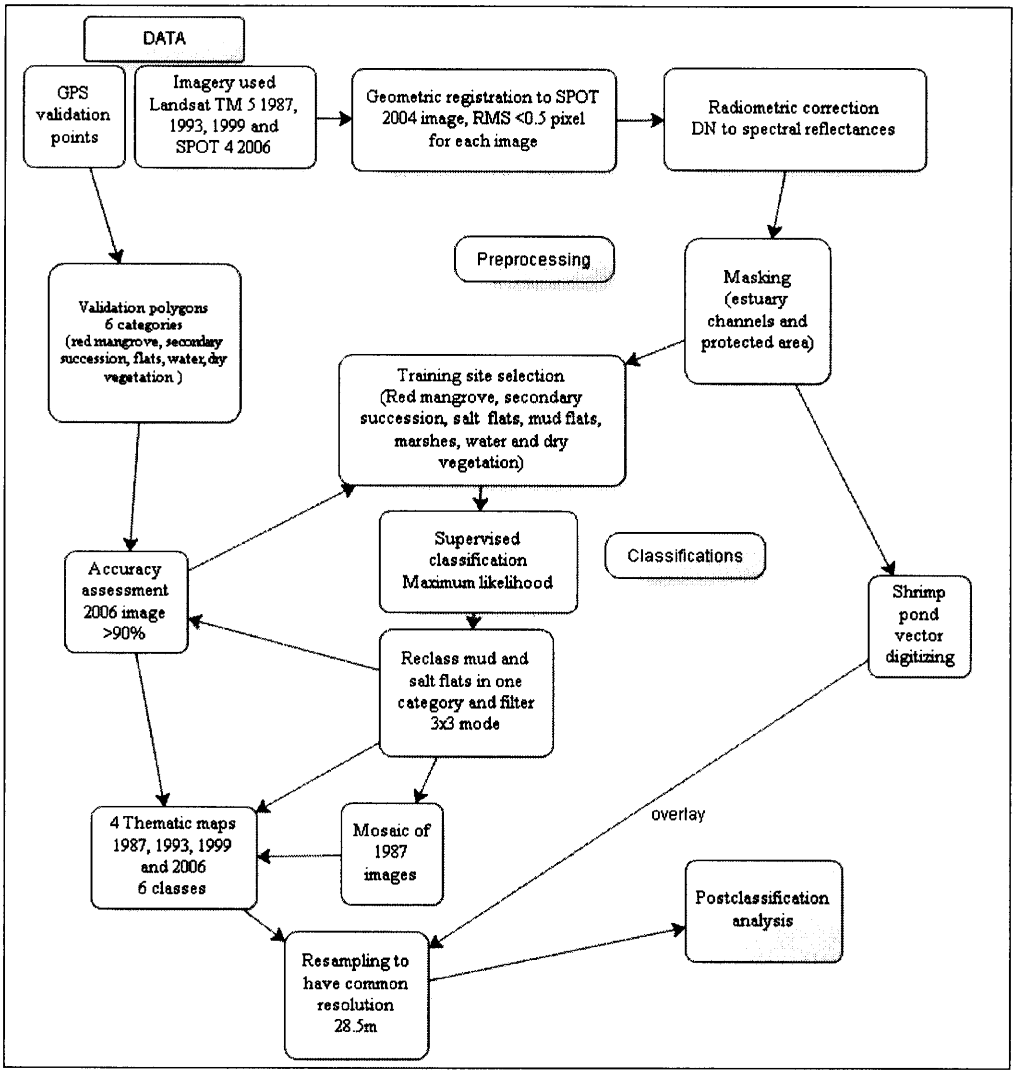
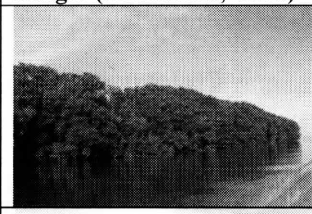


Table 3. Final classes in the thematic maps for the Gulf of Fonseca, Nicaragua.

Land cover classes	Description (MARENA 2006; Ramsar 2000)	Images (Benessaiah, 2006)
Primary mangroves	Principally Rhizophora *spp.* including *R. mangle* and *R. racemosa*. Located in frequently inundated intertidal areas.	
Secondary succession mangroves	Avicennia *spp.* usually located behind Rhizophora *spp.*, on salt flats, in areas inundated only at the highest tides. Their height varies based on their location in the community succession from edge to salt flat. Sometimes mixed with other mangrove species and associates such as Laguncularia *spp.*, *Conocarpus erecta* etc further inland at the transition from mangrove tree communities (saline) to dry forest (freshwater).	
Flats	Sediment accumulation zones inundated only during the highest tides, part of a mangrove succession continuum. Entirely devoid or with very little vegetation composed of stunted Avicennia *spp.* shrubs. For this study, shrubs smaller than 1m and sparsely dispersed were considered part of a salt flat.	
Marshes	Marsh *spp.* located in brackish waters composed of marsh grasses, salicornia *spp.*, algae etc. Exact *spp.* identification was not found for the area.	
Dry vegetation	Generic category including dry deciduous forests, savannas and pastures. In the northeastern part of the protected area, there is a protected savannah area dominated by *Crescentia alata.*	
Water	Water areas excluding main estuary channels, including small and larger bodies of water such as lagoon areas. In the dry season, the time of the classifications, only some parts of the lagoons are remaining.	
Shrimp ponds	Digitized shrimp ponds areas, including water filled ponds and dry ponds (active and abandoned)	

2. 4 Results

2.4.1 Accuracy assessment 2006

The accuracy assessment for the 2006 classification was done before overlaying shrimp ponds. Therefore shrimp aquaculture is not included as a category in the matrix. Overall accuracy (OA) for the 2006 classification, computed by dividing total correct pixels by total number of pixels in the error matrix[25] (Congalton 1991), is of 0.93 and is quite similar to the overall kappa index at 0.90. Both estimates are quite high demonstrating that overall the 2006 classification agrees with the validation polygons randomly collected. Kappa ((accuracy in field- random arrangement)/(1-random arrangement) (Ruiz-Luna *et al.* 1999) also includes the possibility of random contributions to the classification and is commonly used in remote sensing (Green *et al.* 1998; Stehman 1997; Congalton 1991; Rosenfield *et al.* 1986).

Table 4. Error matrix for the 2006 land cover classification, Gulf of Fonseca, Nicaragua.

	Validation polygons											
2006 classification	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	Rows totals	**PA**	**UA**	**KIA**
Red mangrove 1	430	6	0	0	0	0	0	0	436	0.91	0.99	0.91
Sec.Succ* 2	22	315	35	24	51	37	0	0	484	0.75	0.65	0.75
Flats 3	0	2	11280	0	18	1	0	9	11310	0.96	1.00	0.94
Marshes 4	19	19	0	150	9	0	0	0	197	0.46	0.76	0.45
Dry forest 5	1	76	224	154	7176	638	1	0	8270	0.97	0.87	0.95
Water 6	2	1	176	0	176	5738	265	21	6379	0.89	0.90	0.86
Shadows 7	0	0	0	0	0	0	828	0	828	0.76	1.00	0.75
Clouds 8	0	0	6	0	0	0	0	623	629	0.95	0.99	0.95
Columns totals	474	419	11721	328	7430	6414	1094	653	28533			

Note: *refers to secondary sucession. Validation polygon categories match those of the 2006 classification. Overall accuracy 0.93 and overall Kappa 0.90.

When disaggregating the error matrix, differences between accuracies of various land cover types emerge. Producer's accuracy (PA) is a measure of the probability of a reference pixel being correctly classified while the user's accuracy (UA) is more indicative of reliability as it is quantifying the probability that a pixel classified on the map actually represents the chosen land cover class (Green *et al.* 1998; Stehman 1997; Congalton 1991; Rosenfield *et al.* 1986). The Kappa index of agreement (KIA) per class is indicative of the overall accuracy for each individual class.

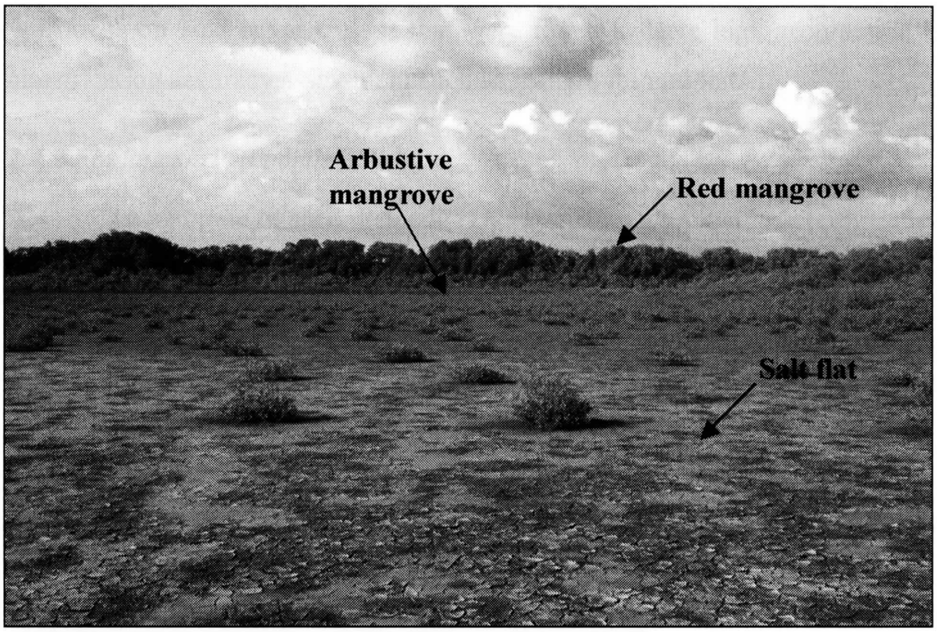
[25] It corresponds to the sum of the main diagonal in the error matrix.

Mangroves, flats and clouds were clearly identified and scored high for PA & UA (>0.9). Dry vegetation, water and shadows have relatively medium-high mapping accuracies for both PA and UA (>0.75). Secondary succession had a medium accuracy with a PA of 0.75 and a UA of 0.65. Marshes were the land cover type with the most confusion, with a PA as low 0.46 and a UA of 0.65.

Relatively low accuracies for secondary succession and marshes are due to the fact that both vegetation types are found in transition zones. Secondary succession mangroves (*Avicennia spp.*) are located in a continuum between red mangroves and salt/mud flats (see photo 1). Green *et al.* (1998) discuss how tall *Rhizophora spp.* (red mangroves) are clearly identified using landsat TM data while "the user's accuracies of all other mangrove habitats was very low (0-29%)" (p. 948). *Rhizophora spp.* (red mangroves) are grouped in relatively homogeneous community stands with a tall canopy (>3m of height), on the contrary *Avicennia spp.* (secondary succession) occupy a larger area with varying sizes and densities (see photo 1). Their identification can be greatly affected by the 'mixed-pixel' effect whereby reflectances from other land categories such as flats, water or dry vegetation interact with mangrove reflectance producing a different signal. Changing backgrounds (wetness, soil types) has a great effect on remote sensing of mangroves (Diaz *et al.* 2003), especially low canopy mangroves sparsely dispersed.

Marshes present a similar case. Marsh species are mostly located at the interface between brackish and freshwater systems, principally in the lagoon areas (see Chapter Four). They intermingle with dry vegetation species such as *Crescentia alata* especially during drier conditions. The main driver affecting the marsh land cover category is the presence of water. Marshes were mostly classified as dry vegetation in the 2006 classification. This could be due to the fact that the 2006 classification is representing the estuarine ecosystem during the dry season when water levels are at their lowest and vegetation is desiccated. Unfortunately the validation points were taken during the wet season (due to access constraints). Efforts were made to take points that are relatively impervious to change in season but this is extremely difficult for marshes that are in a sense season-dependent.

Photo 1. Mangrove succession stages, Estero Real, Gulf of Fonseca, Nicaragua.



Succession stage: red mangrove (*Rhizophora spp.*), followed by arbustive mangrove (*Avicennia spp.*) of diminishing size, until reaching the salt flat usually a highly saline plateau covered or not with various densities of small shrub of *A. germinans* or *A. bicolor* (K. Benessaiah, September 2006).

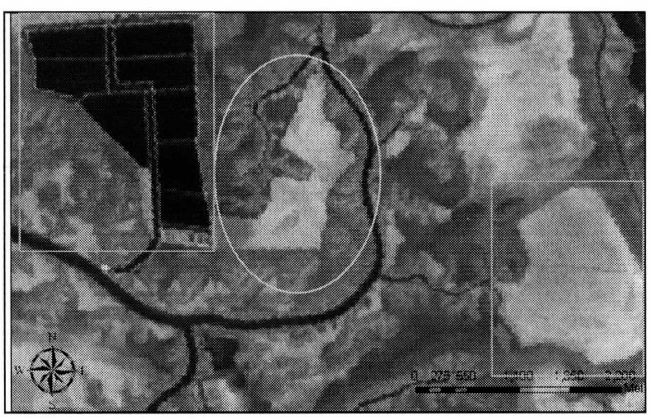
The strong influence of seasonality greatly constrains the use of optical remote sensing technology to identify coastal changes for certain land cover categories. Indeed, most optic satellite imagery in the region is available mainly during the dry season when cloud cover is minimal. However during the dry season, the vegetation in the area is considerably stressed, water bodies-including lagoon areas- are found in their minimal extent and are identical to the spectral reflectance of salt and mud flats or in the case of retention of some water content to wetlands. Input from local inhabitants become therefore invaluable to the identification of some areas such as the lagoons (see Chapter Four).

Change analysis in coastal areas for transitional land cover classes is constrained by the dynamic nature of coastal areas that vary both on short (daily and seasonal) and long term scales (yearly, century) (Blasco *et al.* 1998). Changes in tides, rainfall, temperature etc have great effects on the radiometric properties of coastal land cover classes (Blasco *et al.* 1998) and more so those located in transition zones such as marshes, dry vegetation and secondary mangrove species. To palliate with these constraints, the post classification change analysis will focus on land cover classes that were found to have high accuracy levels in the 2006 classification accuracy assessment such as mangroves and flats.

2.4.2 Finding shrimp ponds 2006

The mapping of shrimp ponds is made challenging by the heterogeneity of shrimp pond arrangements and structures. Map 2 shows legal shrimp ponds (blue squares), one non reported shrimp pond (yellow circle) and surrounding salt flats (other pink colored areas).

Map 2. Shrimp pond identification example.



Based on a 2006 Spot image graciously purchased by McGill libraries

The shrimp pond filled with water is easily identified however the ones without water are harder to discern. Indeed in terms of spectral signatures both land uses (dry shrimp ponds and salt flats) have the same land cover type (that of a salt flat). The legal dry shrimp pond, an industrial owned one, has high walls that can be seen on the image and that clearly identify the shrimp pond. The 'illegal' shrimp pond has lower walls and was identified by a random visit on the field during the GPS collection stage; the illegal pond was not recorded in the official government database. Both shrimp ponds exhibit an angle sharpness that tends to characterize shrimp ponds as opposed to salt flats, however given that the walls of the illegal pond are low; we cannot clearly determine boundaries. Indeed, shrimp pond identification for small scale shrimp ponds with few alterations to the natural environment is more difficult and greatly benefits from field visits and local people's input. In the case of 'illegal' shrimp ponds, it is sometimes difficult to obtain spatial information regarding their location due to their illegal status. It must be noted however that the government has not been very strict in its enforcement of concession areas establishment, an issue in terms of environmental management but a benefit for households that do not have the funds to finance the payments of a concession. Small scale shrimp pond owners mentioned a fear of stricter policies with the proposed protected area management plan; one owner reported that his cooperative decided to expand their shrimp pond to solidify their claim to the area (household # 170).

2.4.3 Land classifications 1987, 1993, 1999 and 2006

The 1987 mosaic covers the entire extent of the protected area. The areal extents for the entire area are the following: 8,732.23 ha of red mangroves, 10,570.77 ha of secondary succession mangroves, 10,864.26 ha of marshes, 18,696.11 ha of dry vegetation, 26,644.84 ha of flats, 1,782.64 ha of water ad 23.56 ha of shrimp ponds. Valerio (2000) finds 31,884 ha of mangroves in the area for 1986 (Valerio (2000) in Núñez-Ferrera 2003: annex 2-3). In this case mangroves are not disaggregated into different types. Another Landsat based study finds for 1986: 13,061 ha of red mangroves, 14, 856 ha of secondary succession mangroves and 29 ha of marshes (for an overall total of 27,946 ha of wetlands)[26] (Velásquez-Mazariegos 1998: 75). DANIDA-Manglar gives a lower estimate for 1988 of 24, 294 ha (10, 673 ha for red mangroves, 12, 775 for secondary succession and 846 ha for marshes) based however on aerial photography digitizing (Curie 1994: 76). Our 1987 estimates when aggregating wetlands (red mangroves, secondary succession and marshes) are 30,167 hectares, which is similar to findings in the first two studies presented above. These differences illustrate quite well the biases in mangrove reporting, due to their multi-scalar categorization, as mentioned in the introduction. In terms of shrimp aquaculture, we find about 24 hectares of shrimp ponds in 1987. Estimates from other studies range from 100 to 180 ha in 1987 (CIDEA 2006: 52; Coze Saborío 2006: 4; Curie 1994: 74), however 130 ha of these correspond to *tapos*, that is an enclosure of part of the seasonal lagoons with a barrier made of

[26] This study clearly underestimates marsh areas and overestimates secondary succession.

mangrove sticks and nets (see Chapter Four for a more length discussion on *tapos*). Given that these *tapos* do not erect permanent walls, they are invisible from space and were not identified in our 1987 classification.

The 1993 classification does not cover the entire area and was the basis for the established common area between 1987, 1993, 1999 and 2006 classifications. In terms of overall wetland extent, the reduced 1987 classification covered 94% of the overall area for the same year. Assuming the same relationship for 1993 for comparison purposes, we found an overall of 24,829.26 ha in 1993 while Velásquez-Mazariegos (1998: 75) estimated 26,564 ha in 1993 and Valerio (2000 in Núñez-Ferrera 2003: annex 2-3) 27,393.81 ha, which when normalized for the smaller size of our 1993 image gives estimates of 24, 970 ha and 25 750.18 ha respectively. These results are quite similar and validate our aggregated 1993 wetlands estimates. In terms of shrimp aquaculture, we found 1697.60 ha of shrimp ponds in the reduced 1993 area. Other studies provide ranges of 1200-1875 ha for shrimp ponds in 1993 for the entire area (CIDEA 2006: 52; Núñez-Ferrera 2003: annex 3-12; Curie 1994: 75).

For the reduced 1999 area, we find an overall of 29, 791.22 ha of wetlands (with 6241.65 ha of red mangroves, 10, 951.24 ha of secondary succession and 12, 598.32 hectares of marshes). Unfortunately there are no estimates of 1999 mangrove extents to compare this classification with. However since that the previous classifications were similar when aggregated to other studies' findings, we assume that this is the case for 1999 given that all images were classified using the same methodology. Aggregated estimates for 1997 state an overall 17, 959.31 ha of mangroves (Valerio 2000 in Núñez-Ferrera 2003: annex 2-3). Velásquez-Mazariegos (1998: 75) finds 14,520 ha for red mangroves, 8320 ha for secondary succession and 20 ha for marshes for an overall wetland extent of 22, 920 ha in 1997. Our findings for 1999 are higher for the overall extent and distributed differently among the different wetland types. 1999 is the year immediately after hurricane Mitch and it is expected that significant changes could have occurred in the biophysical conditions of the estuary. Nunez-Ferrera (2003: annex 2-5) reports that the estuary was flooded for a week with 7m of water above sea level, which illustrates the magnitude of this event. A USGS team shows that two years after the event, the coastal system was still affected by post-Mitch effects, especially due to changes in sediment load patterns. Notably, high impact areas (near the edge of the estuary channels where red mangroves are located) have been greatly affected while inland mangroves (secondary succession) are recovering well (Cahoon *et al.* 2002a; Cahoon *et al.* 2002b). These studies support our findings in 1999 whereby there is a reduction in red mangrove area and an increase in both secondary succession and marshes (both transition areas). In terms of shrimp aquaculture, we estimate an overall of 9788.59 ha for the reduced 1999 area. CIDEA's estimates are lower at about 6191 ha in 1999 for shrimp ponds in production[27]; no estimates are given for constructed shrimp ponds in that year (Coze Saborío 2006: 52). Given that recently abandoned shrimp ponds and active shrimp ponds (both constructed ponds) are difficult to distinguish based on visual assessments, we probably overestimated the extent of shrimp ponds in 1999, a year characterized by massive loss of shrimp pond infrastructure due to Hurricane Mitch in 1998, estimated to be 25% less than the 1998 shrimp aquaculture extent (Coze Saborío 2006: 4). In 1998 and 2000, the constructed shrimp pond extents were of 9602.73 ha and 9602.73 ha respectively (CIDEA 2005). Our 1999 shrimp pond extent reflect therefore constructed shrimp ponds and while it fails to provide an proxy for active shrimp ponds, it does allow an estimation of the effects of shrimp aquaculture expansion on natural land covers.

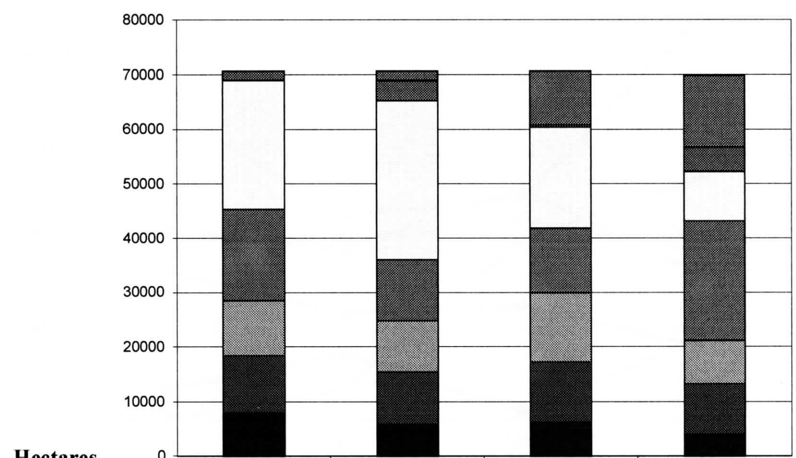
Overall wetland estimates for the reduced area 2006 classification were of 21,140.81 ha with 4005.5 ha of red mangroves, 9238.94 ha of secondary succession and 7896.37 ha of marshes. There are no estimates of wetland extent in other studies for 2006. The accuracy assessment shows high confidence for the red mangrove assessment and lower confidences for the other two transitional wetland types. Changes between years will be discussed further in the change analysis section. In terms of shrimp aquaculture, we estimate 13, 151.14 ha of constructed ponds. Other studies results range between 10,335 ha (productive shrimp ponds) to 13, 751 ha of constructed ponds for the overall area (Coze Saborío 2006; Fuertes 2006; CIDEA 2005: 4-7).

[27] These are aggregated estimates and there are no available spatial layers of 1999 shrimp pond extent.

2.4.4 Post classification change analysis

The post classification analysis consists of a comparison of the common areas of the 1987, 1993, 1999 and 2006 classifications. Table 5 presents the areas (in hectares) of each land cover type in a given year while Table 6 presents trends in land cover changes.

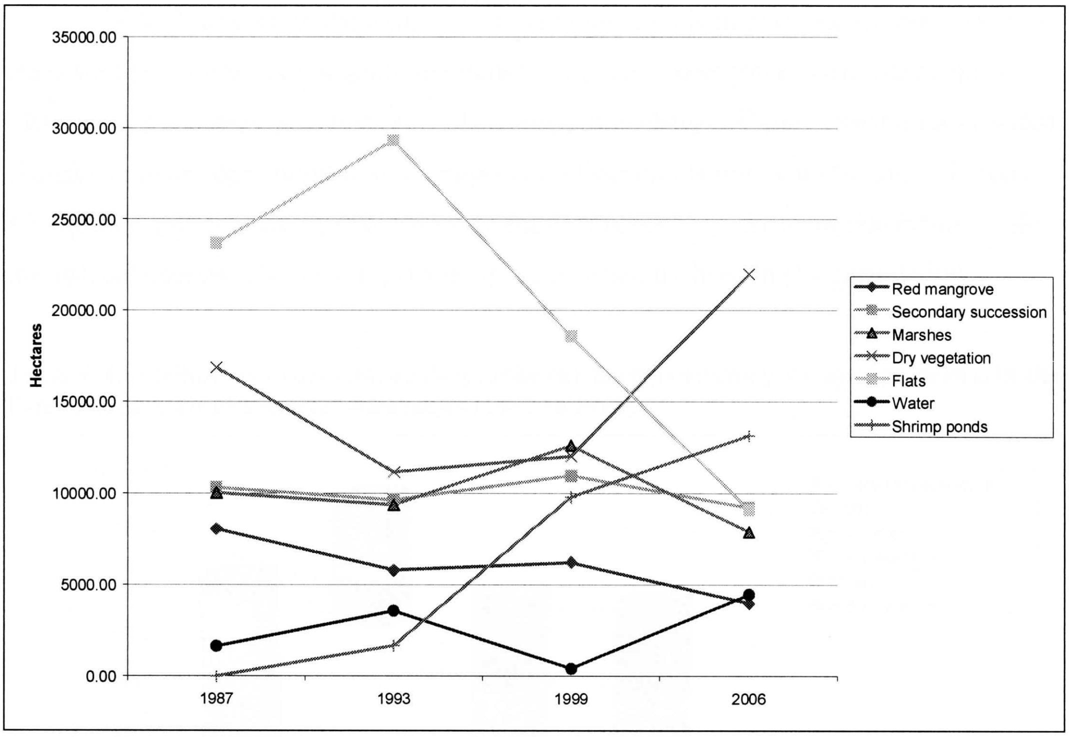
Table 5. Areal changes (hectares) for each land cover class in the Estero Real, Gulf of Fonseca, Nicaragua (1987 to 2006).



	1987	1993	1999	2006
Shrimp ponds	24.00	1697.60	9788.59	13151.14
Water	1647.00	3593.48	438.29	4481.10
Flats	23698.00	29349.11	18561.13	9123.03
Dry vegetation	16843.00	11153.00	12043.23	21972.99
Marshes	10044.00	9382.46	12598.32	7896.37
Secondary succession	10307.00	9653.10	10951.24	9238.94
Red mangrove	8058.33	5793.70	6241.653	4005.5

Water levels oscillated from 1987 to 2006, which reflects both scene specific wetness conditions and wider weather related patterns. Water levels trends are not informative when considered separately but due to the importance of water in the estuary for vegetation patterns, it greatly informs other land categories distribution. The 1987 scene presents homogeneously wet conditions in the estuary whereas 1993 presents very different water regimes between the inland areas (very wet with flooded marshes) and the areas close to the open Gulf (very dry) (see Appendix 3).

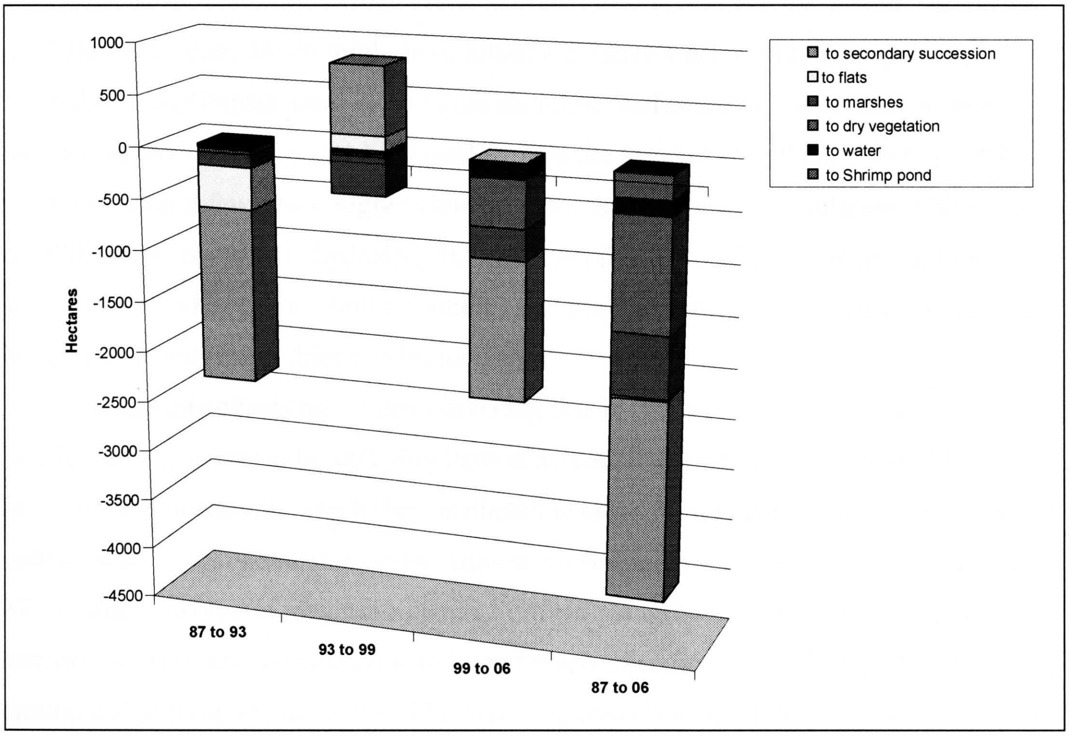
Table 6. Land cover changes in the Estero Real, Gulf of Fonseca, Nicaragua (1987 to 2006).



1999 is similar to 1993 with patchy areas alternating wet and dry conditions, with more water overall in the entire estuary and more a clearly identified marsh system. 1999 received a considerable influx of upstream sediments that settled inland and was greatly eroded close to the estuary mouth (Cahoon *et al.* 2002a; Cahoon *et al.* 2002b), which explains the observed patterns. 2006 presents a much drier estuarine system, with very little water. This can be seen in the important increase in dry vegetation in the 2006 year. Secondary succession and marshes are relatively stable with an increase in 1999, probably due to post Hurricane Mitch, and a subsequent decrease (probably due to 2006 dry conditions. We were expecting a high pressure on secondary succession due to firewood consumption (Avicennia is the prime firewood fuel in this area), but no net change is apparent from the analysis. This is probably explained by a simultaneous change occurring in another land cover type to secondary succession and will be discussed later on in the section. Red mangrove extent gradually reduced by half since 1987, Table 4 presents the trends from red mangrove to other land cover types for 1987-1993, 1993-1999, 1999-2006 and the entire 1987-2006 period

Table 7 shows that the trend of red mangrove loss is mainly due to conversion to other vegetation types, principally secondary succession mangroves (*Avicennia spp.*). Changes in hydrology are most probably causing this change. Curie (1994) mentions that changes in hydrology might have an important effect on mangrove distribution. Indeed *Rhizophora spp.* (red mangroves) are extremely dependent on frequent tide influx while transitional species (*Avicennia spp.*) are more resistant to drought (Hogarth 1999).

Table 7. Contributors to net change (ha) in the red mangrove category by time period in the Estero Real, Gulf of Fonseca, Nicaragua (1987 to 2006).



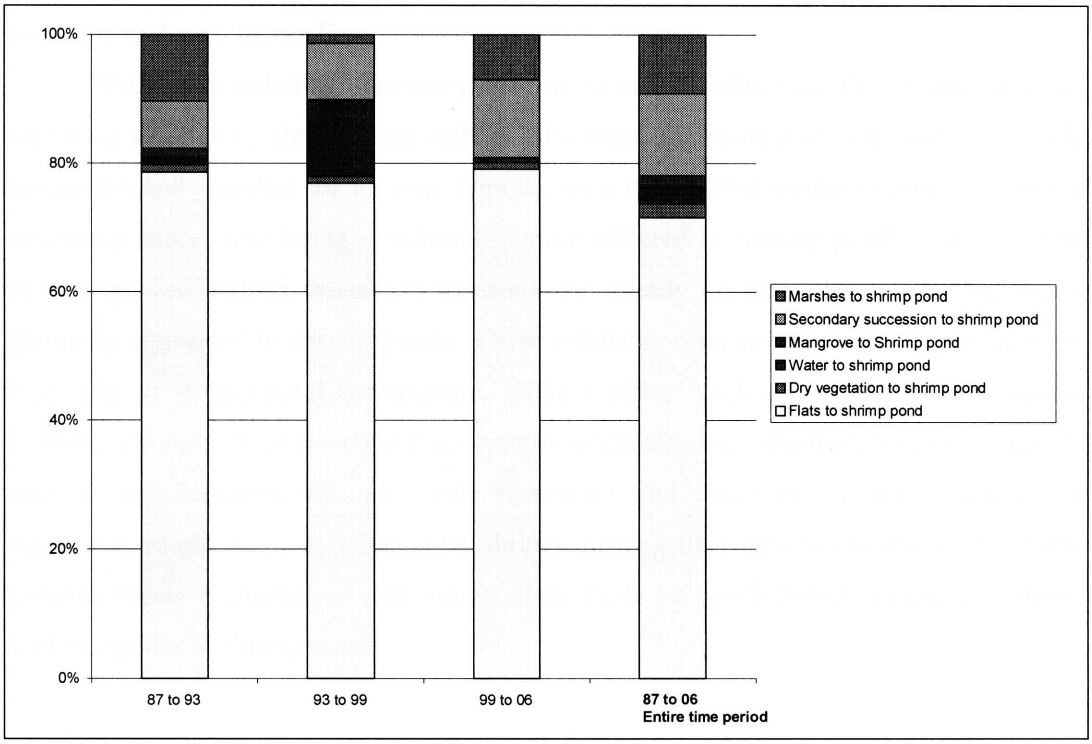
Note: Table 7 shows net conversions in hectares from red mangrove to other land cover types.

Since 1999, there is a negative trend towards conversion of mangroves to drier vegetation types. The 1993-1999 period seems to be an exception in the overall trend as we can observe an increase of red mangroves from secondary succession mangroves principally. Given that there is a high confidence in the accuracy of the red mangrove identification using maximum likelihood, we assume that this trend is due to changes in the biophysical conditions of the estuary. The increase in red mangroves during the 1993-1999 period could be due to temporary differential effects of Hurricane Mitch on different mangrove types. Sedimentation can have positive effects on mangrove growth at a certain rate but cause mortality if excessive (Cahoon *et al.* 2002b). Cahoon *et al.* (2002) also discuss that red mangrove (*Rhizophora mangle*) that dominates the shoreline forest produces a denser, more extensive, and stronger peat than the black mangrove (*Avicennia germinans*), which is predominant in the mixed-species interior forest (McKee *et al.* 2002). Such a difference between mangroves species leads to differences in the effects of sediments on mangrove mortality, more specifically peat collapse is occurring more slowly in the shoreline forest than in the interior forest (Cahoon *et al.* 2002b; McKee *et al.* 2002). Hurricane Mitch might have initially positively affected red mangroves, located in lower impact areas close to the shoreline, and negatively affected secondary succession *Avicennia spp.*, which would explain the trend observed from 1993 to 1999. However, after a few years, higher elevations due to sediment accumulation (Cahoon *et al.* 2002b) and changes in hydrology (Curie 1994) due to both hurricane and potentially anthropogenic effects (i.e. shrimp farming) seem to have favored *Avicennia spp.* that are better able to survive in drier conditions.

Local inhabitants have been observing that in the later years since hurricane Mitch, the area seems to be suffering from drier conditions. Informants observed an increase in temperatures which they attributed to changes in mangrove cover quantity and quality in the estuary and close to the lagoons (households # 152, 169, 37, 46, 49, 54, 6, 87). Changes in type of mangrove cover, from red mangroves to transitional secondary succession, were also associated with higher levels of sedimentation during floods, due to natural and anthropogenic causes. This warming trend is supported by studies looking at climate change in Latin America (Magrin *et al.* 2007). This explains in part the conversion of mangrove to drier vegetation types observed in the 1999 to 2006 time period, which includes dry marshes and savanna like vegetation in the inland parts of the coast.

Flats diminished dramatically overall since 1987. The trend shows an increase from 1987 to 1993, which is probably due to the fact that 1993 except in the marsh system was quite dry overall, but decreases considerably in later time periods. Shrimp ponds increased considerably, especially in the 1993-1999 time period. Table 8 presents conversion percentages from different land cover types to shrimp aquaculture.

Table 8. Contribution of each land cover type to shrimp aquaculture (%), in the Estero Real, Gulf of Fonseca, Nicaragua (1987 to 2006).

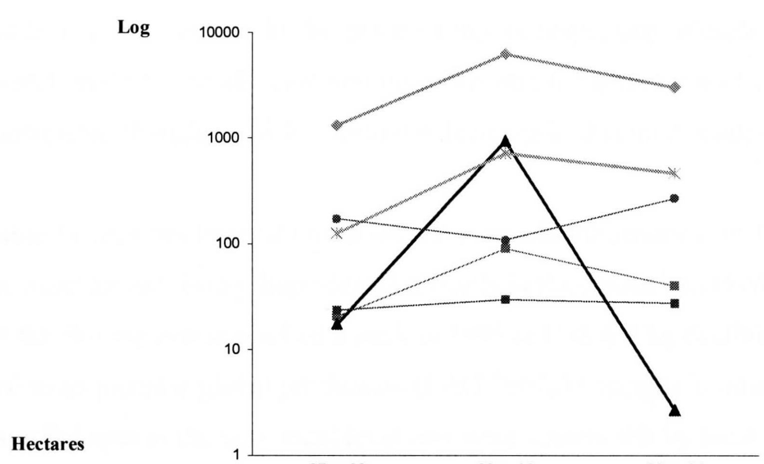


Flats are primarily converted to shrimp ponds (>75% of the types converted for all time periods). This land cover type is favoured by shrimp farmers due to reduced costs (in terms of labour and financial) associated with the construction phase and are also provide optimal soil chemical conditions for shrimp productivity as opposed to mangrove soil that are too acidic (Ochoa Moreno *et al.* 2001). Before the advent of shrimp aquaculture, flats were considered barren areas of little interest beyond occasional firewood collection and shell fish collection closer to mangrove stands, and therefore there was little resistance to the conversion of this land cover type. However, the flat land cover category partly includes seasonal lagoons. During the rainy season, a lagoon estuarine complex is formed where waters originating from the sea meet with superficial waters flowing down from the upper watershed (Núñez-Ferrera 2003). Theses lagoons have similar reflectances to flats and marshes during the dry season. These land cover categories, flats-marshes-lagoons, are part of a continuum in terms of biophysical properties but are differentiated by local inhabitants due to their different roles in local livelihoods. Remote sensing cannot specifically quantify lagoon extent and changes due to their land cover similarities with flats and marshes. Participatory mapping with local people allowed getting an estimate of this important land use category (see Chapter Four).

Wetlands (including secondary succession and marshes) are the second land cover type most affected by shrimp ponds (about 20% when aggregating red mangroves, secondary succession and marshes for all time period), with transitional wetland types (marshes and secondary succession) being considerably more affected by shrimp pond construction than red mangroves. Indeed, transition wetlands are usually located adjacent to flats and are gradually converted to shrimp ponds. These estimates refer to direct effects on land cover types due to shrimp pond construction. Indirect effects such as changes in water quality, hydrological patterns of the coastal ecosystems (including the flats-mangrove continuum), as well as sedimentation are not easily quantified and therefore wetlands including red mangroves might be more affected by shrimp farming than reported in this study. Table 9 presents trends of change per time period while Table 10 shows conversion per year from all land categories to shrimp ponds.

Shrimp ponds have mainly affected flats with an order of magnitude difference, and average at 522.67 ha/year from 1987 to 2006. 1993 to 1999 presented the greatest conversion rates with 1045.29 ha/year during that time period for flats and 1359.09ha/yr for all categories summed. The conversion of red mangrove to shrimp pond remains relatively similar ranging at 13 ha/year. The 1993 image presents high water levels in the inland marsh area; flooded marshes were classified as water thus providing a low estimate of marsh extent. The 1993 to 1993 change analysis for the marsh land cover type reports an estimated 157.23 ha/yr; the actual change in marsh ecosystem is probably higher than estimated but could not be assessed due to a misclassification of marshes with water when flooded.

Table 9. Detailed trends of land cover changes to shrimp aquaculture in the Estero Real, Gulf of Fonseca, Nicaragua (1987 to 2006).



	87 to 93	93 to 99	99 to 06
Flats to shrimp pond	1316.82	6271.71	3037.57
Dry vegetation to shrimp pond	20.55	89.59	40.04
Water to shrimp pond	17.46	943.38	2.68
Mangrove to Shrimp pond	23.56	29.89	27.54
Secondary succession to shrimp pond	125.01	711.53	465.5
Marshes to shrimp pond	171.3	108.44	267.23

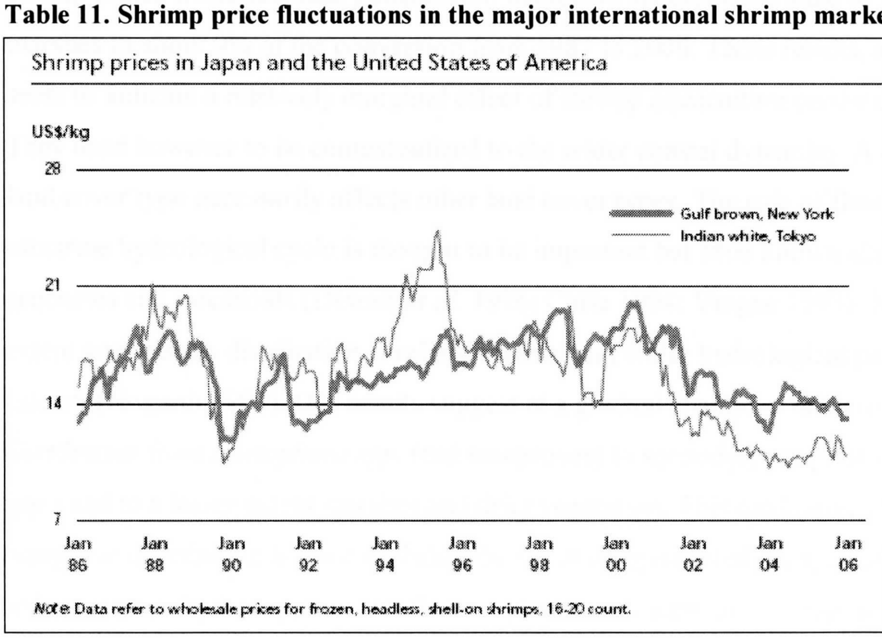
Table 10. Rates of change for conversion from different LC to shrimp ponds in the Estero Real, Gulf of Fonseca, Nicaragua.

Rate of change (hectares/year)	87 to 93	93 to 99	99 to 06	87 to 06
Flats to shrimp pond	219.47	1045.29	506.26	522.67
Dry vegetation to shrimp pond	3.43	14.93	6.67	15.05
Water to shrimp pond	2.91	157.23	0.45	18.85
Mangrove to Shrimp pond	3.93	4.98	4.59	13.13
Secondary succession to shrimp pond	20.84	118.59	77.58	94.49
Marshes to shrimp pond	28.55	18.07	44.54	65.70
All types to shrimp pond	279.12	1359.09	640.09	729.89

The conversion rate to shrimp aquaculture started slowly at 279 ha/yr during the 1987 to 1993 time period; increased exponentially from 1993 to 1999 and gradually decreasing in the 1999 to 2006 period. Local informants indicated that during the 1990s, shrimp prices were quite high (at about 4$/lb of shrimp sold), inputs were cheap (especially diesel), formal credit was easily accessible to local households, the ecosystem was bountiful and flats available for shrimp settlement; all factors contributing to conditions very favourable to shrimp aquaculture development thus explaining the exponential growth. On the contrary since the late 1990s, the Nicaraguan shrimp sector experienced Hurricane Mitch in 1998, shrimp diseases in 1999 and 2000 as well as decreasing international prices for shrimp (see Table 11), an increase in the price of inputs (especially diesel), decreasing availability of formal credit for small scale shrimp farms and the saturation of concessioned space (not all constructed though); which inform the decrease in shrimp conversion (see Chapter Three).

Table 11 presents fluctuations in shrimp prices in the Japanese and American markets, the main global shrimp importers (Europe is in third position) (FAO 2007a; Tobey *et al.* 1998). Shrimp prices reached a peak in 1995 at US$ 6.9/kg declining since to US$ 4.1/kg, due to an increase global production (FAO 2007a).Changes in international market prices have linkages at the very local level that were acutely felt by local producers interviewed (households # 104b, 185, 245, 255, 71, 99) and are reflected in the rate of shrimp pond establishment present in the study area.

Table 11. Shrimp price fluctuations in the major international shrimp markets.



Source (FAO 2007a: 50)

2.5 Discussion: conceptualizing land cover/use changes in mangrove ecosystems.

The supervised classification of the 2006 image has a high accuracy, above 90% for both overall accuracy and the Kappa Index. The supervised classifications for 1987, 1993 and 1999 yield similar results-when aggregated- to that of other studies. The change analysis should therefore reflect relatively well real trends in the estuary.

First, the post classification shows that shrimp aquaculture increased considerably in the 1987-2006 time period, with an average establishment rate of 729.89 hectares/year. This rate was not constant however; it initiated at 279.12 ha/yr in 1987-1993, followed by a peak in the 1990s, with rates averaging 1359.09 ha/yr for the 1993-1999 time period, before declining in the 1999-2006 segment (~ 640.09 ha/yr). This trend follows closely international market trends.

Shrimp aquaculture *directly* affected mainly salt and mud flats (about 70% of the conversion). Red mangroves represent less than 2% of the observed direct conversion to shrimp ponds while secondary succession mangrove species contribute to about 13% and marshes to about 9% of the conversion from 1987 to 2006. These results, at first glance, seem to indicate a relatively marginal effect of shrimp aquaculture on the environment. They need however to be contextualized to the wider coastal dynamics. A change in one land cover type necessarily affects other land cover types. The role of flats in the estuarine hydrological cycle is thought to be important but little known about actual processes and thresholds (Dewalt *et al.* 1996; Curie 1994; Vergne 1993). Mangroves extent and species distribution is reliant on tidal and wider hydrological patterns of the estuary (Hogarth 1999). Our results suggest at a gradual change in mangrove species distribution from *Rhizophora spp.* (red mangroves) to secondary succession (*Avicennia spp.*) and to a lesser extent marshes and drier vegetation. This qualitative change in mangrove distribution is most probably the result of aggregated changes in sedimentation, hydrology and salt flat-mangrove continuum due to fragmentation by shrimp ponds since the 1990s. This implies that shrimp aquaculture did have an *indirect* effect on mangrove ecosystems. A more detailed study of hydrological patterns of the estuary, focusing on the changes in the salt flat areas due to shrimp pond infrastructure increase, would be essential to understand more fully the indirect effects of shrimp aquaculture on the overall ecosystem.

Throughout the study, mangrove change was related both to the ecosystemic as well as the more species specific analysis of change. As such, the study illustrates well that the concept of "mangrove" is context (and scale) dependent (Blasco *et al.* 1998). Ambiguity is present in the definition as the term 'mangroves' applies to both to plants communities and the ecosystem formed by these plant communities in salty, anaerobic conditions (Hogarth 1999). This ambiguity leads to definitional differences, which are not always made explicit, that lead to different 'mangrove' extent estimates. This makes it extremely difficult to scale-up, compare and obtain national and more so global estimates of mangrove extent (FAO 2007b).

Different actors define 'mangroves' according to their beliefs, values and interests. Environmentalists associate mangroves to the wider coastal ecosystem, adopting a more holistic approach but also one that shadows internal dynamics of components of the system. Conversely, promoters of shrimp aquaculture adopt a much too narrow approach that restricts mangroves to *Rhizophora spp.* (red mangroves) undermining the potential importance of associated species and ecosystems. This leads to heated debates as the one seen based on the article entitled "Forests of Tides" written in February 2007 in the National Geographic (Warne 2007) and the response it fuelled from the Global Aquaculture Alliance (GAA) (Global Aquaculture Alliance 2007). More specifically concerning the Gulf of Fonseca, Warne stated in a caption showing satellite images from 1987 and 1999 that "by 1999 shrimp farming had swelled, *wiping out mangroves*, polluting the environment and disrupting freshwater supplies" (p. 143). This quote engendered a heated response from the GAA that responded "Warne's article called the shore zone occupied by mangroves "a prime location for shrimp ponds", but in reality, *this zone is far from optimal.* Shrimp ponds built in mangrove areas can't be properly drained or managed, and the soil often becomes acidified. Shrimp in such ponds are prone to disease and yield only meager crops [...] Decades-long scientific and social studies of the Estero Real region funded by Nicaragua's national shrimp grower's association found that *fuel cutting, not shrimp farms, was the main cause of mangrove loss in the area.*[28]". [author's emphasis].

This debate clearly shows that both authors are not speaking in the same system of reference; the notion "mangrove" is constructed differently for each actor creating a different story from the same data (a 1987 and 1999 satellite image). Willburn (2007: 11) summarizes well the situation:

"The debates pertaining to mangrove loss are often situated around contested definitions of what 'mangrove forests' ought to be considered as a priori to a study. The particular method used when analysing satellite images or aerial photographs can also be a factor in various depictions of mangrove cover and, therefore, variations in representations of coverage. In other words, the methods used to study mangrove deforestation and, therefore, the results are contested and a source of conflict".

There is a need for a common concept for the term "mangrove". Ideally given the complex nature of the coastal system, a multi-scalar definition of mangrove could be incorporated in land cover change studies. Reporting would include a hierarchical structure including mangrove species, associated vegetation communities and associated ecosystems such as flats and lagoons; similar to the reporting done for this study.

The dynamic nature of the coastal system also needs to be recognized and incorporated in change analysis. Blasco *et al.* (1998) discuss the challenges associated with estimating the extent of mangrove areas in a dynamic coastal system. Satellite images provide a one-time-shot assessment that might be heavily influenced by seasonality, wetness level etc. In this case study, the images are obtained from the dry season, due to low cloud cover during that time of year. Consequently, vegetation will be stressed due to water scarcity often which might bias slightly extent and nature of the land cover observed. Additionally certain land covers cannot be observed during the dry season. Seasonal lagoons for example are only visible when water filled, that is during the rainy season. These limitations need to be acknowledged and discussed in a land cover change analysis.

Remote sensing analyses that fail to do so mask to some extent the dynamic nature of coastal wetlands that change seasonally and yearly, in response to changing

[28] While fuelwood collection certainly influences greatly mangrove species regeneration patterns, our data do not show a reduction in *Avicennia spp.* The effect of fuelwood collection is counterbalanced by other coastal dynamics in this case.

climatic, rainfall and runoff regimes. For example, often salt flats describe a dry season land cover type that is converted into a brackish lagoon during the rainy season. Similarly the mangrove ecosystem delimitation is fluctuating according to seasons and climatic cycles (Lacerda 2002). The dynamic interplay between salt flats, lagoons and mangroves is poorly understood, but they seem to be related as mangroves fluctuate based on changing tidal and sedimentation regimes, forming dynamic barriers that restrict inland tidal influences that result in the expansion of the salt flat (and possibly seasonal lagoons) climax communities (Vergne 1993: 5-6). The uncertainties associated with the classification, functions and interdependencies between these seemingly different ecosystems has important implications on how these ecosystems are valued and managed. Barbier *et al.* (2008) illustrate in their study that mangroves loss is not linearly related to loss of ecosystem services, which implies that a balance between shrimp aquaculture and ecosystem services functioning can be achieved. Establishing the nature of the relationship between ecosystem components and the services they provide will imply however the need for a greater understanding of coastal spatial and temporal dynamics, thresholds and drivers in a context of change (daily, annual, decadal) both natural and anthropogenic.

To conclude, land cover change studies are concerned with understanding how the world around us changes but more importantly should be focused on the underlying processes leading to those changes and the resulting observed patterns, which in turn affect the processes in a positive or negative feedback. Land cover change studies occur at all scales from the global, with issues such as climate change, to the local with issues such of biodiversity loss (Lambin *et al.* 2003). While a global focus highlights large scale processes and patterns, it is important also to look at the local scale as a "systematic analysis of local scale land-use change studies, conducted over a range of time-scales, helps to uncover general principles to provide an explanation and prediction of new land-use changes" (Lambin *et al.* 2003, p.231). The potential explanatory and predictive power of land cover studies makes them extremely desirable in a context of resource scarcity leading to the need for decision makers, whether these are governments, local communities or individuals, to choose among different land uses, a process that can be often conflictual. However, land cover change studies should be approached as part of an evolving understanding of a place rather than a definitive static snapshot of a moment. Additionally, methodological assumptions and limitations need to be transparent to allow for constructive discussion and re-evaluation.

CHAPTER 3. "WE ARE ALL INTO SHRIMP": LIVELIHOODS IN PUERTO MORAZÁN

3.1 Introduction

The previous chapter shows how shrimp aquaculture has dramatically altered the landscape of the Estero Real, Gulf of Fonseca since the 1980s. Shrimp aquaculture has also radically transformed the socioeconomic structure of the community of Puerto Morazán. While shrimp aquaculture provides sources of employment and investments to one of the poorest regions of Central America (FAO 2006a) , it also generates social and environmental costs to local ecosystems and their inhabitants (Stonich *et al.* 2003; Alduvin 2002; Varela 2000; Stonich *et al.* 1997; Dewalt *et al.* 1996; Stanley 1996; Stonich 1992; Stonich 1991a). Aquaculture is often presented as conflicting with local livelihoods, shadowing however to some extent the active role played by local people in this industry. Indeed, shrimp aquaculture in Nicaragua is comprised of a diversity of actors, ranging from large scale industries to small-scale locally owned cooperatives (Coze Saborío 2006). This chapter aims to unravel the role played by small-scale shrimp aquaculture in local household livelihoods. To do so, local shrimp producing households are compared to non shrimp producing households in terms of the activities they engage in, incomes derived and assets accumulated. Differences among local shrimp farming households are also analyzed to highlight the existing heterogeneity among actors at the community scale. The chapter uses the sustainable livelihoods framework (Ellis 2000; Ellis 1998; Scoones 1998; Reardon *et al.* 1995) to understand how Puerto Morazán make a living and more specifically the role played by shrimp aquaculture in the overall income portfolios of households. Before turning to community level dynamics, the Nicaraguan shrimp aquaculture context is described.

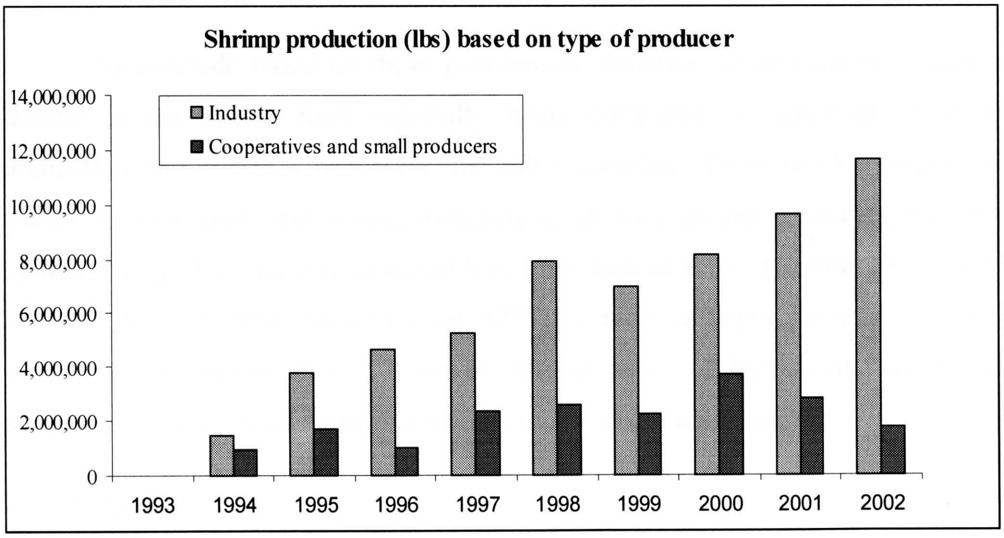
3.2 Shrimp aquaculture in Nicaragua: context

In Nicaragua, fisheries (including aquaculture) constituted 0.27% of the GDP in 1993 expanding to 2.05% in 2004 (Coze Saborío 2006: 19). Most of the shrimp farming development in Nicaragua was initiated in the Estero Real, Gulf of Fonseca and remains greatly concentrated in that geographical zone. Both Nicaragua and El Salvador in the Gulf of Fonseca experienced a later start in aquaculture development compared to Honduras, mainly due to political conflicts during the 1970-1980s. Shrimp aquaculture was initiated by locally-owned shrimp cooperatives (see Chapter One, context section); since the 1990s however their numbers are presently declining (Coze Saborío 2006). A cooperative union organizer indicated that in 1994 there were about 154 cooperatives in Puerto Morazán alone while now the number decreased to 54 cooperatives since from 1998 (#54). He believes that cooperative management issues compounded with hurricane Mitch in 1998 and shrimp diseases in 1999 contributed to that decline; these will be discussed further in this chapter

Some cooperatives still legally in exist but are not operational, either due to pond abandonment or to high level of debt to third parties[29]. These debts often force small-producers to relinquish their concession and pond for a certain amount of time. Many of these transactions are not legally monitored and are not therefore included in national estimates. Despite these caveats, government statistics still provide interesting overall trends for the industry.

Shrimp production by the industrial actors increased almost linearly since 1994 with the exception of 1999 (one year after Hurricane Mitch) while small scale producers present declining shrimp productions from 1994 to 2002 (see Table 12).

Table 12. Shrimp production (lbs) between industry and small-scale producers in the Estero Real, Gulf of Fonseca, Nicaragua

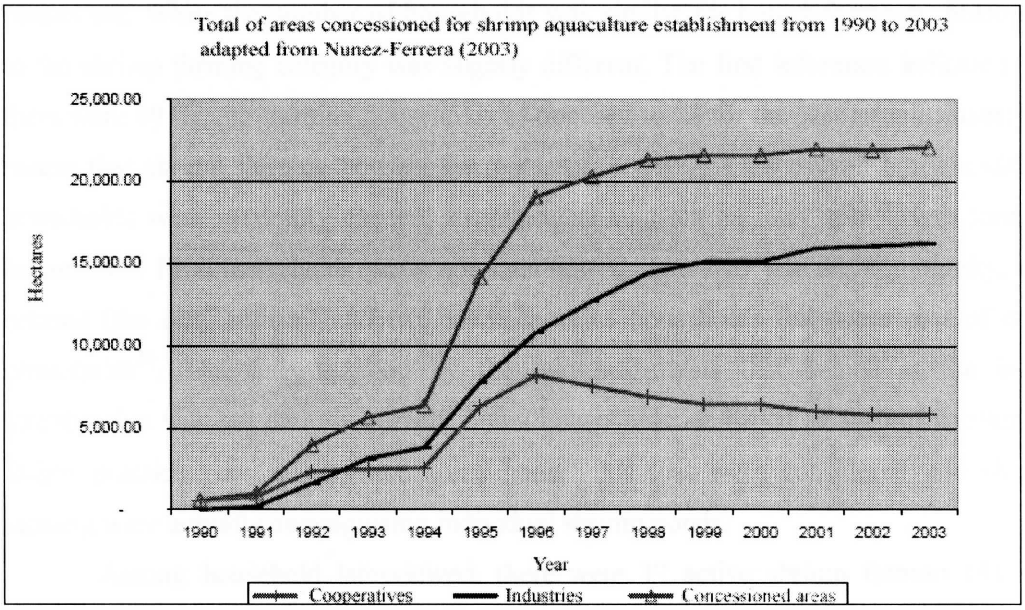


Source: (Adpesca 2005)

[29] including the shrimp industrial sector that finances many smaller scale producers.

Similarly, shrimp concessions are mostly allocated to industrial actors since the mid-1990s and show a declining trend for cooperatives (Table 13). Concessions overall are however reaching a plateau after an exponential increase in the 1990s, which correlates well with remotely-sensed patterns found in Chapter Two.

Table 13. Areas concessioned for shrimp aquaculture, 1990-2003, in the Estero Real, Gulf of Fonseca, Nicaragua.



Source: (Nunez-Ferrera 2003: annex 3-8)

To conclude based on these government statistics, small-scale producers are in decline in the Estero Real especially when compared to industrial actors whose production and concessioned areas are still increasing. These results support at first glance the view that local people, including small-scale shrimp producers, are displaced by forces of globalization represented here by industrial actors (Horton 2007; Stonich *et al.* 2003; Stonich 1998; Stonich *et al.* 1997). A more in depth analysis of small-scale producers' livelihoods shows, however, that in terms of income and assets, shrimp producers are more resilient to change than shown in the above picture.

3.3 Methods

The results are derived from random household surveys done in the community of Puerto Morazán from January to May 2006, stratifying between two groups (shrimp farming and non shrimp farming households). To estimate the sample universe, each household in the community was mapped and two independent informants indicated the main activities performed by each household and whether it was a shrimp farming or non shrimp farming household. 298 housing structures were mapped initially; after consulting with the two informants separately, 267 households were identified. The rest of the housing structures represented fishing processing sites, storage places, shops, empty houses etc. While the number of households was similar for both informants, belonging to the shrimp farming category was slightly different. The first informant indicated that there were 89 shrimp farming households as opposed to 93 for the second informant; this means that shrimp farming households represent 33-35% of the overall households. 80 households were randomly chosen, stratifying among shrimp and non-shrimp farming households. Five households were not interviewed: two had left the community, one refused (the only refusal) and two were cases of households that were part of other households[30]. The categorization by the two informants that helped in the initial stratification was not entirely correct. Some households identified as shrimp farming no longer practiced the activity and some households that were considered non shrimp farming were actually owning/using individual shrimp ponds.

Among household interviewed, there were 37 active shrimp farmers (41 non active ones) and 38 non active shrimp farmers (34 non active ones). Active shrimp farmers refer to households that own or use a shrimp pond (non labor) and had an active pond in 2005. It implies use rather than mere ownership. Statistical analyses mainly include descriptive tables, Student t tests to compare the two groups and linear regression to assess what factors influence income and assets ownership the most. The variables collected include data regarding household demographics (age, education, time of arrival), household activities (type of activities, incomes for each activity and annual calendar), and household assets (equipment, consumer durables, land holdings) for the year 2005. Additionally qualitative information regarding environmental changes, change in livelihood trajectories (through the assessment of a decadal calendar for each

[30] One was the 'bachelor' house of a man that had now lived with his new partner. The other one was a house that looked like a separate structure but was part of a big house.

household) and discussion of shrimp farming development in the community and in the household complement the quantitative findings.

Defining small-scale shrimp farmers is a difficult task due to the different dimensions associated with the term "small-scale". From a land use change perspective small-scale refers to spatial size, from a social sciences viewpoint however it describes the rural inhabitants engaging in the shrimp aquaculture sector. In the Estero Real, rural households have formed cooperatives to share resources (cash, equipment) and labor; especially during the early to mid 1980s due to governmental credit at the time. This implies that rural actors (small scale in the second sense) can own extensive shrimp ponds (medium-large scale based on a spatial definition). These locally based rural actors differ from the industrial shrimp aquaculture sector due to their (more) limited access to the national and international political spheres and markets; which affect their access to formal credit. Additionally these households are hypothesized to possess less technical expertise regarding shrimp aquaculture development, which leads to lower shrimp output (Ramon Bravo, pers.com 2005). Technical support, government subsidies, experience accumulated through time and socioeconomic changes in rural communities[31] (in terms of education for example) has contributed however to a blurring of this divide. Nonetheless differences remain. Industrial pond sizes tend to be smaller, to ensure optimal shrimp management, but occupying large areas overall. Additionally their infrastructure remains significantly more advanced (higher pond walls, ownership of big boats and cars, technical staff, ownership of powerful water pumps), similarly their inputs are higher (feeds, antibiotics). Higher levels of capital and infrastructure development allow the industry to operate some ponds during the dry season as well as the wet season while most 'small-scale' producers cannot.[32]

To conclude, for the purposes of this thesis, small scale shrimp farmers refer to rural-based cooperatives or individual shrimp ponds owned or used (non labor) by a local household in 2005.

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[31] The Sandinista government promoted a very successful alphabetization campaign in rural areas of Nicaragua, raising literacy considerably in a decade.

[32] Some 'artesanal' shrimp ponds can still operate (for very small outputs) during the dry season based on natural water circulation (tides). This necessitates a good pond location.

3.4 Puerto Morazán community profile

"We are all into shrimp" said one informant when asked about people's livelihoods in Puerto Morazán. "There is no other choice" said another, a view held by several households that stressed the vital importance of estuarine resources for the community "we can only live off the estuary, we do not have agricultural lands; our lands are salty". What does it imply however to live off the estuary? Is that entirely the case? Are all activities equally rewarding? Finally what is the role played by shrimp aquaculture in the web of activities that people engage in? This section aims to give a better understanding of how people make a living in Puerto Morazán, comparing those that engage in shrimp aquaculture and those that do not.

3.4.1 Puerto Morazán

Residents of Puerto Morazán mainly rely on the extraction of estuary resources (i.e. shrimp, fish, crustaceans, firewood collection and hunting of iguanas), shrimp aquaculture, as well as services (i.e shops, transport, administrative positions), fisheries trade and to a smaller extent agriculture and cattle ranching on lands from neighbouring communities[33]. The average household contains 5.4 individuals with 2.9 active members (between 15 and 65 years old). The mean number of dependents per household is of 2.5 individuals (<15 and >65 years old). The mean age of household heads is 42 years and the average education for household heads is 4th grade (based on an eleven years school system). Land holdings for agricultural land average at 0.46 hectares per household and concessioned areas for shrimp farming average at 5.47 hectares per household with about 4.28 ha of constructed ponds per household; both are however unequally distributed as will be discussed below. The mean value of total non-land assets is estimated to be 2567 US$ per household and is composed of productive capital (i.e transport, fishing and forest extractive capitals), livestock (mostly small livestock such as chicken, ducks, pigs but also a few larger livestock such as cattle) and non consumer durables (television, sewing machine, video, radio etc). Productive capital averages 1979.4 US$ per household and forms the most important non-land asset followed by consumer durables (mean 473.5 US$) and livestock (mean 113.6 US$).

[33] See Figure 5 for incomes derived from all activities during the dry and wet season and consult appendix 4 for a short description of all activities.

3.4.2 Incomes and assets

Incomes and assets were found to be highly unequally distributed when stratifying among shrimp farming and non shrimp farming households (see Table 14).

Table 14. Mean incomes and assets (community, shrimp and non shrimp producers).

Means	Community	Non Shrimp producers	Shrimp producers	t test	p
Incomes	n=75	n=38	n=37		
Dry income (USD)	1641.01	1211.02	2082.62	-2.8636	0.0055
Wet income (USD)	2377.37	1641.34	3133.29	-4.1582	0.0001
Total income (USD)	4018.38	2852.36	5215.91	-3.7760	0.0003
Non land assets					
Consumer durables (USD)	633.50	414.24	858.68	-2.3025	0.0242
Livestock (USD)	113.65	15.29	214.66	-1.0515	0.2965
Marine transport (USD)	978.31	740.56	1222.50	-1.3506	0.1810
Land transport (USD)	137.02	175.39	97.62	0.7100	0.4800
Fishing assets (USD)	688.04	435.45	947.46	-2.3641	0.0207
Forest extraction assets (USD)	16.04	11.22	20.99	-0.8118	0.4195
Freezer (USD)	160.00	111.46	209.86	-0.9965	0.3223
Non land assets total (USD)	2566.56	1792.15	3361.89	-2.5572	0.0126
Land					
Shrimp concessions (ha)	5.47	0.70	10.38	-9.7849	0.0000
Shrimp ponds (ha)	4.28	0.12	8.55	-9.7104	0.0000
Agricultural land (ha)	0.46	0.08	0.85	-1.4403	0.1541
Labor					
Male active members	1.41	1.24	1.59	-1.6317	0.1071
Female active members	1.53	1.45	1.62	-0.8180	0.4160
Dependents	2.47	2.18	2.76	-1.4883	0.1410
Age household head (years)	42.45	38.42	46.59	-2.7397	0.0077
Education household head (years)	4.11	4.03	4.19	-0.1742	0.8622
Education of the household active members (years)	5.44	4.84	6.02	-1.5593	0.1234
Past aquaculture involvement (yrs)	6.96	1.37	12.70	-9.0164	0.0000
Time arrival (years)	29.07	24.47	33.78	2.4595	0.0163
Food and housing					
Food expenditures dry (USD)	686.91	595.22	781.08	-2.1626	0.0339
Food expenditures wet (USD)	763.91	665.70	864.77	-2.1491	0.0349
Food expenditures all year (USD)	1450.82	1260.92	1645.85	-2.1948	0.0314
Housing structure (1 to 3.5)	2.18	1.77	2.59	-4.5068	0.0000

Note: Where 1 corresponds to a 'rancho' made out of mangrove wood with a thatch roof and 3.5 is a cement house with a zinc roof. Intermediary stages exist where the walls are built with pressed wood or bricks and/or the roof is made out of shingles.[34]

[34] This ranking reflects households' own vision of a high status house rather than intrinsic values of the materials themselves; indeed often times 'ranchos' are more adapted to local microclimatic conditions than higher status houses.

Shrimp producers have significantly higher incomes, with a mean yearly income of 5215.91 USD versus 2852.36 USD for non shrimp producers. Similarly shrimp producers are significantly more endowed in non land assets, with mean non land assets of 3361.89 USD as opposed to 1792.15 USD for non shrimp producers. Land transport (bicycles, motorcycles and cars) is the only non land assets where non shrimp producers are better endowed; the difference is not however significant. Shrimp producers are also significantly better endowed in terms of access to land, both for agricultural and shrimp farming concessions. While this difference is self-evident regarding shrimp aquaculture, the difference in terms of non shrimp land holdings is not necessarily a given and deserves attention. Shrimp producers own a mean of 0.85 hectares per household as opposed to 0.08, a difference of a factor of ten that is, however, not statistically significant.

Shrimp and non-shrimp farming households are not significantly different in terms of labor characteristics (active members, dependents, education of household head and of household active members) except in for age of the household head. Household heads in shrimp farming households are on average 47 years old while non shrimp farming household heads are younger, around 38 years old. This difference in demographics of household heads could explain the differential access to shrimp farming concessions. Indeed, present shrimp farming households' heads were about 25 years old when shrimp farming was initiated in the area, when land was easily available and the population was smaller. On the contrary non shrimp farming households' heads were 25 years old in the 1990s when shrimp farming growth was exponential and land was increasingly harder to obtain. The difference could also reflect differences in households' life cycles. Shrimp farming ownership is often an activity dominated by a *padre de familia* (head of the family network) while other activities such as fishing are often dominated by younger male members of the household (due notably to the hardships associated with that type of activity).

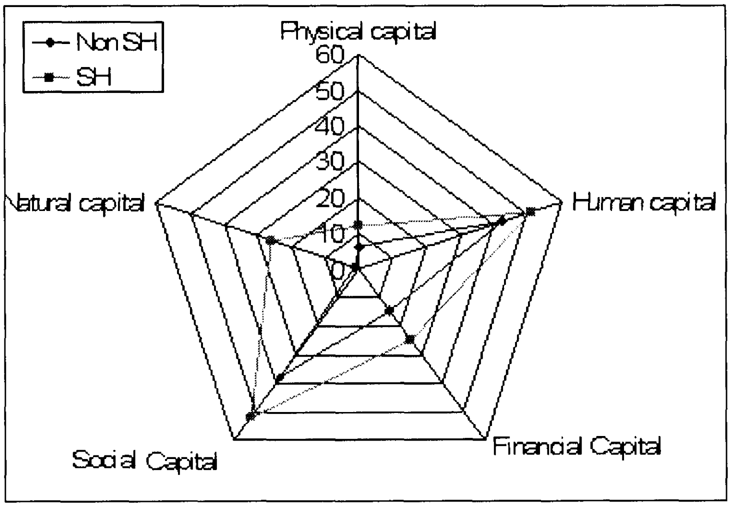
These observations are supported by the significant differences observed in terms time of arrival in the community and past aquaculture involvement between the two strata. Time of arrival of shrimp farming households predates by a decade that of non-shrimp farming households. Additionally, shrimp farming households are involved for an average of thirteen years in shrimp aquaculture while non shrimp farming households were engaged in shrimp aquaculture for an average of a little more than a year. Most shrimp farming households are households that entered in shrimp farming at the very beginning. A minority of non shrimp farming households were past shrimp farmers that abandoned the activity due to repeated losses and/or conflicts within the cooperative structure. A couple of informants indicated that they left the shrimp farming cooperatives after a few years due to internal conflicts over management decisions. One informant mentioned "working in a group is not for me, it is too difficult to make a decision, that why I left" when relating to his past shrimp farming activity.

The wealth divide between shrimp farming and non shrimp farming household is apparent when examining expenditures such as food consumption and housing structures of the two groups. Shrimp producers have significantly higher yearly food expenditures, a difference that is maintained during the dry and wet season. Similarly housing structures for shrimp producers tend to convey high status (i.e. cement walls and zinc roof as opposed to the more 'traditional' *rancho* made of mangrove wood and thatch roof). Most shrimp farming households are spatially located in the center of the community, which is more urban than the periphery. This includes a paved road for some parts, proximity to the church, bar and main plaza. The next section briefly presents graphically the differences between shrimp and non shrimp farming households based on the livelihood asset pentagon.

3.4. 3 Asset pentagon

The livelihood asset pentagon is a powerful visual tool to represent variations in main asset categories (human, physical, financial, natural and social) between different groups (Carney 1999). Human capital broadly defined represents the quantity and quality of household labor (experience, skills, health, labor size etc.); it was estimated in this case based on the number of active male and female household members, education of the household head and the household members as well as age of the household head. Physical capital comprises the basic infrastructure and productive capacity of each household; it is here an aggregate of productive assets (fishing equipment, forest extraction, transport etc.), consumer durables and livestock. Financial capital refers to financial resources available to households; here overall income and food expenditures are used as a proxy. Natural capital represent natural resources stocks that are being used by households to make a living; amount of agricultural lands, shrimp concessions and shrimp ponds as well as access to the lagoons were used as proxies for this type of capital. Lastly, social capital broadly refers to social resources that people rely upon for their livelihoods. It was approximated here by the type of housing, time of arrival and belonging to associations, churches etc. The first three types of capital are relatively easy to measure whereas social and natural capitals are harder to estimate. Natural capital requires measuring use and access to natural resources including public goods whose stocks are hard to quantify. Social capital is a relatively fluid concept that ranges from relationships with neighbors to the ability of a group to organize itself. The asset pentagon presented below is by no means an absolute measurement but serves to compare in relative manner the two groups. Each capital was normalized in terms of percentage of the highest value for each indicator and then represented graphically in Figure 4, which shows different types of capitals for shrimp and non shrimp farming households for the year 2005. Shrimp producers have more assets for all types of assets but particularly in terms of natural and social capital. They are also moderately more endowed in physical and financial capitals. Human capital is relatively similar between the two groups showing that compared to the other asset types, non shrimp producers are (overall) well endowed in human capital.

Figure 4. Asset pentagon comparing shrimp (SH) and non shrimp producers (non SH).



The asset pentagon is particularly useful in providing a snapshot of asset distribution for a given time period, it does not explain well however relationships between asset types or change. Chapter Four discusses the case of the lagoon fisheries and shows how financial capital (obtained mainly through the exploitation of natural capital i.e. shrimp extraction) mediated through the existence of social networks (social capital) determines greatly the accumulation of physical capital (investments in boats and fishing equipment) thus leading to the accumulation of more financial capital and other types of capital in a positive feedback. The next section shows how seasonality plays a key role in local livelihoods and describes determinants of total, dry and wet season incomes.

3.4.5 Determinants of total, dry and wet season incomes

Seasonality plays an important role in the community shaping the nature of livelihood activities available. The wet season is referred to as a time of abundance as opposed to the dry season. This is apparent based on the significant difference in average incomes earned by the community during the dry (~ 1641 USD) and wet season (~ 2377 USD); a difference that holds true when stratifying between shrimp and non shrimp producing households (see Table 14, p.60).

Shrimp, the most valued natural resource, is available mostly during the wet season when seasonal lagoons and shrimp ponds get filled with water. Since the early 2000s of a new commercial dry season shrimp fishery emerged, providing new sources of income (see Chapter One, context section). Indeed, a small shrimp nicknamed '*fievre*'[35] (*Protrachypene precipua*) present in abundant quantities at the mouth of the Gulf of Fonseca became commercially valuable in the post-Mitch era. Other shrimp species, present in lower numbers, are also captured with fievre during the dry season including 'titi' (*Xiphopenaeus riveti)* and el 'rojo' or 'rayado'(*Trachypenaeus birdy)* (Vásquez *et al.* 2005). Despite this economic opportunity, the dry season remains a time of scarcity. Additionally, the year 2005 was reported by most households to be an extremely favorable year for dry season shrimp fishing and a poor year for wet season shrimp

[35] Fever in Spanish

farming and fishing. The difference in earnings between dry and wet season are therefore potentially higher in other years.[36]

Table 15 presents results from regression models of total income for the entire year (2005), as well as for the dry and the wet season based on productive assets (fishing, forest extraction and storing equipment, marine and land transport), shrimp pond size, ownership of agricultural land, number of active male and female household members, time of arrival as well as age and education of the household head.

Table 15. OLS regression models of total, dry and wet season income generation (USD), Puerto Morazan, Estero Real, Nicaragua.

Incomes (USD) 2005	Total income	Dry season income	Wet season income
Productive assets (USD)	0.22 (2.02)**	0.10 (1.88)*	0.12 (1.82)*
Shrimp ponds (ha)	177.06 (3.55)***	65.02 (2.65)**	112.04 (3.73) ***
Agricultural land (ha)	136.48 (1.20)	42.44 (0.76)	94.04 (1.37)
Male active members	976.99 (3.26)**	533.42 (3.61)***	443.56 (2.46) **
Female active members	651.07 (2.14)**	241.71 (1.61)	409.37 (2.23) **
Age household head (years)	-9.41 (-0.42)	0.83 (0.07)	-10.25 (-0.75)
Time of arrival (year of arrival)	-19.82 (-1.14)	-8.07 (-0.94)	-11.75 (-1.12)
Education household head (years)	170.08 (2.59) **	71.16 (2.20) **	98.92 (2.51) ***
Constant	39267.27 (1.13)	15642.04 (0.91)	23625.23 (1.13)
N	75	75	75
F(6, 66)	8.39***	6.83***	7.38***
Adj R-squared	0.4440	0.3865	0.4081

$p<0.1$*, $p<0.05$**, $p<0.001$***

Total income is significantly positively related to shrimp pond size (ha), productive assets (USD) and number of active members (both male and females). This indicates that income is mostly related to (co) ownership of productive shrimp aquaculture land, as well as ownership to means of estuarine extraction (productive capital) and access to household labor. Wet season income follows similar trends to the total income regression model, which is predictable given that most of the yearly income is obtained during the wet season. Dry season income is explained by the same variables as the wet and total income models excepting female active members. During the dry

[36] Informants informally reported that during the following dry season in 2006 dry season fishing was very poor. Many households reported being indebted due to high hopes of similar abundant catches as the year 2005.

season, only access to male labor is significantly related to dry season income. This is explained by the lower availability of employments for women during the dry season. Indeed women informants indicated that the economic life of the community in terms of processing and trade- women's jobs- is mostly active in the wet season whereas the dry season presents very limited options for women livelihoods.

This subsection presented the main determinants of total, dry and wet income for the community as a whole. The next section describes in more detail livelihood activities for the community as a whole as well as between the two strata studied.

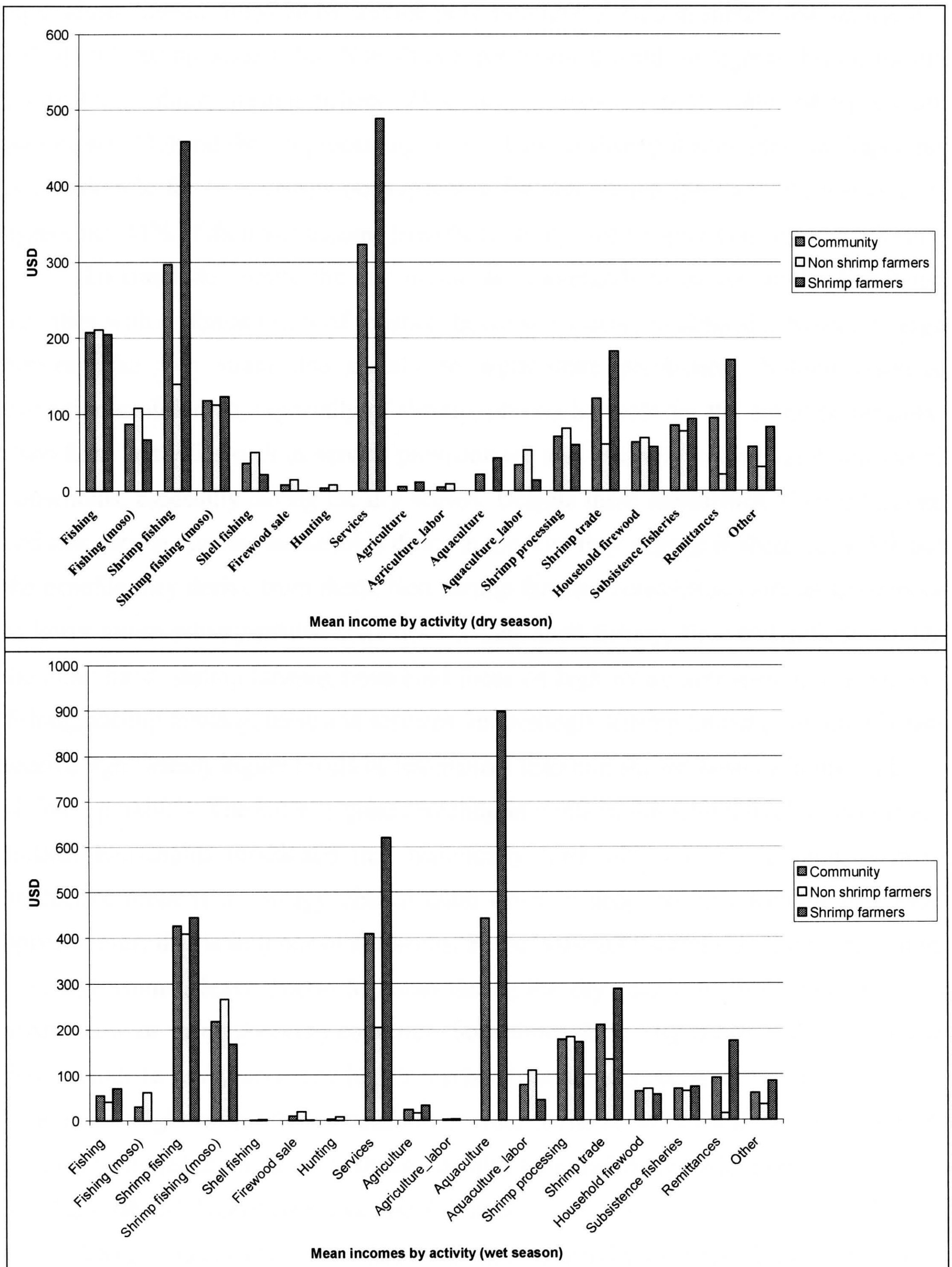
3.4. 6 Livelihood activities

Figure 5 presents the incomes derived for each of the livelihood activities present in the community of Puerto Morazán for the dry and wet season by strata. The grey bars shows results aggregated for the entire community while yellow and pink bars reflect income per activity for non shrimp farming and shrimp farming households. Appendix 4 provides a brief description of each activity.

The community as a whole derives most of its dry season income from services, fishing (shrimp and fish) and shrimp trade. This trend holds when stratifying the sample but the ranking of income reliance varies among both groups. During the dry season, non shrimp farming households derive most of their income from fishing (17% of their total income) first, followed by service provision (13%), shrimp fishing direct access (12%) and as *moso*[37] (9%). Shrimp farming households rely mostly on service provision (23%), shrimp fishing (22%), fishing (10%) and on fourth position shrimp trade (9%). Despite these different rankings, both groups rely principally on similar activities during the dry season. Their reliance differs however in terms of degree. Shrimp producers rely mostly on the two activities, services and shrimp fishing, that provide 45% of their dry season income. On the contrary non-shrimp producers rely on a wider range of activities with fishing, of shrimp and fish, constituting the core of their dry season income (38%).

[37] A *moso* refers to someone that does not have a boat or main fishing equipment and work, in return for a lower share of the catch (1/3), for someone that has productive fishing capital (gets 2/3 of the catch).

Figure 5. Livelihood activities during the dry and wet season (2005), Puerto Morazan.



In the wet season, the community derives most of its (aggregate) income from aquaculture followed by services and shrimp fishing. Shrimp and non shrimp farming households rely on very different set of activities. Shrimp producers focus mostly on aquaculture (29%), followed by service provision (20%), lagoon shrimp fishing lagoons (14%) and shrimp trade (9%). Non shrimp producers depend on lagoon shrimp fishing primarily, as direct shrimp fishers (25%) and as *mosos* (16%), followed by service provision (12%) and shrimp processing (11%). Lagoon shrimp fishing plays an important economic role for both groups but especially for non shrimp farmers, which derive an aggregated 41% of their wet income from that activity (see Chapter Four for more detail).

To conclude, during the dry season all households focus on similar livelihood activities with different levels of reliance. In the wet season, livelihood activities diverge between the two strata due mainly to aquaculture production. Natural resource extraction/exploitation, especially of shrimp, plays a key role for the entire community. 'Non farm' activities such as service provision are also essential to the overall income of households, especially during the dry season. Despite these similarities, shrimp farming and non shrimp farming households differ in the way they engage in these activities and the benefits they derive from them. Non shrimp farming households work as laborers or in lower return estuary-related activities (fishing, shell fishing, firewood collection). On the other hand, shrimp farming household focus on high return activities such as shrimp fishing, shrimp farming, trade and services. Interestingly shrimp farming households also receive significantly higher levels of remittances than non shrimp farming households ($t= -1.7641$, $p=0.08$*). The latter is quite revealing in terms of household livelihood options. Indeed, households mentioned that historically (and still today) migration to more productive areas is a strategy chosen quite often in order to deal with limited local opportunities; that is in times of hardships. Some household members, oftentimes young men and women, leave Puerto Morazán during the dry season to find employment in urban areas or in neighboring countries. Sometimes these migrations extend to longer time periods (a few years). The higher levels of remittances received by shrimp farming households might reflect the existence of a wider social network for these households. It can also be linked to the fact that shrimp farming households are 'older households'.

3.4. 7 Livelihood diversification vs. specialization

The previous section presented all livelihood activities existing in the community based on the type of activity and to some extent household functions within these activities (self employed or share/wage labor). The present section analyses in greater detail livelihood activities based on sectoral organization ('farm' vs 'non farm'), a grouping that allows for a better understanding of patterns of diversification versus specialization of the households examined.

Farm incomes refer here to incomes derived from activities related to the "production or gathering of unprocessed crops or livestock or forest or fish products" (Barrett *et al.* 2000), here it designates incomes derived from fishing (shrimp, fish, shell fish), wood and firewood extraction, hunting, agriculture and aquaculture. Non farm incomes refer to all other sources of incomes. In the specific context this applies to service provision, shrimp processing and trade, remittances and other (pensions, interests etc). Table 4 presents income levels of the community (aggregated means) as well as shrimp and non shrimp farming households based on a sectoral ('farm' and non farm) division of income sources for the dry and wet season. Income shares for each group during the dry and wet season are indicated in parentheses.

Table 16. Income levels and shares by sector (dry/wet season) in Puerto Morazan.

YEAR 2005	DRY			WET		
Mean (USD)	Community	NON SH	SH	Community	NON SH	SH
Farm income	974 (59%)	854 (71%)	1096 (53%)	1428 (60%)	1071 (65%)	1794 (57%)
Off farm income	667 (41%)	357 (23%)	987 (47%)	950 (40%)	570 (35%)	1340 (43%)
total	1641 (100%)	1211 (100%)	2083 (100%)	2377 (100%)	1641 (100%)	3133 (100%)

Note: Income share in parentheses

Both shrimp and non shrimp farming households rely more heavily on farm incomes than non farm incomes. However, this reliance varies by season and across groups. Non shrimp farming households are particularly dependent on farm incomes during the dry season (71% of their total dry season income) whereas shrimp farming households are moderately less dependent with farm incomes constituting 65% of their dry season income. Dependence on farm incomes decreases during the wet season (mostly due to shrimp trade and increased revenues from services) for both groups. Despite lower revenues, non shrimp farming households have an almost equal distribution of income sources between farm and non farm incomes during the wet season whereas shrimp farmers are moderately more reliant on farm income during the wet season (mostly due to aquaculture). To conclude, non farm incomes plays an important role in household's income levels and income shares for both groups. The relatively low income share of non farm incomes during the dry season especially for non shrimp farming households seem to indicate that it does not act as a safety net during the most difficult time of the year. This is mainly due to the fact that non farm incomes are significantly tied to the economic growth of the community. Shops need customers who become scarce in the dry season, similarly shrimp trade is significantly reduced during the dry season and so is shrimp processing. During the wet season however, households in both groups choose to diversify in both farm and non farm income sources thus minimizing risk by increasing the opportunity for a beneficial windfall from one activity. Shrimp farming households specialize in shrimp aquaculture during the wet season.

This differences in livelihood diversification are also illustrated by the normalized Herfindhal-Hirschman index (H*). The Herfindhal-Hirschman index originates from industrial organizational economics to analyze situations of monopoly, it can however be extended to the analysis of specialization/diversification in terms of number of livelihood activities that different groups engage in (Barrett & Reardon 2000). H* was computed for both groups, comparing number of activities for the dry and wet season (see Table 3). The index ranges from 0 (low levels of concentration- that is highly diversified) to 1 (extreme specialization). H*= (H- 1/N)/(1-1/N) where N represents the number of activities counted in the community and H represents the non normalized Herfindhal-Hirschman index. H is defined as the sum of squares of the income shares of each activity. Its formula is represented by equation 1 below where s_i represents the income share of each activity i in the community, and n is the number of activities.

Table 17. Herfindhal- Hirschmann normalized index (H*) assessment of livelihood diversification, Puerto Morazan, Nicaragua.

		NON SH	SH
wet	H*	0.08	0.11
dry	H*	0.04	0.09

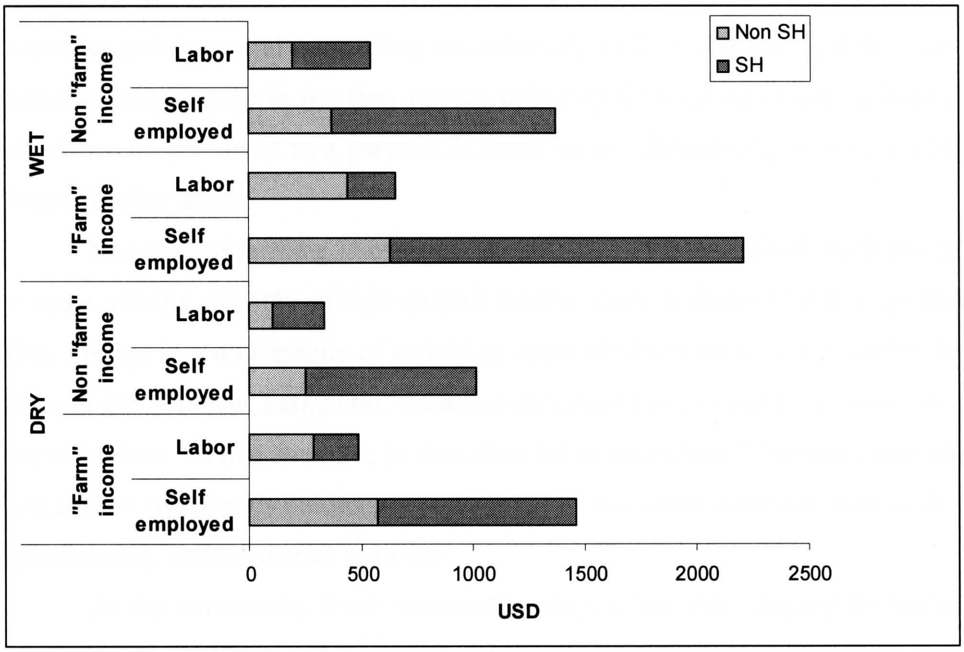
$$H = \sum_{i=1}^{n} s_i^2 \quad (1)$$

Livelihood activities are overall relatively unconcentrated for both groups, which signifies a moderate level of livelihood diversification. During the wet season, however, shrimp farming households are moderately concentrated specializing in shrimp aquaculture, while on the contrary non shrimp farming households are especially diversified during the dry season.

3.4. 8 Self employed vs. share/wage labor

Households differ in terms of their means of access to livelihood opportunities. Figure 6 presents differences between farm and non farm income sources based on shrimp/non shrimp households function (self employed or wage/share laborers) for both dry and wet season.

Figure 6. Farm and non farm income sources by function (self employed or wage) in Puerto Morazan, Nicaragua (2005).



Shrimp farming households tend to obtain their income primarily through self employment while non shrimp farming households are more reliant on wage/share labor income sources. During the dry season, non shrimp farming household obtain about 70% of their income through self employment as opposed to about 80% for shrimp producers. Reliance on labor increases for non shrimp farming households during the wets season where about 40% of their income comes from wages/shares. On the contrary, shrimp farming households obtain most of their income from self-employment. This increased reliance on wage/shares for non shrimp farming households during the wet season reflects the availability of employment in aquaculture, lagoon fishing and shrimp processing activities during the wet season whereas in the dry season only shrimp fishing provides a source of wage employment.

3. 4. 9 Livelihood profile: conclusion

Shrimp farming households are significantly better endowed in terms of asset accumulation for all types of capital but especially natural and social capital. Predictably their incomes are significantly higher all year round. In terms of livelihood activities, shrimp farming households focus on high capital return activities which correspond to all shrimp related activities ranging from fishing shrimp, growing shrimp to shrimp processing and trade. Shrimp producers also dominate 'non farm' income activities, such as service provision and trade. They are relatively well diversified in term of the range of activities they engage in but they remain primarily focused on shrimp related activities; which can be perceived as a paradox in terms of conceptualizing their specialization vs. diversification levels.

Non shrimp farming households are reliant on their relatively high human capital to make a living. 30-40% of their overall income share is derived from wage/share labor. They engage in a multiplicity of activities, most of which are of lower capital return (i.e. fish and shellfish *spp.* extraction, firewood collection etc), to make a living as resumed by one informant "to live, we have to do a little bit of everything". Services also play a vital role in their livelihoods but mainly correspond to low value activities such as food selling (tortillas etc), small fisheries trade etc.

At the community level, seasonality plays a key role shaping resources that are available. The difference between the dry and the wet season is visible even though informants indicated that 2005 was a relatively good dry season and bad wet season. Indeed, the dry season was marked by a spectacularly abundant dry season shrimp fishery and low production levels of shrimp during the wet season due to an early change in temperature and rainfall. Therefore, we can assume that differences in incomes between the two seasons can be further exacerbated in regular years.

This section focused on the community of Puerto Morazán, comparing shrimp/non shrimp farming households. The next section examines intra-sectoral differences among small-scale shrimp producers in Puerto Morazán.

3.5 Heterogeneity of small-scale shrimp farmers

Small scale shrimp farmers are a heterogeneous group, varying in terms of the size and technical level of their shrimp farm as well as the benefits derived from those shrimp ponds. Three main levels of informal institutional organization are present: *cooperativas, collectivos* and *individuales. 'Cooperativas'* or cooperatives refer to shrimp ponds that are owned by ten or more members and that have a specific legal status. *'Collectivos'* are shrimp ponds owned by members of a same family. The distinction is not a legal one and many times, depending on the number of members, they are classified as cooperatives in the official government registrar. Lastly, *'individuales'* refer to privately owned shrimp farms possessing no more than 10 members, usually between 1 and 3. In this paper, we will mainly distinguish between cooperatives and private small-scale shrimp farms, which can be roughly separated based on the number of owners.

The previous section shows how shrimp farming households are better off than non shrimp farming households both in terms of incomes and assets. While this holds true in aggregate, the shrimp farming group presents inter-sectoral variability. In order to highlight this variability, total yearly income for 2005 was stratified by terciles (n=25 for each group) corresponding to low, mid- and top level overall incomes. Shrimp producers were then classified based on those terciles. Most shrimp farming households belong principally to the top level tercile (n=20) with an average shrimp earning of 1055.81 USD, there is however a moderate number of households belonging to the mid-level (n=10) earning an average income of 956.72 USD from shrimp aquaculture and a few low income tercile (n=7) earning about 361.84 USD. Top level shrimp farming households (the majority) relies on shrimp aquaculture, shrimp fishing and services. Mid-level shrimp farming households specialize more on shrimp aquaculture. Their level of shrimp earning is similar to the top level group but they benefit less from complementary sources of income. The most striking difference therefore is between shrimp aquaculture earnings of top and mid-level strata and the low level group. What determines shrimp aquaculture earnings? Why are there differences between small-scale shrimp farmers?

3.5. 1 Determinants of small-scale aquaculture

3.5.1.1 Shrimp aquaculture earnings

The previous section illustrated how small-scale shrimp farmers differ in terms of their income generation capabilities. To better understand the determinants of shrimp aquaculture earnings, a regression model was performed based on household and shrimp farm related information (see Table 18). Results show that shrimp aquaculture earnings are best explained by the size of the shrimp farm area, the time of pond establishment, the shrimp pond technological level and the number of co-owners.

Table 18. OSL regression model of household shrimp aquaculture earnings (2005) in Puerto Morazan, Nicaragua.

Shrimp aquaculture earnings (USD)	Coef. (t)	t	P>t
Pond establishment (years)	37.80	2.26	0.03**
Shrimp pond technology (number of pumps)	335.94	2.88	0.01**
Number of (co) owners	-62.15	-2.21	0.03**
Shrimp farm area (ha)	62.94	3.76	0.00***
Male active members	16.21	0.23	0.82
Female active members	64.14	0.85	0.40
Age household head (years)	-1.44	-0.30	0.77
Education household head (years)	20.01	1.26	0.21
Constant	-70.50	-0.29	0.77
N	75		
F(8, 66)	11.1***		
Adj. R2	0.5222		

Note: p<0.1*, p<0.05**, p<0.001***

The first three independent variables are positively related to shrimp aquaculture earning. Shrimp aquaculture earnings are greater for larger, long established, technologically-advanced shrimp farms. This description seems to refer to shrimp cooperatives. Indeed, cooperatives are to some extent described as possessing a significant past history, occupying relatively large areas and with some levels of technological advancements. The model finds however that an increasing number of co-owners relates to lower shrimp farming incomes. Cooperatives and collectivos have an important number of owners usually more than ten in order to qualify for legal status as a cooperative. A status that is beneficial in terms of taxes and subsidies according to informants. Often, however, members of cooperative appoint fictional co-members such as spouses and daughters to attain the required number. There seems therefore to be a tradeoff in shrimp farming between the number of co-owners and shrimp farm size, technological level and experience (pond establishment).

3.5.1.2 Size of shrimp ponds and concessions

Shrimp area size (in hectares) was identified to be significant for shrimp aquaculture earnings. What determines however the size of the active and concessioned shrimp area? Table 19 below present regression models explaining active shrimp area and shrimp concession size.

Table 19. Linear regression models of shrimp concession and active shrimp area in Puerto Morazan, Nicaragua (2005).

Year 2005	Shrimp concession (ha)	Active shrimp area (ha)
Agricultural land (ha)	0.23 (0.89)	0.28 (1.2)
Age household head (years)	0.06 (1.14)	-0.002 (-0.05)
Time arrival (years)	-0.0002 (-0.01)	-0.003 (-0.07)
Education household head (years)	-0.02 (-0.14)	-0.03 (-0.25)
Male active members (number of)	1.13 (1.68)	0.81 (1.33)
Female active members (number of)	-0.12 (-0.17)	-0.64 (-1.02)
Being part of a cooperative (dummy)	6.32 (3.94)***	3.24 (2.24)**
Experience in shrimp farming (years)	0.12 (1.07)	0.28 (2.88)***
Constant	-1.39 (-0.02)	6.18 (0.08)
N	75	75
F(8, 68)	7.46***	6.53***
Adj R-squared	0.4112	0.3740

Note: p<0.1*, p<0.05**, p<0.001***

Shrimp concession size is determined significantly only by the independent dummy variable 'being part of a cooperative' where 0 refers to non shrimp farms and individually owned ones and 1 refers to shrimp cooperatives. Similarly active shrimp farm size is significantly explained by cooperative belonging and household's experience in shrimp farming (number of years in the activity). An early entry in shrimp farming determines significantly present active shrimp farming area. Indeed, in the 1980s access to land was relatively easy according to household informants and local cooperative formation was supported by left-wing state policies. In the 1990s, a neoliberal government was set in place that facilitated the entry of industrial actors in the estuary, sometimes at the expense of local shrimp producers. These findings relate strongly with the findings of the previous section that showed that shrimp farming earnings were related to large shrimp farm areas, with early pond establishment.

3.5.1.3 Cooperative enrollment

Early pond establishment seems to be greatly related to cooperative enrollement, at least in early years (1980s). A logistic regression model (Table 20) testing shrimp cooperative enrollment was performed in order to better understand what determines entry in cooperatives, a factor that was found to be important in many dimensions of shrimp farming earnings and shrimp farm size.

Table 20. Household level logistic regression model of shrimp cooperative enrollment in Puerto Morazan, Nicaragua (2005).

Shrimp cooperative in 2005	Coef.	z	p
Age household head (years)	-0.01	-0.36	0.718
Time arrival (years)	0.02	0.86	0.391
Education household head (years)	-0.003	-0.03	0.974
Entered aquaculture 1985-1990	1.82	1.66	0.096
Entered aquaculture 1990-1995	3.12	2.68	0.007
Entered aquaculture 1995-1997	-2.61	-0.88	0.378
Entered aquaculture 1997-1998	0.85	0.30	0.765
Entered aquaculture 1999-2001	-2.33	-1.61	0.108
Entered aquaculture 2002-2004	3.15	2.06	0.040
Entered aquaculture 2005 (present)	1.73	1.28	0.200
Constant	-48.72	-0.89	0.371
N	75		
LR chi2(10)	44.64		
Log-likelihood	0.44		

This logistic regression model shows that being part of a cooperative is mostly determined by early time of entry (pre 1995) or during the 2002-2004 time periods. This is explained mostly by shrimp aquaculture production history. Indeed in the pre-1995 time period, the estuary was still dominated by small scale cooperatives and land concessions were easily obtainable. Additionally credit was easier to obtain in the pre-1990s time period. During 1995-1998, the sector is characterized by an important entry of non local actors, namely the industrial shrimp farming industry (Coze Saborío 2006). Additionally in 1998 Hurricane Mitch devastated shrimp aquaculture infrastructure causing many small (and large) scale shrimp producers to abandon the activity. The years 1999-2001 are characterized by abundant shrimp productions for those that remained in the sector. Many households reported very high earnings due combined high productions post-Mitch and high international shrimp prices. Additionally some industrial shrimp producers had abandoned their shrimp ponds post-Mitch, which were later reclaimed by newly formed shrimp cooperatives. Therefore in 2002-2004 there is a wave of entry/re-entry in shrimp cooperatives by many households.

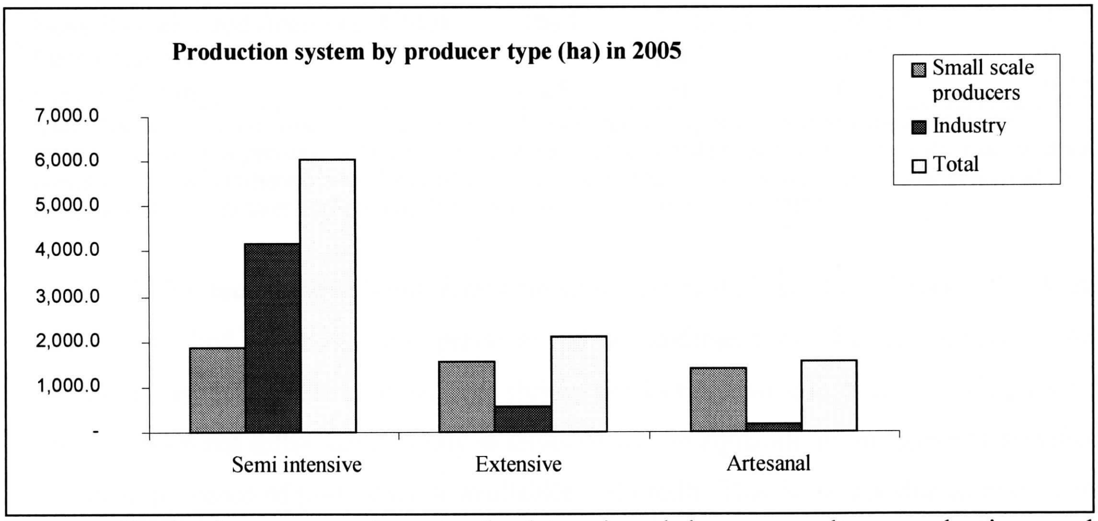
3.5.1.4 Type of production

Aquaculture can be divided in general categories based on the productive system used. The number of categorization varies but forms part of a continuum from extensive aquaculture (entitled 'artesanal' in Nicaragua) to highly intensive systems. The first corresponds to a productive system characterized with no or very low inputs, low stocking densities, low productions and very basic infrastructure with small pond walls, use of natural water bodies, no or very basic water pumping systems. Semi-intensive system usually have a more developed infrastructure with some fertilizer and planned feeding system, more developed water pumps and smaller pond sizes, bigger pond walls. Finally intensive systems have plastic lines or concrete walls, very precise feeding, aeration and fertilizing schedule, shrimp seeds coming from laboratory as opposed to the wild, small pond sizes (FAO 2006a; FAO 2006b).

The majority of productive systems in Latin America correspond to some version of the semi-intensive system (FAO 2006a); it is important however to remember that these classifications are part of a continuum rather than clear-cut categories. Extensive systems utilize mainly natural productivity of the surrounding coastal ecosystem for feed and shrimp larvae, use manual labor for the construction of earthen ponds characterized by low walls and depend on natural water cycles for pond water renewal; overall they have very low inputs in general and usually relatively low outputs. At the other end of the spectrum intensive systems rely on high levels of technology (both infrastructure and knowledge) and necessitate therefore considerable amounts of capital. An intensive system is basically a closed system where feed, fertilizer, shrimp seeds, water cycling are anthropogenically controlled. Semi-intensive systems are located somewhere in the middle of this continuum. Despite an apparent disconnect with the natural ecosystem of more technologically based productive systems, semi-intensive and intensive shrimp aquaculture still depends considerably on the natural ecosystem for its growth. A study in 1994 estimating the ecological footprint of a semi-intensive shrimp farm in Colombia found that it needed a spatial ecosystem support (i.e. coastal area) equal to 35-190 times the surface area of the farm (Larsson *et al.* 1994). Given that there are about 13,000 hectares of shrimp ponds in the Estero Real presently that would imply that about 455,000 hectares of coastal ecosystems need to be functional for the industry to be thriving; more than what physically exists.

To some extent, the production system (extensive, semi-intensive and intensive) acts as a proxy for separating the industry from the small producers (Ramon, pers.com 2006). Indeed, as can be seen in Table 21, the industry is mainly operating under a semi-intensive system. Small scale producers are, however, more heterogeneous and are found in all productive system types. We can consider that extensive and artesanal systems are a proxy for small scale producers but we cannot assume that semi-intensive systems are only restricted to industrial actors.

Table 21. Shrimp aquaculture by production system and producer types, Nicaragua (2005).



Production systems importantly determine shrimp aquaculture production and therefore to some extent benefits (Ochoa Moreno *et al.* 2001), which explains why technological level is a significant factor determining shrimp aquaculture earnings.

Table 22 presents a comparison of "low" and "higher" technology small-scale shrimp farms. It compares two typologies of small-scale shrimp farms based on their technology levels using a Welch's t test (a modified version of student's t test accounting for unequal variances among sampled groups). Ownership of functional pumps is used to separate artisanal (low technology) shrimp ponds from semi-intensive shrimp ponds (higher technology).

Table 22. "Low" and "higher" technology 'small-scale' shrimp production systems in Puerto Morazan, Estero Real, Nicaragua.

Means	All (n=25)	Low tech (n=18)	Higher tech (n=7)	Welch's t test
Pump owned value	4500	500	14785.71	-6.52***
Number of functional pumps	0.48	0	1.71	-6.00**
Larvae purchase (dummy)	0.52	0.33	1	-5.83***
Number of (co) owners	7.16	6.33	9.28	-1.81*
Family labor	6.66	5.58	9.43	-2.65**
Wage labor	1.8	1.11	3.57	-2.47**
Shrimp farm establishment (year)	1995-1996	1997-1998	1990-1991	3.36**
Active shrimp farm size (ha)	44.68	35.97	67.07	-2.20*
Shrimp production (lb/year)	12,641	2,864	34,986	-2.96**
Investment (USD/year)	9618.77	7182.95	15708.33	-1.58
Price obtained for shrimp (USD per lb)	0.85	0.612	1.4	-3.33**
Benefits declared /member (USD)	719.34	653.02	889.86	-0.59
Benefits estimated /member (USD)	1094	343.24	3024.54	-1.73
Debt (dummy)	0.56	0.56	0.57	-0.07
Credit (dummy)	0.68	0.67	0.71	-0.22

Note: Larvae purchase (where 0 is no purchase of larvae but fishing or reliance on natural estuarine productivity and 1 is purchase of larvae of wild origin to specialized larvae extractors (usually from another community)). Debt (where 0 is no debt and 1 is debt to someone). Credit (where 0 is no credit received for that year and 1 refers to credit received that year). p<0.1*, p<0.05**, p<0.001***.

Higher technology shrimp farms are significantly different from lower technology ones in terms of larvae purchase practices, labor available, time of establishment of the shrimp farms, active shrimp farm size, shrimp production and sale price of shrimp. Both farm types do not differ significantly in terms of shrimp aquaculture investments, benefits obtained, presence of past debts or availability of credit. This is mostly due to important variability in the dataset related to benefits and investments. In terms of productive capacity, higher technology shrimp farms occupy bigger shrimp farms- average shrimp farms of 67 hectares- as opposed to 36 hectares for lower technology shrimp farms. They also have greater numbers of co-owners (~9 co-owners per farm versus 6 for lower technology shrimp ponds). Their labor pools are also bigger with an average of 9 family members and 4 wage laborers being employed throughout the year. Lower technology shrimp farms mainly depend on family labor with about 6 people being employed throughout the year and only 1 external wage laborer.

Yearly investments are lower for low technology shrimp farms (~ 7183 USD vs. 15,708 USD) but this difference is not statistically significant due to a high variability across the sample. Similarly larvae purchase[38] is lower for low technology shrimp ponds with only 33% of the sample purchasing wild shrimp seeds and the rest relying on estuary natural productivity. On the other hand, higher technology shrimp producers all purchase wild shrimp seeds; most of them however prefer to buy wild shrimp larvae collected in the area of Pedro Ramos[39] than those offered by shrimp hatcheries. This preference has a monetary reason (the price of wild shrimp seed is lower than that of laboratory shrimp seed) but is also rooted in a belief, partly supported by experience, that laboratory larvae have lower survival rates and are more prone to contract diseases. Lastly, debt owing and credit is similar for the two groups. However these categorical factors do not indicate differences in debt and credit levels. Credit levels are represented partly by the amount invested (USD/year) for shrimp production. Indeed, most of the time, especially if the shrimp farm has a past debt, investment funds are obtained by credit from intermediaries. Higher technology shrimp farms require more credit but are also better connected to those same creditors that rely on the promises of technology (pumps are often used as collateral) for good investments' returns.

These differences in technological levels affect yields and product prices. Higher technology shrimp farms obtain greater yields with about 34,986 pounds per year whereas lower technology shrimp ponds obtain about 2,864 pounds per year; a statistically significant difference. When adjusting for farm area, we see that higher technology shrimp ponds obtain an average 522.19 lb/ha/year versus 79.56 lb/ha/year for

[38] Larvae purchase is entirely reliant on wild seeds purchased on shrimp seed fishermen located in communities bordering a different estuary reputed for its good shrimp seed quality. Small-scale shrimp farmers are reluctant to purchase more costly laborary shrimp seeds as they consider them less resistant to diseases.

[39] Another mangrove area in Nicaragua with some shrimp farming and specialized in shrimp larvae collection

lower technology shrimp ponds. Interestingly, the price fetched on average for shrimp produced varies significantly between the two groups with lower technology shrimp producers selling their shrimp at twice a lower price (~ 0.612 USD/lb) than higher technology shrimp producers (~ 1.4 USD/lb). This difference is rooted in differences in shrimp sizes between the two systems. Often, lower technology shrimp farms try to have three harvests a year and leave less time for the shrimp to grow. Also, lower technology shrimp ponds do not add feed to their ponds thereby being limited by natural estuarine productivity. These are offset (theoretically) by the lower levels of investments, economic and labor-wise, required to grow shrimp. Surprisingly, the returns obtained (declared and estimated) are not statistically different between the two groups. Again this is due to the variability across the two groups whereby some failed considerably and others had a good windfall. Benefits for lower technology shrimp ponds average between 343-653 USD per owner. Interestingly the benefits declared are higher than those estimated for that group. This could be due to a discounting of natural productivity investments when detailing the inputs to the shrimp production. On the contrary returns for higher technology shrimp ponds average between 890-3025 USD per owner with returns estimated being importantly higher than those declared. This could be due to many factors including undeclared costs of production, differential earnings between shrimp farm members, reluctance to declare earnings etc…

The lack of apparent difference in returns earned between the two production systems can be related to the fact that the year 2005 was a bad year for shrimp producers. Indeed, the second harvest was cut short for many shrimp farms by an abrupt change of temperature and heavy rainfall (caused by Hurricane Stan) that caused shrimp production to be small[40]. In these circumstances, "higher" technologicy level shrimp ponds can be more vulnerable due to the important investments that they made; whereas lower technology level shrimp ponds have less inputs to account for and therefore less risk (and often times as a trade off less returns). It is also related to the high level of debt associated with the shrimp aquaculture sector. Indeed since Hurricane Mitch, many small-scale shrimp producers reported owing important amounts of money to intermediaries and banks, sometimes for amounts as high as a 100,000 USD with interests accumulating;

[40] Shrimp harvests are very sensitive to climatic changes.

which greatly limits real benefits accumulated. Consequently, many informants mentioned that "now we only work for the debt". Many informants indicated that they did not repay those debts unless they had substantial benefits accumulated. The shrimp farms that managed to reinvest in their infrastructure post-Mitch had such windfalls in the years 1999-2000, repaying most of their debt. Many informants no longer had access to formal credit- due to unpaid debts- and had to rely on intermediaries (*financieros*). Many lost access to their shrimp ponds for a few years after Mitch but investments in physical capital remained. Interestingly, Nunez-Ferrera (2003) mentions that most debt owed to the government is due by industrial actors as opposed to small producers (which are taxed lesser amounts however). The next section presents in more detail the challenge and risks that small shrimp producer's associate with the industry.

3.5.2 Challenges to small scale aquaculture

Shrimp aquaculture challenges are related to biophysical, financial and institutional constraints. Biophysical challenges include too low or high rainfall, extreme weather events, sedimentation, contamination and disease spread. Too little rainfall fails to fill shrimp ponds and thereby requires water pumps to fill the ponds, a luxury not available to artesanal shrimp ponds (households # 46, 71). On the other hand, too much rainfall damages shrimp pond infrastructure especially for shrimp ponds located in certain areas where water flows and/or shrimp ponds with low walls (made using human labor) (households # 183, 153, 91, 85, 46, 294, 104, 191, 245, 192, 71, 54). It also causes damage to the road network, affecting access to markets and thus shrimp trade. Heavy rainfall also brings important levels of sediments from the upper watersheds that carry contaminants from agricultural fields (households # 106, 185). Lastly, heavy rainfall causes changes in estuarine salinity which affects the biological cycle of shrimp larvae. This can cause increased likelihood of shrimp diseases and reduced rates of survival for shrimp seeds (households # 188, 275, 245, 170, 57). Extreme events such as hurricanes and floods were also listed as an important concern (households # 262, 294, 77, 85, 104b).

Shrimp diseases were related to declining water quality in the estuary (households # 275, 54, 38, 170, 248, 262, 294, 71, 85, 87, 91) and were an important source of concern. Shrimp producers mentioned the Taura and White spot disease events that occurred in the mid to late 1990s devastating considerably shrimp aquaculture sector. Many households blamed the shrimp aquaculture industry for this decline in water quality (due to excessive inputs in the form of feeds and antibiotics) and therefore for the shrimp diseases (households # 188, 104b, 69, 191, 218, 49, 52, 169, 275, 54, 19). One informant stated "the industry plants [shrimp seeds] excessively and since shrimp cooperatives are stuck close-by, we are taking their grey water", the same informant also amended his statement by declaring however that "they [the industry] are reducing their intensity of shrimp seeding, contamination is reduced now".

Lack of financial resources was cited as a major reason for small-scale shrimp farming vulnerability (households #99, 49, 192, 262, 218, 223, 275, 48, 63). Indeed, many challenges mentioned previously such as damage to shrimp infrastructure with heavy rainfall, lack of water during low rainfall, diseases can be greatly mitigated with increased inputs and adequate technological levels. One informant indicated that "without money, one cannot work especially due to shrimp diseases", another said "money can kill [shrimp] diseases with drugs and a good water pump [to recycle the water]. In the past, there was more natural wealth; shrimp seeds, feeds, drugs and lime were not needed [in the shrimp pond]. In the mid-1990s inputs increased, costs increased and shrimp prices as well as shrimp quality decreased". Many informants cited high costs of maintenance (households #104, 153, 185, 46), especially in light of recurring extreme weather-related events that destroy part of the shrimp infrastructure. Inputs (feeds, shrimp seeds, drugs, diesel, lime) also increased importantly while shrimp prices decreased (households #104b, 185, 245, 255, 71, 99 and Table 11 for international shrimp prices).

Credit is mainly available through informal channels of intermediaries often times themselves operating in highly risky environments. Many times, shrimp traders lend the money at the beginning of the season in exchange for fidelity and slightly better prices at the time of the harvest. Interests rates are as high as 10% per month or 40% at the end of the harvest season. This lack of formal credit restricts entry of small-scale newcomers in the industry as summarized by one informant "It is difficult getting financing from traders, they only lend when someone already has an operational shrimp pond". It also creates an important source of resentment by local shrimp producers that feel that they are unable to control market prices due to the important number of intermediaries (households #104b, 116, 77, 99) as shown by the following quote "a key issue is the difficulty to organize ourselves, to control global production". Lastly, many households mentioned that they were unable to leave shrimp aquaculture despite a desire to do so due to the high levels of risk associated with the activity. Past debts, incurred especially since Hurricane Mitch but also due to bad organization or smaller weather events, prevents them to leave (households # 152, 169, 104b, 177, 185, 71, 116, 77). Indeed, shrimp aquaculture represents the fastest and more successful capital earning activity in the community. Faced with high levels of debt many households have no choice, if they ever dream of repaying their debts, to continue working in shrimp aquaculture. One informant simply said "we have no choice but continue". Some households have already lost their shrimp ponds to investors, a reality that is not indicated in official records.[41] Some plan to return to low technology (artesanal) shrimp production systems after the debt is repaid "my plan is to pay the debt and then operate under an artesanal system. Not everyone will be able to do so, it really depends on the quality of your pond". Others opt for further investments in technology, considering that the artesanal system is too weak, with the hopes that a good year will come "the only way to continue [shrimp aquaculture production] is to enter in debt and have good calculations" or "if you want to stay [in shrimp farming] you have to be in debt". One informant ironically concluded "now we only work for the debt, input costs have risen and prices are lower, we need to harvest more to collect less, we stay mainly in hopes to collect more one day, like a lottery".

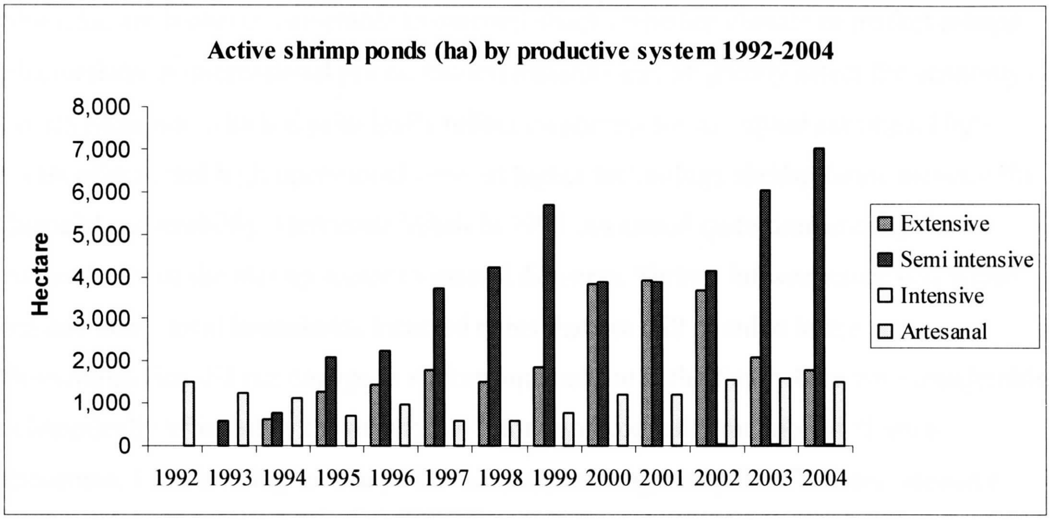
Lastly, lack of internal cohesiveness and administrative issues were cited as a constraint (households #104b, 177, 218, 37, 294, 258). This was especially the case for shrimp farming cooperatives (households # 102, 157, 277, 99) that were regarded as highly disorganized and unable to effectively manage their shrimp farm. One informant explained that "in the past people did not have a culture of money management, instead of (re)investing in their pond, they build their cement houses during the shrimp fever [in the 1990s]". A perceived lack of managerial skills created a bad image for local shrimp cooperatives, which partly explains the reluctance of formal institutions to provide formal credit. While from a management stand point, this tendency to spend money may seem to

[41] They were not classified as active shrimp pond owners for 2005.

be "bad business", from a household perspective, it fundamentally redistributes risk by investing in social networks (alcohol, status housing) and productive capital (boats, fishing nets etc.). Chapter Three shows how shrimp farming households in the 1990s basically invested in productive assets which allows then in the present to dominate all high return activities as opposed to mainly specializing in shrimp aquaculture. Natural disasters in the form of floods, hurricanes, droughts etc, are predicted to intensify in the future (IPCC 2007). In this context, households' strategies to diversify their asset base seem like a sound investment even if from a single activity stand point it forms bad business. However it also creates conflict and discontent for segments of the community who do not benefit from this highly 'informal' redistribution of funds. Cooperatives created winners and losers between those that were able to capitalize on the cooperative system and those that were exploited within that same system. Often old patterns of local social differences were replicated within these cooperatives with the local elite controlling the means of production. Many shrimp producing households now operate within their own family networks, relying to some extent on family social bonding to prevent and control collective work. Others still rely on the original cooperative system, hoping however that they learned from the past. The difficulty involved with a collective management system but also the potential benefits in terms of resources and labor accumulated explain the trade-off that was found in the regression model accounting for shrimp aquaculture earning (see Table 18).

Table 23 illustrates the evolution of different productive systems in Nicaragua from 1992 to 2004. Areas under extensive productive systems (mostly cooperatives) are in decline, which supports findings from Chapter Two and this chapter. Interestingly, areas under artesanal production are slightly increasing while areas under semi-intensive production are considerably augmenting, exceeding pre-Mitch productions. This supports the findings that households are either investing in further technology or regressing to former productive systems while the cooperative system is stagnating.

Table 23 Evolution of productive systems in Nicaragua from 1992 to 2004



Source: Adpesca database (2005).

3.6 Discussion: what future for small-scale shrimp farmers?

Shrimp farming households indicated that they had entered the activity in hopes of a better life. Many wanted to be less reliant on estuary extraction "we thought shrimp farming was a better trade, a bigger one, I was among the first. We did not want [in the 1980s] to be so heavily dependent on fishing and mangrove extraction. We thought we could better our lives, we had to fight. Now there are no results".

Shrimp aquaculture did bring results however. First, remaining shrimp farming households are considerably better off than non shrimp farming households. Most shrimp farming households are part of the community for a long time period and were involved in initial efforts to start shrimp aquaculture in the area. While aquaculture brings important revenues to these households, other high return activities such as services, shrimp fishing and shrimp trade also contribute importantly to their income portfolios. Shrimp farming households are not solely richer because they control aquaculture; they are better off because they control all high return means of production. The next chapter shows how this control is mediated through the acquisition, mainly due to shrimp aquaculture earnings, of productive capital.

Shrimp farming households, and to some extent the entire community of Puerto Morazán, are however vulnerable to external shocks whether climate or market related. Fluctuations in international prices, natural disasters etc. all greatly affect the economy of Puerto Morazán, which is principally reliant on shrimp for its capital earnings. High levels of debt and high operational costs of higher technology shrimp farms increase this financial vulnerability. Hurricane Mitch in 1998 illustrated quite dramatically the vulnerability of the shrimp sector to natural disasters. Shrimp infrastructure was wiped out and many local households incurred debts that are still overdue in the present. Households that did not engage in shrimp aquaculture at the time where not considerably economically affected by the event; one informant ironically mentioned "I am a fisherman, I had nothing to lose [with hurricane Mitch], boats float". Semi-intensive shrimp farms, a model favoured by the government due to its adherence to an ideal of technical progress and high levels of production, require high levels of investments, between 10-15,000$ per harvest twice a year; which create a high risk in case of production failure due to a multiplicity of factors including climate-related hazards, diseases, low prices and high costs of inputs as well as an increased debt in the sector. A risk that small-scale shrimp farmers are not very well equipped to address due to a very narrow margin of financial capabilities and market links. This explains partly the regional decline of shrimp cooperatives (and to some extent small-scale shrimp farms) whereby "cooperatives initiated the [shrimp aquaculture] activity, representing 100% of the production in the late 1980s, 33% in 1995 and only 5% in 2004" (Saborio Coze, 2006:5).

To conclude, at the local level, households that engaged in shrimp farming were able to accumulate wealth and control/restrict access to key livelihood activities. At the regional level however, local shrimp farmers are increasingly marginalized due to changes in available credit, important risks inherent to shrimp aquaculture and increased environmental and market demands of the industry. This emphasizes the key role played by scale in assessing the role played by local shrimp farmers as agents of change. It greatly changes the way we conceptualize losers and winners. Poverty alleviation and integrated coastal management policies in Nicaragua are devised based on the government data which identifies local shrimp farmers as being increasingly marginalized. While this presents part of the overall picture, it does not present the entire situation. Other segments of the community are more vulnerable, in terms of income and asset distribution, to changes in local livelihoods. Conversely shrimp producers are not sustainable on the long run, which makes them considerably vulnerable to climate and market based shocks. They are however better endowed in terms of incomes and assets, including social capital, which can help them to mitigate these shocks.

The next chapter looks in more detail at the socio-ecological dynamics introduced by shrimp aquaculture in the Estero Real.

CHAPTER 4: SOCIO-ECOLOGICAL CHANGES IN THE LAGOON FISHERIES OF THE ESTERO REAL, GULF OF FONSECA

"Spatial arrangements matter a great deal in human history. They reveal the social arrangements that helped produce them" (White 1995: 15)

The Estero Real, Gulf of Fonseca, Nicaragua is an ideal case study for analyzing human-environment interactions in the context of rapid change driven by shrimp aquaculture growth since the 1980s. Shrimp aquaculture has directly and indirectly affected other coastal livelihood activities such as firewood collection, fishing and shrimp fishing. The example of lagoon fisheries is used to illustrate how social-ecological systems interact in a dynamic manner in response to changes in the overall coastal system. A mixture of qualitative household interviews concerning environmental changes, past history and livelihood activities, and present livelihood portfolios, combined with quantitative analyses of household incomes and assets were undertaken to understand these local system dynamics. Participatory geographical information system (GIS) techniques were also used to identify key lagoon and fishing areas as well as other landmarks of interest in order to spatially analyze patterns of lagoon change. The results show that shrimp aquaculture has brought about changes in demographic and biophysical pressures, fishing technologies used, and land tenure that affect access and productivity of the lagoons and thus dependent livelihoods. This paper concludes with policy and management suggestions regarding the design of the proposed protected area management plan and potential rural development schemes.

4.1 Shrimp aquaculture vs. mangrove forest debate

Mangroves occupy approximately one quarter of global tropical coastlines (Chhabra *et al.* 2006) and provide a series of ecosystem services, including coastal erosion control, water purification, nurseries for aquatic species, and context-specific socio-cultural services (Moberg *et al.* 2003). Despite their importance for coastal livelihoods, mangrove ecosystems are under threat due to pressures from alternative land uses such as urban development, agriculture and aquaculture (MEA 2005). Because of these pressures, an estimated one third of global mangrove areas have been lost over the past fifty years (Alongi 2002: 341). Pond aquaculture was identified as a main threat to mangrove ecosystem due to pond establishment and changes in hydrology, increased sedimentation, water contamination (Alongi 2002; Paez-Osuna 2001b; Paez-Osuna 2001a).

On the Nicaraguan side of the Gulf of Fonseca, shrimp aquaculture was initiated at the local level with the support of the socialist Sandinista government (Coze Saborío 2006; Saborío Coze 2006). There is a diversity of existing aquaculture activities, ranging from large scale industries to small-scale cooperatives, which influences both local household economics and spatial dynamics (see Chapter Three). It is therefore important to identify the role that shrimp aquaculture has played in local household livelihoods and determine how these households have influenced coastal land uses. Existing 'conflicts' between estuary resources users are more complex and nuanced in the Nicaraguan case than what was portrayed in the Honduran side. The changing socio-ecological dynamics in the lagoon fisheries of the Gulf of Fonseca illustrate well the interdependent biophysical, socioeconomic and political changes in the region, partly driven by shrimp aquaculture development.

4.2 Methods

Triangulation - based on published and unpublished information, semi-structured and informal interviews, participant observation as well as GIS and remote sensing analyses - was performed to obtain a more complete understanding of the dynamics at play (Bernard 2006). Establishing trust between community members and the researcher was essential to allow people to feel comfortable discussing sensitive issues openly and honestly while at the same time interacting with and criticizing the research process, which ensures relevance to the community (Bernard 2006). This was achieved by living in the community from January to May 2006, and again in September of 2006, which provided the opportunity to get closely acquainted with the people of Puerto Morazán during both the dry and wet seasons.

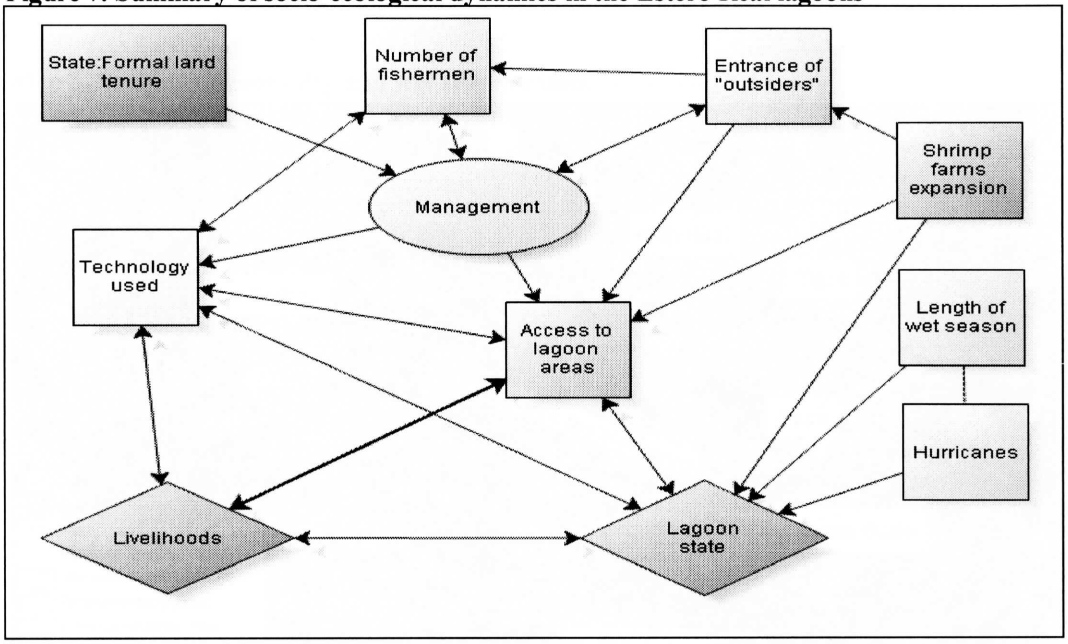
To obtain an estimate of the number of existing households, I mapped the community and conducted seventy five surveys (representing 30% of the entire community) with randomly chosen households, stratified into households that engage in shrimp farming and those that do not. Seven other households were also interviewed based on their knowledge of the social and environmental system. Participant observation and informal interviews provided additional information to the analyses. The sustainable livelihoods framework was used for the household surveys to cover all aspects of coastal livelihoods, including human, physical, natural, social and financial capitals for the year 2005 (Allison *et al.* 2001; Ellis 2000; Ellis 1998; Scoones 1998). Open-ended questions were asked related to environmental changes, past livelihoods and history of the community and of each individual household. Statistical analyses were performed on the quantitative data (n=75) while the qualitative data (n=82) was analyzed after being coded thematically. Households were asked to identify on a map: main fishing areas, lagoon areas (dry and wet season) as well as sites of interest (including villages, fishing camps etc). Given that not all households felt comfortable with maps, areas were also identified directly in the field with the help of local informants during visits to fishing camps, shrimp farms and land cover type surveys. These results were used to estimate dry and wet season extent of main lagoon areas.

4.3 Conceptual framework

The focus on seasonal lagoons was driven by local informants concerns. Indeed when asked about environmental changes for the past 20 years, informants mentioned consistently the observed changes in lagoon fisheries both in terms of reduced access to and a decline of lagoon catches. Lagoons became in a sense a 'microcosmos' of the entire estuary. Issues of changing social, economic, demographic and environment factors observed at the estuary scale were also present in a smaller scale in the lagoons. Figure 7 presents a synthesis of the main drivers of change as identified by local informants and supported by local government, NGO and academic reports.

Each of these drivers is discussed in further detail in the subsequent sections. Section 4.4 synthesizes the situation for lagoon shrimp fisheries in 2005 (biophysical characteristics and socioeconomic importance). Section 4.5 discusses historic changes in land tenure and management (mauve colored box) as driven by changes in demographics (yellow box), technology (salmon colored box), biophysical factors (pale blue box) as well as shrimp farming encroachment (green box).

Figure 7. Summary of socio-ecological dynamics in the Estero Real lagoons

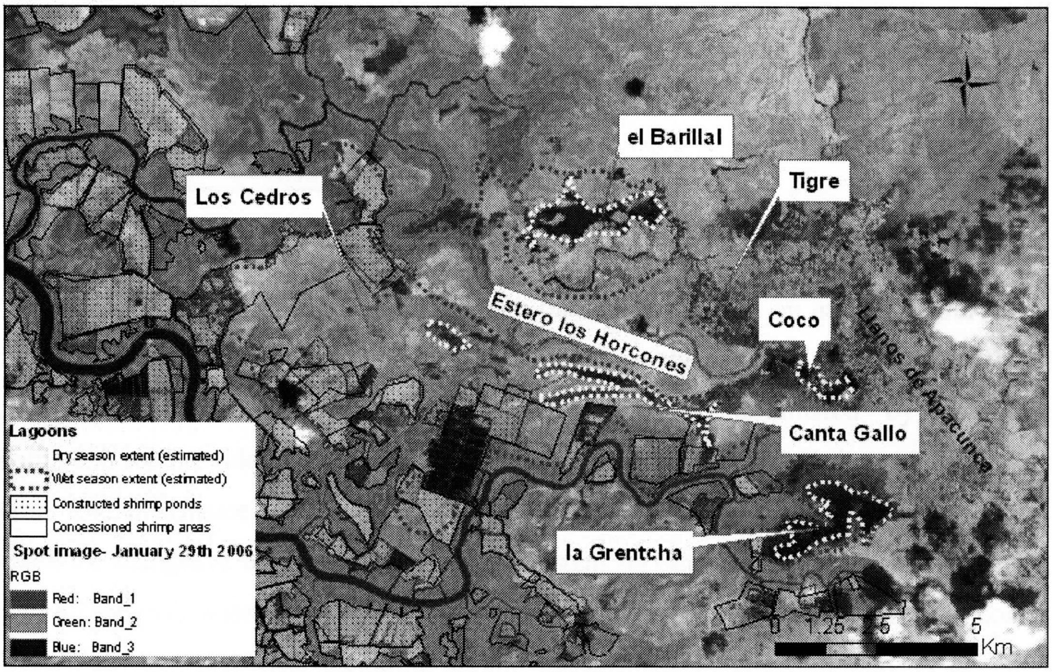


4.4 Lagoon shrimp fisheries in 2005

4.4.1 Biophysical characteristics of the lagoons

The major lagoon complex is formed during the rainy season in the mid-section of the Estero Real (see Map 3). Several communities are found in proximity to these lagoons, including the larger communities of Puerto Morazán and Tonalá in the municipality of Puerto Morazán, and communities from Rancheria in the municipality of Chinandega and Palo Grande in Somotillo (Alcaldía Municipal de Puerto Morazán 2004). The average rainfall in the Estero Real averages 1600 mm per year with about 95% of the rainfall occurring during the wet season, which takes place between May/June and October/November (MARENA-MIFIC-CPC 2006).

Map 3. Seasonal lagoons dry and wet season extent



During the wet season, a lagoon estuarine complex is formed where waters originating from the sea meet with superficial waters flowing down from the upper watershed (Núñez-Ferrera 2003). These lagoons, when not supplied with water during the dry season, become salt/mud flats or marshes depending on water availability; often small water bodies, relics of the greater lagoon complex, remain year round. Lagoons are extremely important for biodiversity, as they host shrimp and fish larvae during part of their reproductive cycle (Vásquez *et al.* 2005; Núñez-Ferrera 2003). The main lagoon areas historically used by the community of Puerto Morazán are presented in Map 3, with both the estimated dry and wet season areas summarized in Table 24.[42]

[42] Currie (1994) reports that Danida-Manglar estimates an area of 3492 hectares of lagoons based on a 1988 arial photograph. No further details are given however whether these refer to the dry/wet extent and to all lagoons.

Table 24 Lagoon extent (in hectares) in the Estero Real, Gulf of Fonseca, Nicaragua.

Lagoon locations	Lagoon extent (ha)	
	Dry	*Wet*
Canta Gallo complex	195	4500
Grentcha	227	501
Playa Catarina	94	627
Barillal	262	1327
Tigre	0	153
Coco	57	198
Total	*835*	*7306*

4.4.2 Socioeconomic importance of the lagoons

The residents of Puerto Morazán are particularly reliant on natural resources for their livelihood, like many rural communities living on the edges of natural areas (World Bank 2008; IDRC 2006). The estuarine ecosystem, dominated by mangrove communities, provides goods such as firewood, timber, fish, and shrimp, that are used both for subsistence and sale (Bilio 1999; Hogarth 1999). Additionally, the coastal estuarine mangrove ecosystem provides ecosystem services such as hurricane buffering, erosion control, water filtering and biological productivity that directly benefits coastal livelihoods and activities, including shrimp farming (MEA 2005; Moberg *et al.* 2003; Lacerda 2002; Hogarth 1999). Direct estuary extraction, including fish, shrimp and shell fisheries, provides 46% of the total yearly income of all households averaged. Seasonality greatly determines livelihood activities and thus household incomes (see Chapter One). Most households stated that the dry season was a season to get by, while the wet season was characterized by affluence as expressed by the abundance of shrimp both in shrimp ponds and the lagoons.

Lagoon fisheries account for 27% of the wet season income and 16% of the mean yearly income for all households averaged. Lagoon shrimp fisheries, aquaculture and service provision provide the main sources of income of the community (see Chapter Three). Fifty two households (out of 75) drew direct income from lagoon fisheries.

Non shrimp farming households are significantly more dependent on lagoon fisheries than shrimp farming households. Resource dependence refers to the contribution of resources to overall household (yearly) income (World Bank 2008). Lagoon fisheries resource dependence for non shrimp farmers (36% of wet season income and 20% of total yearly income) is twice that of shrimp farming households (18% of wet season income and 11% of total yearly income). This difference was found to be significant in a Student's t test comparing lagoon fisheries resource dependence between shrimp farmer's and non shrimp farmers (t=2.2870, p=0.0251). Two reasons account for this difference. First, shrimp farmers have an additional source of income through shrimp aquaculture that contributes importantly to their overall income (see Chapter Three). Additionally, lagoon fisheries coexist temporally with shrimp aquaculture. Indeed shrimp aquaculture at the local scale is practiced mainly during the wet season when lagoons open up. Fundamentally, lagoon fisheries for shrimp farming households act as a complement to shrimp farming and, in times of bad shrimp harvest, as a safety net (household #170). It is an activity usually done by the younger members of the shrimp farming household (household #102). For non shrimp farming households, lagoon fisheries are the only way to directly acquire shrimp for sale (the most valued estuary resource) thus contributing to a greater share of their income portfolios. Despite these differences in resource dependence, there is no significant difference between shrimp farming households and non shrimp farming households that engaged in lagoon fisheries based on a Student's t test analysis (t=-0.5, p=0.6192) and averages at 884.9 USD for non shrimp farming households and 987.0 USD for shrimp farming households. This suggests that some non shrimp farming households probably specialize in lagoon shrimp fishing.

Interestingly, access to the lagoons is different between shrimp farmers and non shrimp farmers. Twenty nine non shrimp farming households used the lagoons as opposed to twenty three shrimp farming households (Figure 8). While this difference is not statistically significant based on a two-sample test of proportion (Z=1.33, p= 0.184), the two groups differ in terms of labor conditions in the lagoon fisheries. Indeed, non shrimp farming households access the lagoons principally as *mosos*; that is labor for households that have the necessary fishing equipment in return for a share of the shrimp catch (usually a third while the owner of the equipment has two thirds of the catch). This difference is supported statistically as the proportion of non shrimp farmers working as labor for lagoon fisheries is greater than that of shrimp farmers working as labor for lagoon fisheries (Z= 2.08, p=0.038). This means that more non shrimp farming households are employed as laborers in the lagoons than shrimp farming households.

Furthermore, lagoon earnings are considerably lower for households accessing the lagoons as *mosos* (n=27) averaging at 604.9 USD while households accessing the lagoons directly (n=25) earn about 1281.2 USD, a statistically significant difference in lagoon incomes (t=3.7613, p= 0.0004).

Figure 8. Access to the lagoon by shrimp farming and non shrimp farming households in Puerto Morazan (2005).

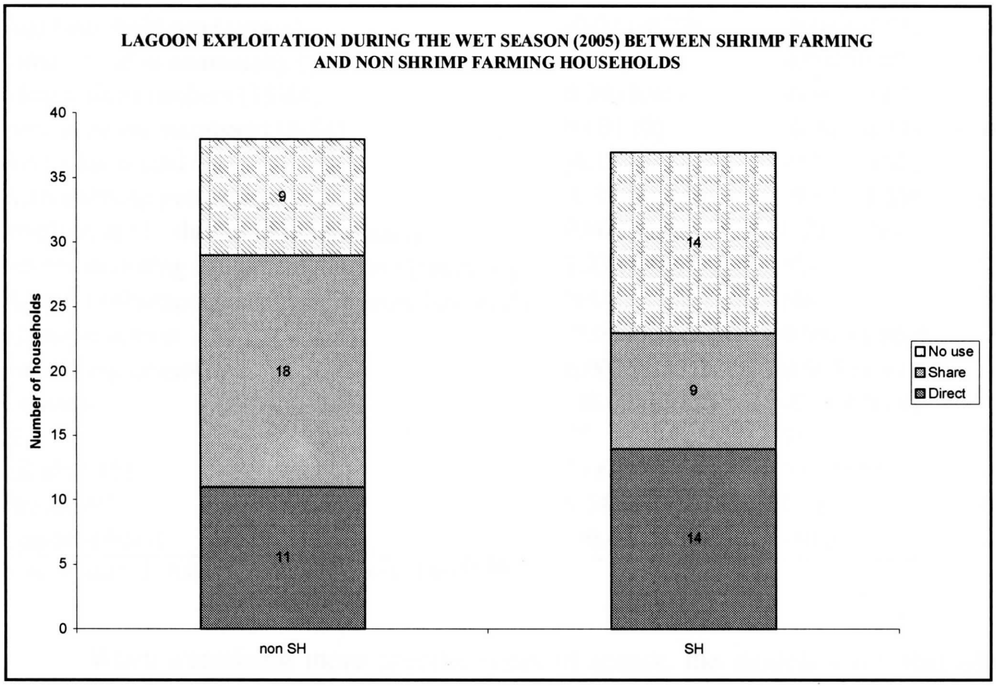


Table 25 below presents logistic regression models testing for the main factors affecting lagoon entry and then lagoon entry based on the type of access (as *moso* or directly).The model shows that the main factor related to lagoon entry is ownership or access to fishing equipment. There is a cyclical relationship potentially at play here however as households possessing equipment will be more likely to engage in lagoon fishing and thus have a higher likelihood of accessing the lagoon commons. This does not undermine the fact that lack of ownership or access of fishing assets through friends, family or cooperative members (extended social network), greatly limits entry to the lagoons for households. This issue of access and fishing assets ownership (technology) will be discussed in greater detail in Section 4.2. Interesting ownership of boats was not found to be significant.

Table 25. Logistic regressions models for lagoon entry and type of entry (2005), Puerto Morazan, Nicaragua.

Categorical dependent variables	Lagoon entry	Type of access[43]	
		Direct	*Moso*
Age household head (years)	-0.02 (-0.73)	-0.04 (-0.53)	-0.01 (-0.42)
Time arrival in community (year)	0.01 (0.63)	0.004 (0.08)	0.02 (0.84)
Male active members (15-64)	0.39 (0.91)	-0.95 (-0.69)	0.57 (1.33)
Female active members (15-64)	0.001 (0)	-0.34 (-0.37)	0.39 (0.88)
Agricultural land (ha)	-0.15 (-0.54)	-0.09 (-0.08)	-0.41 (-0.59)
Active shrimp pond (ha)	-0.11 (-1.25)	-0.57 (-1.8)*	0.12 (1.49)
Involvement in shrimp farming (years)	0.003 (0.04)	0.21 (1.36)	-0.07 (-1.1)
Access to fishing equipment_dummy [social K]	1.23 (1.66)*	NA	2.00 (2.53)**
Parents in shrimp aquaculture_dummy [social K]	NA	NA	-1.78 (-1.92)*
Marine transport	-0.00003 (-1.44)	0.002 (1.86)*	-0.001 (-1.46)
Fishing equipment	0.003 (1.83)*	0.005 (1.99)**	-0.001 (-1.09)
Constant	-28.02 (-0.62)	-9.59 (-0.09)	-42.00 (-0.85)
N	75	75	75
LR chi2(11)	31.62***	74.81***	41.69***
Pseudo-R2	0.3420	0.7835	0.4253
Log-likelihood	-30.42	-10.33	- 28.16

Note: p<0.1*, p<0.05**, p<0.01***, p<0.0001****

When examining more specific types of access, the models show that different factors explain lagoon access for direct and *moso* entries. Direct access is best explained by fishing assets and marine transport ownership and negatively significantly related to active shrimp pond ownership. The latter highlights the fact that lagoon fishing and shrimp aquaculture are temporally co-existing; households have to make a choice between the two activities and often opt for shrimp aquaculture given commitments made in terms of financial, social and labor investments. *Moso* entry is best explained by a household's social capital assets. Households that had access to a boat through friends, family or cooperative members (n=19) were significantly more able to access the lagoons than households that had no equipment and no access through social networks (n=25).

[43] Direct access refers to people that went lagoon fishing with their own equipment (self-emplyed) while *moso* describes share wage laborers that access the lagoons by associating with equipment owners.

Additionally, households that had parents (father or mother) owning a shrimp farm[44] were significantly favored in terms of lagoon access. The latter could be explained by the fact that extended families opt to maximize their returns whereby the father works the shrimp farm and the sons exploit the lagoons.

The reliance on equipment loaned from family members and friends highlights the importance of social network for access to the lagoon fisheries. Households that have high social capital have the opportunity to engage in lagoon fishing thus enabling often poorer households of an extended network to benefit from lagoon earnings. On the contrary, households with less strong social networks have fewer opportunities to benefit from the lagoons.

4.2 Changing socio-ecological dynamics of the lagoon areas

In the 1970-1980s the seasonal lagoons were communally managed by the community of Puerto Morazán. Lagoon fisheries took a significant commercial importance after the decline of Puerto Morazán as a port of national significance and the prohibition of mangrove wood extraction in the late 1970s (see context section, Chapter One for a more detailed account of changing livelihoods from 1930-1980). In the mid 1960-1970s, Salvadorian traders acted promoters of local fisheries, providing credit and equipment in exchange for estuary resources, especially *camaron cocido*[45] that was coming from the winter seasonal lagoons; thus playing a key role in the commercialization of a fishery that was not in demand in Nicaraguan markets.

The reasons for establishing community-based management of the lagoon fisheries were not extensively commented upon by local informants. However, several factors that were discussed with informants can explain why they chose to engage in communal management. First, the fisher population was still low in the 1980s and exclusion was relatively easy to monitor and enforce initially. Second, shrimp was increasingly valuable and controlling the resource made economic sense. Lastly, the political climate during the aftermath of the Sandinista revolution encouraged the formal

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[44] In a cooperative or alone.

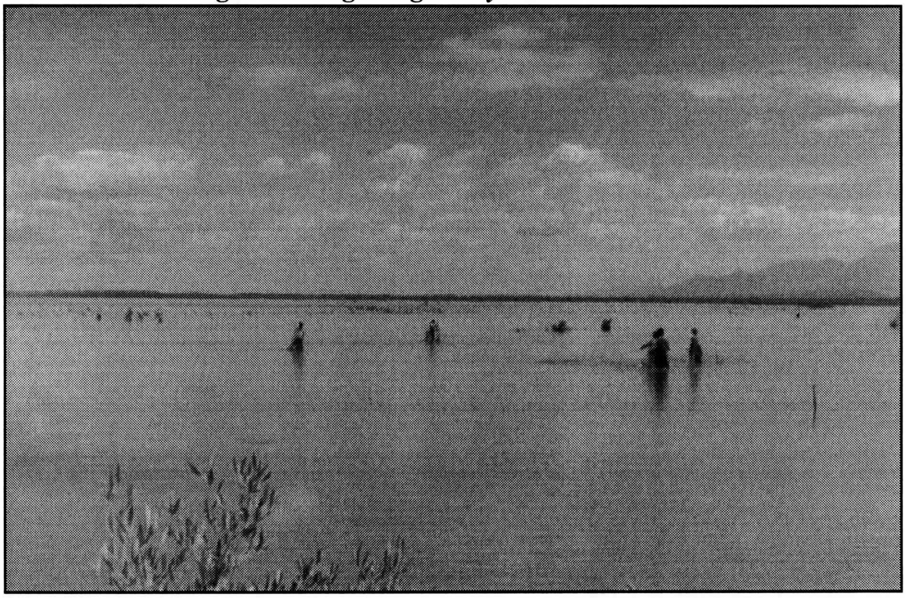
[45] *Camaron cocido* is shrimp cooked at low temperatures with a salt for conservation. It was mainly purchased by Salvadorians.

creation of cooperatives and fishing associations. The following section discusses in more detail the community lagoon management of the 1970-80s and the subsequent change in lagoon management regime.

4.2.1 Community management 1970-1980s

In the 1970-1980s, lagoon fisheries were communally managed by a village committee that appointed 'rotations' for each resource user to a selected lagoon with a given technology. Initially, harvesting technology was restricted to *atarayas*[46] (see Photo 2) but eventually one *bolsa*[47] per fishing team was allowed in the lagoon. Several lagoons were included in the communal system, all part of a wider lagoon complex, including Coco, Grentcha, los Horcones, Barillal, Canta Gallo, Canta Gallito, Tigre, los Cedros (see Map 3).

Photo 2. Winter lagoon fishing using *atarayas* in Honduras



Source: CODDEFAGOLF, 2005

Each appointed fishermen had one day to fish in a selected lagoon with specific equipment, allowing the catches to be partially controlled by the community. There was no community sale of the extracted resources however. Each fisherman made his own

[46] Cast nets
[47] A *bolsa* or bag-net is presently used to catch shrimp both in the mouth of the estuary and in seasonal lagoons.

arrangements, usually selling to local and Salvadorian traders that in turn commercialized the resources in the national and/or regional markets.

The community-pool lagoon resource management collapsed in the 1990s. Several factors explain this collapse and are congruent with situations occurring in other lagoon fisheries in Brazil, India, Mexico where local community management collapsed due to development pressures, demographic and technological changes as well as changes in the resource base itself (Berkes 2006; Kurien 2005; Seixas *et al.* 2003a).

4.2.2 Collapse of lagoon fisheries communal management in the 1990s

Interviewed households mentioned management organizational issues such as increasingly high costs of enforcement (high incidence of free riding), corruption (rent seeking amongst powerful family networks), as well as changes in lagoon areas access, technology, and population demographics as factors that changed the 'rules of the game' and led to a collapse in communal management. Table 26 presents the main factors discussed with interviewed households that explain the collapse of the lagoon fisheries management system.

Table 26. Summary of changes (1980-2005) in lagoon fisheries management system in the community of Puerto Morazan, Nicaragua.

Factors	1980s	2000s
Governance	Fishing rotations (*'turnos'*)	Unorganized
Population	Low	High
Technology	Labor-intensive (*ataraya*)	Capital-intensive (*plastico*)
Environment	Longer lagoon season (June-Dec) Deeper lagoons	Shorter lagoon season (July-Oct/Nov) Shallower lagoons "2-3 m difference between 1976 & 2003" (CIDEA, 2006)
Commons (# of lagoons)	8	2
Shrimp farms	None or few	Pond Encroachment

4.2.2.1 Demographic changes

a) Changes within community population growth

In the community there were about 10 houses in 1946, 28 houses in 1960-70, 160 houses in 1994 and about 267 houses in 2006.[48] Presently there is an average of 5.4 people per household, and, assuming that this rate stayed constant (which is not a given)[49], there would have been 54 people in 1946, 152 in 1960-1970, 864 in 1994 and about 1442 inhabitants in 2006. Informants estimated that there were about 15-20 fishermen in 1960-1970, 60 fishermen in 1990 and more than 400 fishermen presently. CIDEA[50] estimates about 20-30 fishermen in 1950, about 200 in 1960-1970, 250 in 1990 and 440 in 2005 (CIDEA 2006). Currie estimates about 200 lagoon fishers in 1994 (Curie 1994). While these numbers vary, the estimates of rate of population of growth remain about the same. From 1990 to 2006 the number of people in the community (and the number of fishermen) doubled. The exact number of fishermen is unknown as there are no existing reliable statistics of overall fishermen populations (MARENA 2006). The present growth rate is about 3.5% per year with about 80 births per year (CIDEA 2006: 43).

This important population growth in the last decade is partly due to the development of shrimp farming in the region. It attracted many households from Nicaragua and Honduras, which came to work as shrimp pond owners/cooperative members or as wage labourers for shrimp farms (both industrial and cooperatives). Many of these households had some type of previous link with the community in the form of extended family networks. Shrimp farming acted as a pull that reunited household members which had migrated in the past after the decline of Puerto Morazán as a trading port. Population growth is also due to medical advancements and increased health provision in the rural areas, especially since the 1980s. Determining the main driver of population growth (here economic attraction or health amelioration) was not possible given that the two drivers are intrinsically interconnected.

b) Entrance of 'outsiders' and loss of lagoon areas

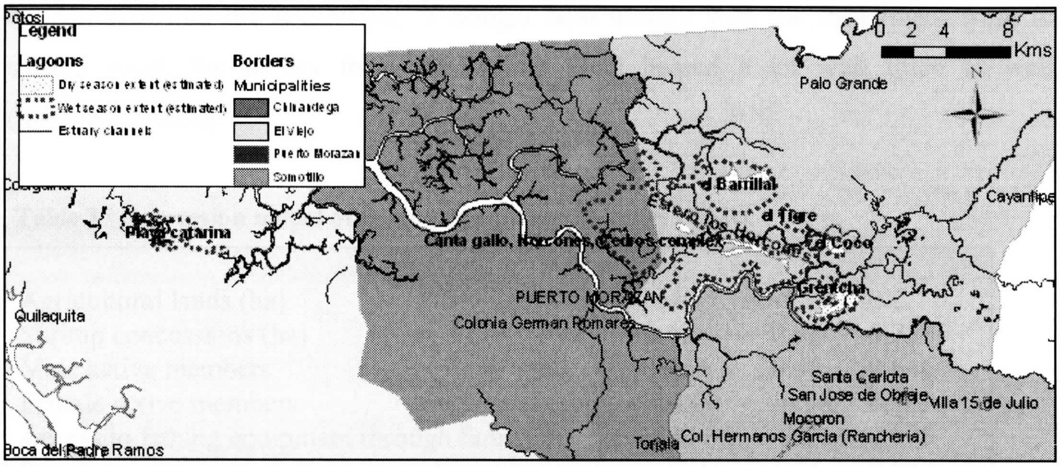
[48] Based on household interviews, my own map for 2005 and a map created by the municipality in 1994.
[49] Birth and infant mortality rates have most probably changed since the 1940s especially given improvements in the health care system introduced in the 1980s with the Sandinistas.
[50] Centro de Investigaciones de Ecosistemas Acuaticos.

The 1990s shrimp boom created an incentive for populations of communities neighbouring the estuary, such as Palo Grande (Somotillo) and Rancheria (Chinandega), to engage in shrimp farming and shrimp fishing in the seasonal lagoons. This created turmoil in the community of Puerto Morazán given that it specialized in shrimp extraction and because no other activities besides trade and natural resource extraction (fishing, shrimp fishing and shrimp aquaculture) were possible on 'salty lands'. Informants stated repeatedly that the lagoons were historically used by people in Puerto Morazán[51] and that these other communities have access to good arable land. The latter point is interesting because informants were not opposed to poor 'outsiders' using the lagoons if driven by need but they saw the involvement of other seemingly richer (due to perceived land availability) communities as unacceptable. It is unclear to what extent other communities shared the lagoons. Currie (1994: 85) mentions that "Puerto Morazán fishermen travel to harvest , amongst others, the seasonal lagoons located at the northeast of lagoon Canta Gallo [while] fishermen other communities such as Tonala and El Viejo also use these [lagoon] resources and have programmed a rotation to coordinate harvests between different communities". This inter-community rotation was not mentioned by people in Puerto Morazán. This could be due to the efforts by people of Puerto Morazán to establish a claim, a created politicized past, and it could be also due to a greater level of socialization with neighbouring communities such as Tonala and el Viejo, that are not targeted by *morazaneños* in the intercommunity dispute, as opposed to ones further away such as Palo Grande and Rancheria (located in different municipalities) (see Map 4).

On the other side, Palo Grande claimed the lagoon of Barillal and Rancheria that of la Grentcha based on the argument of geographical proximity of their communities to these lagoons. Today, this inter-community conflict persists despite inter-municipality negotiations (Municipal council, pers. com. Sept 2006). Puerto Morazán fishermen deplore the loss of access of these two lagoons and claim that physical violence was and will be used by the other communities if Morazaneños[52] enter these waters.

Map 4 Municipalities bordering the Estero Real, Gulf of Fonseca, Nicaragua (2005).

[51] Informants also stated that these lagoons were also shared to a small extent with neighbouring communities of Tonalá and El Viejo.
[52] People of Puerto Morazán



4.2.2.2 Technological and infrastructural change

Shrimp farming reconnected Puerto Morazán with national and international markets. It brought attention to an area considered marginal by the state from the 1960 to the 1980s. Credit for shrimp development was given first by the Sandinista government to cooperatives starting as early as the late 1970s and then by the Chamorro and Aleman governments to mainly industrial shrimp farming initiatives (Coze Saborio 2006). Shrimp farming allowed local fishermen to modernize their equipment switching from paddle to motorized boats. Fishing nets in the lagoons changed from *atarayas* to *bolsas* with *plastico*. This equipment was essential in order to access many shrimp ponds that were on the estuary but also allowed households to increase their fishing range and efficiency. A multiple regression analysis with fishing assets (boat, motor, nets) as the dependent variable and ownership of agricultural lands, shrimp concession size, male and female active members, education of household head, age of household head, access to fishing equipment through social network and past shrimp farming engagement shows that the latter two are significant in the regression (Table 27). This highlights once again the key importance of belonging to a strong social network (social capital). It also indicates that those households that engaged in shrimp farming in the past have more fishing equipment assets than those that did not engage in shrimp farming. While it could be possible that the relationship is in reverse, namely that the wealthier fishermen engaged in shrimp farming, interviews with local households tend to support the first assumption (households # 214, 218, 228). It was stated that boat motors came with shrimp cooperatives and the revolution: "I bought boat motors with the investment from the shrimp pond; the money from the shrimp pond helped a lot with trade as well" (household #228).

Table 27 Regression model of fishing equipment holdings (USD).

	Coef.	T	P>t
Agricultural lands (ha)	-144.35	-1.29	0.2
Shrimp concessions (ha)	16.42	0.32	0.752
Male active members	136.64	0.46	0.646
Female active members	-114.00	-0.38	0.709
Access to fishing equipment through family	-1844.94	-2.91	0.005
Past involvement in shrimp aquaculture (dummy)	1127.15	1.76	0.083
Age household head (years)	-12.00	-0.57	0.569
Education household head (years)	-70.70	-1.06	0.291
Constant	2260.47	2.02	0.048
N	75		
F(8, 66)	2.54		
Prob > F	0.0179		
Adj R-squared	0.1426		

In the mid 1980s[53], INPESCA (ministry at the time dealing with fisheries) brought an expert from Mexico to show the *tapos* technique to a newly created fishermen's association in Puerto Morazán (#46, 294, 170, 138, 223). The technique consisted of enclosing part of the seasonal lagoon with a barrier made of mangrove sticks and nets in order to capture shrimps more easily. An estimated 130 hectares were enclosed (Currie 1994). The first year was a failure due to a ruptured wall but the second year was successful, so much so that many of those that partook in the experiment reported investing in permanent assets such as houses. "With that [money] I bought my house" one informant said (household #170). However, the rest of the community objected to what was perceived as a privatization of the commons. Statements abound that show the strong resistance to the enclosure of the lagoons by a subset of the community. "There

[53] Most local informants mentioned 1982 as the date when the *tapos* experiment was initiated. Another showed me a document dating from 1978 from a local newspapers article from that time that had presented a story on the matter. CIDEA in its publication mentions the project as starting in 1987 (CIDEA 2006). Currie (1994) mentions that there was an initial shrimp farm being promoted from 1981-1983 by INPESCA (the ministry of industry at the time) that was abandoned due to political issues. A later project in 1987 was promoted again by INPESCA inspired by the Mexican tapos. In any case, the *tapos* experiment was started before the 1990s when the industry grew exponentially and the industry joined in.

was a fight to leave the lagoons alone" another informant said (household #223). One of the fishermen that were involved in the *tapos* experiment recalls, "we wanted to continue in 1984 but since it was a natural lagoon, the community arose against it, they told us that we could not continue like that and so we left and we looked for a salt flat [later on] to build a shrimp pond" (household #170).

The *tapos* experiment is quite revealing because it illustrates the different spatial patterns of informal land tenure for the community. Salt and mud flats were considered barren areas of little interest beyond occasional firewood collection and shell fish collection closer to mangrove stands, and therefore there was little resistance to the enclosure of those land cover types. However, lagoons, with their high productivity and livelihood importance for shrimp fishing, were *de facto* common-property of Puerto Morazán. Rules were set that established appropriate behaviour and resistance existed when enclosure efforts arose.

The concept of the *tapos* remained, however, and in the late 1990s a new lagoon fishing technique locally called *plastico*[54] was introduced; it became widely used in the early 2000s (#276). *Plastico* consists of setting a mangrove stick barrier, similarly to the *tapos* technique, but instead of a net durable black plastic is installed (see Photo 3). In the middle of the structure a passage is left where a *bolsa* (bag-net) is set. The mini-dam creates a current that brings shrimp and other aquatic residents into the net, making the process simultaneously more efficient and more wasteful in terms of by-catch. This technology, as it evolved, was incompatible with common-pool resource management as it required an important investment in a permanent structure that could not be rotated and that was not shared amongst users.

Some informants mentioned that it started being used as a reaction to an observed biophysical change in lagoon conditions, namely the loss of water that greatly threatened the lagoon resources (see Section 4.2.2.3). *Plastico* was therefore introduced to retain water. Ironically, on the long term it created a negative feedback whereby sediment was accumulated behind the *plastico* wall instead of returning to the main channel of the estuary (households #116, 152, 170, 57, 91, 294, 18, 213, 223, 258, 49, 92). This

[54] *Plastico* means plastic in Spanish and refers here to the sheets of durable black plastic sheets used to create a fixed gear fishing structure (see photo 2).

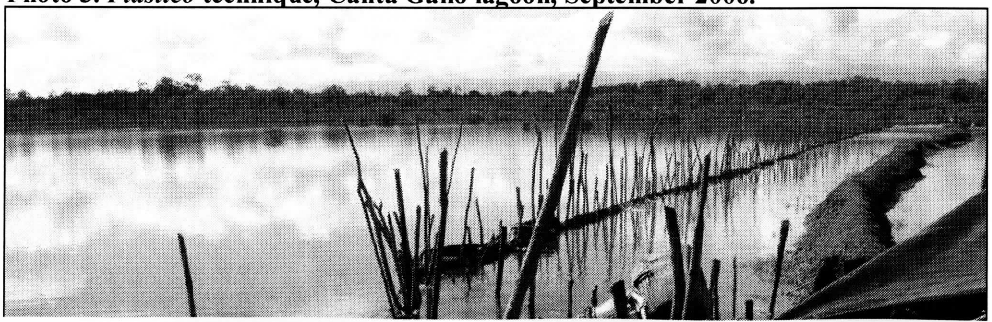
contributed to an overall decrease in lagoon depth which has dramatic implications for lagoon fisheries (see Section 4.2.3.4). Additionally, fishermen stated that in the long run, *plastico* prevented shrimp and other aquatic species larvae from entering or exiting the lagoons, thus lowering the overall productivity and biodiversity of the system (households #19, 223, 129, 294,157, 191, 223, 276, 49, 192). Despite this overwhelming condemnation of *plastico*, fishermen are locked in a prisoner's dilemma whereby one's restraint is effective only if everyone is restrained; in absence of guarantees fishermen feel that they will be losers if they stop using this technique. This is illustrated by the following quotes:

"I am against the use of *plastico* but since the majority does it, I- in order to earn a bit- entered in this as well" (household #99) or "people think: if I do not put *plastico* I am lost" (household #102).

The use of *plastico* created tensions between 'have and have-nots'. Indeed, *plastico* is expensive and needs to be replaced every 1-2 years. It therefore poses an economic barrier to those that do not have the capital to invest in extensive *plastico* infrastructure (households #18, 213, 223, 258, 276, 99, 102, 218, 192). Armando[55] a relatively poor fisherman mentioned that "those that have money have plastic, the others don't catch anything" (household #18). Despite complaints about its negative environmental effects and its contribution to inequality of access, there is an economic incentive for the subgroup that possesses this equipment to extract resources intensively. "Those that have *plastico* do not want to remove it, they take advantage [of the lagoons] more than others," explained a shrimp fisher (household #258).

The barrier to entry to the lagoons is also spatial in the sense that a physical barrier is created in the lagoons whereby the first *plastico* installed is in a better spot than the one behind it and so forth (households #99, 218). Acts of vandalism (plastic shredding and/or stolen plastic, destruction of the mangrove stick structure) were frequently reported thereby increasing the cost of erecting and holding a *plastico* structure and decreasing the levels of trust between fishermen.

Photo 3. *Plastico* technique, Canta Gallo lagoon, September 2006.



Plastico's importance for lagoon earnings is illustrated by the comparison of lagoon earning between those that own *plastico* and those that do not. In a Student's t test comparing lagoon earnings of *plastico* owners (n=17) and non *plastico* owners (n=35), among household that went to the lagoons, lagoon earnings were found to be significantly lower for the latter (t=-3.9181, p=0.0003***). This supports statements made by local household in the surveys.

In order to better understand what most influences lagoon earnings among the entire population, a OLS regression model was tested for lagoon earnings (USD) with demographics (age of household head, time of arrival, gender of household head, dependents), labour assets (active male and female household members), land assets (agricultural lands and shrimp ponds in 2005), years of involvement in shrimp aquaculture, access to fishing equipment through social network (family, cooperative co-members and friends), marine transport (boats and motors) as well as fishing equipment as independent variables. Table 28 presents the results of the model.

Table 28. Linear regression testing for lagoon earnings in 2005 in Puerto Morazan.

Year 2005 *Independent variables*	*Lagoon earnings USD (dependent)*
Age household head (years)	-7.48 (-1.25)
Time arrival in community (years)	-2.53 (-0.53)
Male household members (number of)	131.09 (1.69)*
Agricultural land (hectares)	1.04 (0.03)
Active shrimp ponds (hectares)	12.29 (0.76)
Involvement in shrimp farming (years)	-28.48 (-2.24)**
Access to fishing equipment [social network](dummy)	154.02 (0.88)
Boat (USD)	1.17 (1.66)
Motor (USD)	-0.09 (-0.76)
Transmallo (USD) [fishing equipment]	0.13 (0.79)
Bolsa (USD) [fishing equipment]	-0.39 (-1.47)
Manga (USD) [fishing equipment]	3.69 (3.14)***
Plastico (USD) [lagoon specific fishing equipment]	3.08 (2.52)**
Ataraya (USD) [lagoon specific fishing equipment]	1.73 (1.34)
Constant	5519.90 (0.58)
N	75
F(14, 60)	4.48***
Adjusted R-squared	0.3970

Note: p<0.1*, p<0.05**, p<0.01***

Table 28 shows that ownership of *manga* nets followed by *plastico* best explains lagoon earnings significantly. While the importance of *plastico* in lagoon fisheries is supported by testimonies of local fishermen, the role of *manga* ownership is more puzzling. *Manga* nets were found to be less widely distributed among the population and reflected somewhat more traditional fishing practices. Many experienced fishermen explained that in the past, fishing was done using *mangas* rather than *transmallos, bolsas* and *plastico. Manga* ownership could be therefore a proxy for fisher's experience.

Two other independent variables significantly explain lagoon earnings: number of male active household members and involvement in shrimp farming. The first is easily understood. Fishing is dominated by men and having many active male members in one household ensures that labour is available for lagoon fishing. Involvement in shrimp farming is negatively linked to lagoon earnings, meaning that households that have been engaged in shrimp farming for many years have little lagoon earnings as opposed to households that have been engaged in shrimp farming for a smaller amount of time. This reflects a certain degree of specialization with households that have invested a long time in shrimp farming being less involved in lagoon fishing. Indeed, shrimp farming and lagoon fishing are two activities that are both occurring during the wet season; households must choose how to allocate resources and labour between these two activities.

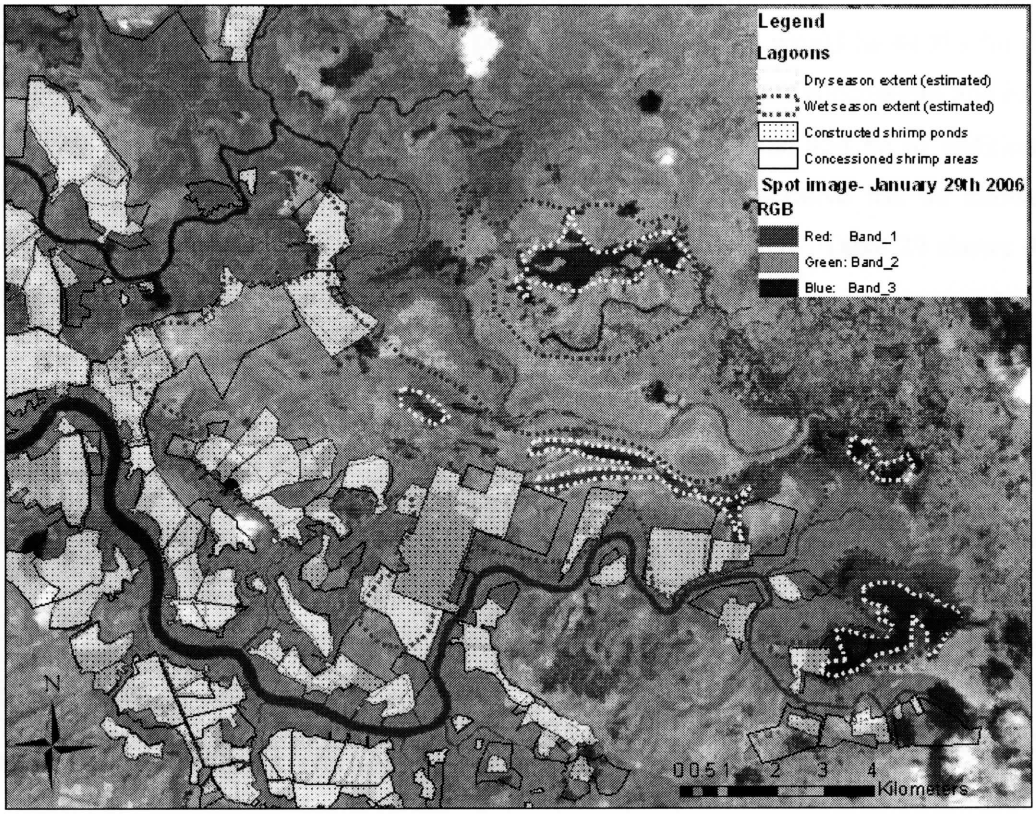
The regression model presented in Table 28 also shows that fishing net ownership, specifically *manga* and *plastico* ownership, most significantly determine lagoon earnings. Past shrimp farming involvement greatly influences fishing equipment ownership. Indeed, shrimp farming indirectly plays an important role in the change of access/differential earnings in lagoon areas. Lagoon fisheries now depend considerably on capital to purchase nets, especially *plastico*. Shrimp farming households possess significantly more fishing nets than non shrimp farming ones when compared in a Student's t test ($t=-2.3641$, $p=0.0207$). Richer households tend to be households that practiced shrimp farming during the 1990s. In the community, shrimp farming households have significantly more income than non shrimp farmers ($t=-3.78$, $p=0.0003$). Consequently fisheries equipment ownership, facilitated through shrimp farming growth, is key to lagoon fisheries present success. This is mitigated by the availability of labour for young households willing to work as *mosos* for a lower percentage of the catch earnings. There is a moderate correlation (0.5) between being a lagoon *moso* and having access to fishing boat/equipment through family or cooperative partners. Indeed, jobs tend to be given to friends or family members. This allows benefits to trickle down to less fortunate households in the family's extended social network and in return it allows (wealthier) households a reliable access to labour. However it also restricts households that are not well connected or newcomers from the benefits of accessing the lagoons, thus highlighting both the positive and negative aspects of social capital (Turner 2007).

4.2.2.3. 1990s Shrimp farming encroachment and its consequences

a) Direct effects

Direct conversion from lagoon land cover to shrimp pond reduces the amount of area available to fish (#7, 196). As discussed previously, there was a strong resistance in the early 1980s to conversion of lagoon areas to *tapos*, even if these were temporary land conversions. Most shrimp aquaculture cooperatives are located near the major lagoon area used by the community of Puerto Morazán, categorized as the Canta Gallo complex based on the name of one of the major and most anthropogenically affected lagoons (see Maps 3 and 5).

Map 5. Shrimp development and lagoon areas close to Puerto Morazán



La Grentcha was encroachedby only one shrimp farming cooperative, about 8% of land conversion, owned by a family in Tonalá, the municipal capital. In contrast, 21.3% of the Canta Gallo complex was converted to shrimp aquaculture cooperatives as opposed to only 12.8% of industrial presence, for a total of 34%. However, these percentages mask differences in sheer numbers of ponds between industry and cooperative. There are three 'industrial' shrimp ponds as opposed to thirteen cooperatively owned ones supporting about ten members per cooperative. Another important difference is that many cooperatives are not operating under intensive production systems and most are either artesanal shrimp farms or on the way of becoming semi-intensive, and depend heavily on natural productivity and tide recycling dynamics

(Ochoa Moreno *et al.* 2001; Tobey *et al.* 1998). Lastly cooperatives have tended to establish themselves in or close to lagoon areas that are found in proximity to traditional fishing sites whereas industrial presence in lagoons is particularly strong close to the mouth of the estuary where water quality is better (Ramon Bravo, pers comm. 2006).

It is important to emphasize that not all the concessioned areas are presently developed. Should that occur, then the potential area converted would be 44.8% for the Canta Gallo complex. Cooperatives have developed almost all their concessions and have an additional 31 ha allowed whereas the industry has a potential 454 ha of additional permitted land conversion. In la Grentcha, the resident cooperative has an allowed additional 65 ha, totalling 21% of potential lagoon area converted. Table 29 shows the present and future legally allowed expansions.

Table 29. Shrimp farming encroachment and potential expansion in the lagoon areas, Estero Real, Gulf of Fonseca, Nicaragua.

Within lagoons (2005)	**Estimated lagoon area (ha)**		**Constructed pond (ha)**		**Concessioned pond (ha)**		**Legal potential expansion (ha)**		**Lagoon area encroached (%)**		**Potential area encroached (%)**	
	Dry	*Wet*	*Ind*	*Coop*	*Ind*	*Coop*	*Ind*	*Coop*	*Ind*	*Coop*	*Ind*	*Coop*
C.Gallo complex	195	4500	576	958	1028	989	452	31	12.8	21.3	22.8	22.0
Grentcha	227	501	0	40	0	105	0	65	0.0	8.0	0.0	21.0
Total	422	5001	576	998	1028	1094	452	96	11.5	20.0	11.5	21.9

Note: Adapted from MIFIC GIS database (Fuertes 2006).

These quantitative changes are important but they mask differences in pond production systems (that affect greatly water quality and aquatic species) and infrastructural organization. Interestingly, most shrimp ponds were not built according to their concessioned areas and most are found outside the boundaries of planned growth (see Map 5), which poses issues for future management of the area.

b) Indirect effects

Despite significant land conversion within the lagoon areas, local informants focused mainly on perceived qualitative changes in lagoon productivity. This could reflect actual differences between small-scale and larger scale operations in terms of levels of inputs (feeds, antibiotics etc). It could also form part of a peasant ethos to protect one's own within the same village. This could be the case, especially since the informants were mainly discussing the Canta Gallo complex where cooperatives are concentrated. Given that local shrimp farming ventures are a motor of economic development in the community and that most local cooperatives are actually located close to lagoon areas and/or other traditional fishing spots in proximity to the community, it seems logical that some informants would have a bias in favour of local shrimp cooperatives as opposed to industries. The opposite could be true as well, where some informants feel negatively towards the local community elite and are more favourable to industrial shrimp farming. Most often, however, interviewed household members were critical of industrial shrimp operations and more divided about locally initiated shrimp farms.

Most households did not mention direct land cover conversion but were concerned about indirect effects of shrimp farming proximity. Pollution from the effluents of shrimp ponds were identified as harmful to aquatic species (households #2, 274) but more households put the blame on industrial shrimp ponds (households # 169, 289, 32, 46, 196). Another indirect effect of shrimp proximity that was mentioned was the effect of ditches and canals constructed by shrimp ponds on lagoon water retention. Many households blamed shrimp farms for creating channels that caused lagoon water to rejoin the estuary channels at a faster rate (households # 170, 177, 227, 262, 276, 51, 102). Again, industrial shrimp ponds were blamed more extensively than cooperatives. More specifically, a certain shrimp aquaculture company that encroaches particularly far into the lagoon of Canta Gallo is blamed for constructing numerous ditches and channels (household #116, 157, 177, 227, 289, 49, 77, 294, 89, 196, 102, 63, 262).

4.2.2.4 Climatic drivers: the interplay of local and global

Rainfall is extremely important to the existence of winter lagoons; indeed it is mainly rainfall that determines water levels. Many informants mentioned that the local climate had changed. In particular, rainfall was identified as being less frequent and less abundant (households #37, 116, 188). Hurricanes, on the other hand, were reported as being more frequent and their arrival less predictable (households #77, 85, 104, 54). The local climate was said to be hotter, affecting "both shrimp and people" (household #169). Shrimp species live in a specific temperature gradient and increased (or lowered) temperatures influence their productivity (Ochoa Moreno *et al.* 2001). This increased heat was attributed to overall change of mangrove cover quantity and quality in the estuary and close to the lagoons (households #152, 169, 37, 46, 49, 54, 6, 87). This change is described in detail in Chapter Two. Changes in mangrove cover were also associated with higher levels of sedimentation during floods (household #116).

Hurricane Mitch in 1998 also greatly affected the lagoon system. It flooded the estuary for about a week with 7 m of water above sea level (Núñez-Ferrera 2003). Beyond the humanitarian crisis it caused, it also radically transformed the estuary and lagoons. The main estuary channel became wider and shallower due to massive input of upper watershed sediments (household #54). The lagoon complex of Canta Gallo had an additional 3 m of sediment deposited, according to a 2006 CIDEA study that compared bathymetry in 1976 and 2000 (CIDEA 2006; Coze Saborío pers.comm. 2005). Local lagoon users supported the findings of this study (households # 19, 191, 200, 275, 37, 294, 262). Mitch also created more natural channels in the estuary that cause water to leave the lagoon system at a faster rate rate (households #63, 294, 116, 138, 227, 258, 262, 93). Often these channels were initially breached by fishermen that sought to create channels to set their nets at the interface estuary and lagoon (households #102, 258).

To conclude, increased sedimentation due to natural disasters, such as hurricane Mitch, as well as changes in technology (*plastico*) and loss of mangrove cover, combined with changes in the exit routes for water, due to anthropogenically created channels (by shrimp farms and to some extent by fishermen themselves) and channels resulting from strong flood events, all contributed to a diminution of lagoon water retention. This reduction in water depth due to both increased sedimentation and more rapid water loss creates a need for more rain in order for seasonal lagoons to be formed previously (households # 116, 188, 192, 213, 258, 37,48,93, 255). However, according to informants, the rainy season starts later in August-September sometimes even October and ends in November as opposed to June to December in the past. Additionally rainfall events are more unpredictable and more intense. These findings are consistent with findings at regional and global scales for natural disasters patterns (Munich Re 2006). For *morazaneños*, this leads to smaller lagoon seasons with more frequent 'extreme events' such as lagoons flooding, which affect lagoon fisheries output and dependent livelihoods.

4.2.2.5 Organizational issues

The collapse of the management of the lagoon fisheries by the village communities was mainly driven by demographic changes brought about both due to internal population growth and the entrance of new players in the system (households #213, 258, 46, 218). A point came when the number of fishermen created conditions whereby each individual fisherman had access to the lagoons only once or twice for the entire season, leading to very little overall gain from the lagoon management system (household #37). This reduced access was compounded by the fact that some lagoons were taken by other communities, thus reducing the number of lagoons available for each fisherman's rotation (households #46, 218). Lastly the change in technology created an incentive to free-ride for individual fishermen that had capital to invest in fishing equipment to establish a permanent fishing spot within the lagoon rather than partake in the community rotation (households # 258, 223, 37, 192, 99). Additionally, the village committee was accused at worst of favoring their own family networks by appointing the best shifts to their own[56] (household #213, 294) and at best of being so disorganized that appointments and enforcement were inefficient (households #37, 258, 218, 192). The fatal blow was given by Hurricane Mitch, which radically transformed the lagoons' biophysical conditions. Indeed, the hurricane caused flooding with 7 m of water above sea level, affecting greatly lagoons and shrimp ponds (Núñez-Ferrera 2003). CIDEA estimated that between 1976 and 2000, the depth of the main lagoon Canta Gallo was reduced by 3 meters due to sedimentation (CIDEA 2006; Saborio Coze 2006 pers. communication). After such a change, "nobody wanted to manage the system" stated one informant (household #294).

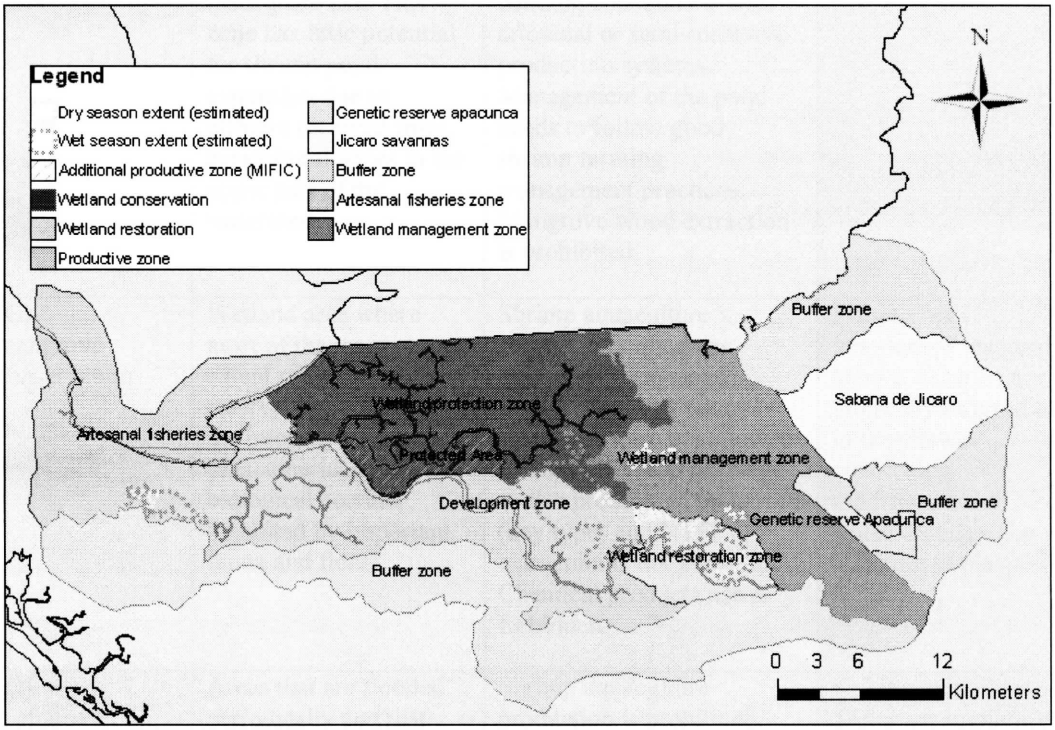
4.3 Brief description of the proposed management plan

While at the community level "nobody wanted to manage the system", the opposite occurred at the governmental level (see context section of Chapter One for a detailed

[56] Fishermen reported that shrimp fishing was driven by cycles that were determined by the tides and the moon; some tides were better than others in terms of predicted lagoon shrimp windfalls.

account of the increased presence of the government, at least on paper). A management plan for the Estero Real was concluded in 2006. The protected area expanded from 55,000 hectares to 84, 759.82 hectares with an added buffer zone of 64, 570.12 hectares (MARENA 2006: 5). The proposed protected area was divided in 6 major zones, surrounded by the buffer zone (see Map 6).

Map 6. Management zones according to the proposed protected area plan (2006).



Source: (MARENA 2006), adapted from MIFIC GIS database accessed in Sept. 2006.

Table 30 presents each of the zones the activities permitted as well as restricted for each zone. For this chapter, only the zones affecting directly seasonal lagoons spatially where retained and described in Table 30.

Table 30. Proposed management zones for the Estero Real protected area (2006).

Zone	Description	Allowed uses	Analysis

(A) consolidation and productive diversification	Aquaculture concentrated in this zone. These zones were in the past mainly salt/mud flats surrounded by zone riparian mangrove stands	Shrimp pond on salt flats only with official concession granted by MIFIC based on a previous EIA. The shrimp species cultivated cannot be exotic.	Fishing is not mentioned
(B) mangrove restoration	Zones where wetlands where greatly deteriorated due to inadequate use. This zone has little potential for shrimp pond expansion due to effluent received from agricultural zones in the upper part of the watershed.	Shrimp aquaculture production only in areas already constructed or with pending concessions with artesanal or semi-intensive production systems. Management of the pond needs to follow good shrimp farming management practices. Mangrove wood extraction is prohibited.	Fishing is not mentioned
(C) mangrove conservation	Wetland area where most of the mangrove extent remains in the reserve, important for the integrity of the Mesoamerican biological corridor, inhabited by important fauna and flora	Shrimp aquaculture production only areas already concessioned. Modifications of natural ecosystems are not allowed. Changes in water drainage is also prohibited, mangrove (any type) and NTFP extraction is not allowed. Chemical products use is forbidden.	Fishing not mentioned, seasonal lagoon fisheries are indirectly referred to in the clause concerning modifications of water drainage (i.e referring to plastico & canals).
(D) mangrove management	Areas that are flooded periodically and that include a series of channels, lagoons and wetlands important for the hydrodynamics of the lower part of the estuary, it's bordering the 'genetic reserve of Apacunca'	Shrimp aquaculture production is prohibited. Land use cannot be changed. *Artesanal fisheries is allowed* but not fishing with gillnets, explosives or toxic substances. A flooded zone cannot be enclosed for any end. These wetlands will be state lands according to the general law on the environment (ley 217).	Fishing mentioned. *Tapos* are implicitly prohibited

Source (MARENA 2006). Note: Only the zones pertaining (spatially) to lagoons are described.

While seasonal lagoon fisheries are implicitly recognized in two of these zones, they are by no means discussed in depth (Table 30). Furthermore seasonal lagoon fisheries are located in between zones. The wider Canta Gallo complex is found at the border of four different management zones. This creates a situation of uncertain land tenure especially given that the natural land cover itself is not easily divided in separate landmarks.

Additionally, many informants felt that protecting natural resources was positive since it allowed 'fish and shrimp to rest and reproduce' and stopped 'mangrove clearing' (households #2, 9, 10, 22, 32, 54, 57, 99, 214, 218, 258, 276). However most households, including those that desired further protection of natural estuarine resources, felt that restricting fishing and to a smaller degree shrimp farming is impossible since there are no other activities in Puerto Morazán. This is summarized by one informant as follows "When one has work protecting is good but most people have no other alternative than to keep fishing" (household #57).

Consequently, many informants thought that the management plan did not correspond to local realities- especially that of fisher people- and was negative for local livelihoods (households #6, 26, 49, 54, 157, 169, 170, 185,196, 213, 223, 226, 262, 275, 276, 294). Additionally, 20% of the households surveyed were not aware of upcoming changes in estuary use (households # 29, 34, 46, 51, 52, 69, 85, 87, 152, 188, 200, 255, 261, 266, 289). More importantly many households viewed MARENA, the environmental ministry, and by extension the management plan as promoting "extremist views" (household #54) at odds with local realities that they [the government officials] had never experienced (households #37, 116, 152, 183, 192, 246). This can create negative feedbacks whereby increased degradation occurs rather than the intended protection. One informant mentioned that in light of the new upcoming restrictions associated with these proposed management zones; his cooperative decided expand their pond size (beyond their allowed concession) to prevent future shrimp farming expansion restrictions (household #177).These negative perceptions have implications for both the effectiveness and the legitimacy of the protected area. This is especially true in the lagoon areas considered by *morazaneños* to be part of their village's commons.

5. Discussion: Putting the lagoons back onto the map

The decline in lagoon fisheries both in terms of catches and reduced access is caused by interrelated socio-ecological dynamics resulting from changes in demographics, technologies, lagoon environmental conditions and land tenure. Environmental changes compounded by anthropogenically induced land use changes are jeopardizing the existence of the lagoons. The conceptual framework presented at the beginning of Section 4 (Figure 7) summarizes graphically the socio-ecological dynamics discussed in this paper.

More specifically, shrimp farming brought about changes in local land tenure from a communally managed lagoon system to open-access estuarine environment in certain areas and privately-concessioned shrimp ponds in others. Privatization is both direct, as shrimp ponds replace previously open-access areas, and indirect due to changes in access to important natural resources such as the lagoon areas. The lagoon areas, as opposed to shrimp farms *per se*, were found to be the source of muted local negotiations and sometimes conflict. Indeed, lagoons, where local fishermen fish shrimp in the rainy season, were communally managed in the 1980s to maximize equality in return for all fishermen in the community. The advent of shrimp farming had the indirect effect of providing capital to some select households, generally in the form of motor boats and fishing nets. This created a rise in income and asset inequality among households. Households with most productive capital (boats, motors, nets) had higher returns and sometimes restricted access to the most lucrative natural resource-based activities, including the former communally managed lagoon fisheries. The existence of social networks encompassing friends and extended family members of this subgroup allows for poorer households to engage in lagoon fisheries; however, failure to belong to a favored network seriously limits the options for other households.

Privatization of the mangrove ecosystem benefits, at the local level, households with access to capital or to high return activities. This indicates an increase in social differentiation and income inequality since the advent of shrimp farming, a process very similar to that observed in Thailand and Vietnam a decade ago (Lebel *et al.* 1992). However, at a different scale the story is quite different. Indeed small scale shrimp farms are in decline due to the risky nature of the industry. In the 1980s, Nicaraguan cooperatives owned 100% of the industry, but this percentage lowered to about 30% in the mid-1990s and 5% in 2005 (Saborio Coze 2006: 5).

This increased social inequality deserve attention from policy makers because lagoon shrimp fishing was identified by local households as a main source of income for poor households and a main safety net for all households, including shrimp farming households in bad shrimp farming years. Increased social inequality and decline in lagoon fisheries after the introduction of shrimp farming were processes that were also identified in Vietnam and Thailand in South East Asia (DaCosta *et al.* 2007; Luttrell 2006; Lebel *et al.* 2002; Luttrell 2001; Adger *et al.* 2000). The South East Asian experience can serve as an example for the still less developed Latin America. Further attention needs to be given to lagoon fisheries by government officials. Particularly, specific clauses need to be introduced in the proposed management plan regarding lagoon areas and their management, which is not currently the case (MARENA 2006).

In terms of policies and management schemes that would make a difference at the local level, it is important to realize that lagoon earnings and access are unequally distributed in the community. This is partly mitigated by the existence of social networks that allow benefits to trickle down but is not extending to all poor households. This means that a policy that aims to increase distributional equity while at the same time decrease environmental degradation of the lagoons will have to deal with all the factors identified as driving the socio-ecological dynamics of the lagoons. The present management plan does not recognize lagoons as historic commons and divides the lagoons in different management zones, which will lead to further uncertainty and enhance the existing 'tragedy of the commons'. One first step would be to recognize the area as an area distinct from other estuary areas. Another would be to reunite all stakeholders at the community scale (different households with different assets) and between communities (especially those that are presently in conflict). Policies aiming at bettering access to fishing equipment for poorer households without recognizing the uncertain land tenure would lead to further degradation of the lagoons. The biophysical aspect also needs to be recognized, especially that of canals and ditches. Human modifications aiming at retaining water could improve lagoon fisheries by allowing water retention for a longer time. These modifications would need to respect biological cycles of the species targeted. This approach would follow the notion expressed by one informant that 'lagoons are natural shrimp farms'. This approach could be at odds however with preservation of the biodiversity conservation service provided by lagoons. Attaining a balance between use and conservation is needed. That implies first putting the lagoons back onto the map.

CONCLUSION

"The environmental consequences of a technology does nor rest like some ghost within a machine, ready to be released by the flick of a switch. They are the results of factors and relationships beyond the machine itself [...] It is the interrelationships of these elements [social, technological and economic systems] that hold the key to environmental change."(White 1980:94)

The overall purpose of this thesis is to understand and learn from the observed human-environment interactions driven by shrimp aquaculture development in the Estero Real, Gulf of Fonseca, Nicaragua. The three chapters provided an analysis of environmental and social changes that were experienced by the community of Puerto Morazán, in the Estero Real estuary and addressed the two-fold objectives presented at the beginning of the thesis.

The first objective pertained to observed spatial and temporal changes in land cover/land use from the 1980 to the present, focusing on shrimp aquaculture and coastal wetlands change. Chapter Two illustrated the exponential increase in shrimp aquaculture areas especially during the 1990s era. It also showed that shrimp aquaculture directly affected primarily salt and mud flats (70% of the areas converted) and to a lesser extent vegetated wetland ecosystems (about 20% of the areas converted with only 2% related to red mangrove species.). Chapter Two also emphasizes the fact that shrimp aquaculture, compounded with other biophysical changes, led to significant indirect changes in wetland ecosystems. Namely there was a significant conversion of red mangrove species. to secondary succession species which indicates the presence of disturbance in the system; a change that was associated with decreases in local biodiversity and productivity according to local informants. The chapter concludes with the observation that mangrove land cover/use analyses are made difficult by unclear categorizations and issues associated with the dynamic nature of the coastal system itself. The first can be solved by using a more rigorous and clear methodology which acknowledges the multi-scalar nature of mangroves from ecosystem to plant communities. The second can be mitigated by integrated expert knowledge of the coastal system and supplemented when possible by remote sensing analyses which include at least dry and wet season images.

Findings in chapter Two were complemented by findings in chapters Three and Four for the first objective. Chapter Three illustrated the changing trajectory of small-scale shrimp producers, providing explanations to the patterns observed. Chapter Four used the lagoon fisheries as a case study to show existing social-ecological dynamics leading to a degradation of lagoon fisheries and livelihoods. It shows how shrimp aquaculture impacted lagoon fisheries directly but also indirectly through changes in hydrological water flows, sedimentation and contamination. Lastly, the observed spatial and temporal changes in land cover/uses in the estuary are related to the government proposed management plan. Chapter 4 shows how the management plan fails to recognize informal community land tenure arrangements, represented here by the seasonal lagoons.

The second objective sought to analyze the direct and indirect implications of shrimp aquaculture for local livelihood; it is addressed in Chapters Three and Four. Chapter Three shows how salient the issue of scale is to identify winners and losers in a system. The chapter first presents community livelihood activities, incomes and assets - divided by shrimp and non shrimp producers. Shrimp producers are found to be better off in terms of both incomes and assets by specializing in most high return livelihood activities. At the local level therefore they, as a group, are clearly the 'winners' in terms of wealth and capacity. Small-scale shrimp producers are also however a heterogeneous group that is highly vulnerable, due to the high risk levels of shrimp aquaculture as an activity, to external shocks whether climate or market based. At the regional scale, small-scale shrimp producers are clearly the losers of the shrimp industry as a whole, disappearing at a fast pace.

Chapter Four demonstrates how shrimp aquaculture led to a direct and indirect privatization of other 'high' earning activities and areas such as the lagoon fisheries. Directly, through encroachment of shrimp ponds in lagoon areas and indirectly through the emergence of increased inequality, which limit access to the lagoon areas. Chapter 4 also emphasizes the important role- both positive and negative- of social capital. On one hand small-scale shrimp aquaculture exacerbated existing social divides, creating a clear economic inequality between shrimp and non shrimp producers. On the other hand, however, access to the lagoons was facilitated for those that are associated by family or friendship ties to shrimp farming households. Additionally access for fishing to estuary channels close to small-scale shrimp farms is still possible by virtue *of being* a community member; a fact that is not always the case with industrial shrimp producers that do not know fishermen as well as fellow community members do. One informant told me the tragic anecdotal story of someone that was shot by shrimp industry guards while collecting shell fish on a salt flat close to a shrimp pond. Fear of theft is so strong that access to estuary is somewhat linked to ties of friendship that one has. In September 2006, our research boat experienced a similar event, fortunately less tragic, when passing close to an industrial shrimp pond. While the situation in Nicaragua is not as tense as that of Honduras (Varela 2000), tensions are present hiding below the muddy waters of the estuary.

Privatization of an estuary which was until recent times communally used and managed is a legacy of shrimp aquaculture. Shrimp aquaculture created wealth, attracting people and investment in the area; it also led to increased patterns of social inequality, which translate in unequal access to natural resources. Resistance to this change was attempted by many local people but gradually as small scale shrimp producers became more numerous and benefited from the system, this resistance eroded considerably, focusing principally on some industrial shrimp ponds that clearly infringed upon the local commons. However, small scale shrimp farmers find it exceedingly difficult to remain competitive in a changing economic and biophysical context. Costs of production are rising, prices are reduced and debts accumulate. Additionally, natural disasters- small and big- are recurring more frequently and are predicted to become even more unpredictable with climate change. In that context, a change in the conceptualization of space from community commons to private lands poses great threats to local communities that are at high risk of losing these newly created private lands. A process of coastal "latinfundiazation" that was observed in South-East Asia whereby shrimp aquaculture first marginalized a sub-segment of local communities, enhancing local elites, before marginalizing these same local elites that were not able to compete with larger player

(Luttrell 2006; Lebel *et al.* 2002). The same process, at a first stage, is presently being played out in the Estero Real.

The establishment of a protected area management plan can represent a hopeful opportunity to counter these potential negative developments. To do so however there is a need first to recognize existing communal land tenure arrangements. Realistic and compatible goals between environmental and development agendas also need to be set. Shrimp aquaculture is in Puerto Morazán to stay at least for the medium term. Shrimp aquaculture did bring economic revival to a community that was living at the margin, since the destruction of the train network in the 1960s. The decline of the activity would have major socioeconomic repercussions on a community (and a region) that is highly dependent on shrimp for its capital earning. Fishing, both fish and shrimp, also needs to be acknowledged however as a key complementary activity, which supplements incomes and diets, and provides a safety net for times of hardships. To become effective the protected area management needs to genuinely incorporate multiple actors in a multilevel governance system from sub-community groups to national levels (Berkes *et al.* 2003). Each level is key to reconcile- or at least negotiate - contrasting interests and needs.

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APPENDICES

Appendix 1. McGill University Ethics Approval

McGill

Research Ethics Board Office
McGill University
845 Sherbrooke Street West
James Administration Bldg., rm 419
Montreal, QC H3A 2T5

Tel: (514) 398-6831
Fax: (514) 398-4644
Ethics website: www.mcgill.ca/research/compliance/human/

Research Ethics Board I
Certificate of Ethical Acceptability of Research Involving Humans

REB File #: 111-1205

Project Title: Mangroves, shrimp farming and coastal livelihoods: land cover/use changes in the Gulf of Fonseca, Central America

Principal Investigator: Karina Benessaiah **Department:** Geography

Status: Master student **Supervisor:** Prof. Raja Sengupta

Granting Agency and Title (if applicable): N/A

This project was reviewed on December 13, 2005 by

Expedited Review ___
Full Review ✓

George Wenzel

George Wenzel, Ph.D.
Chair, REB I

Approval Period: January 11, 2006 to January 10, 2007

This project was reviewed and approved in accordance with the requirements of the McGill University Policy on the Ethical Conduct of Research Involving Human Subjects and with the Tri-Council Policy Statement: Ethical Conduct For Research Involving Human Subjects

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*All research involving human subjects requires review on an annual basis. A Request for Renewal form should be submitted at least one month before the above expiry date.
*If a project has been completed or terminated and ethics approval is no longer required, a Final Report form must be submitted.
*Should any modification or other unanticipated development occur before the next required review, the REB must be informed and any modification can't be initiated until approval is received.

cc: Prof. R. Sengupta

Appendix 2. Household Survey Instrument

This appendix presents the household survey template used for the interviews in the community of Puerto Morazan. The household survey in printed format was formed of 7 pages double-sided.

ENCUENSTA- MORAZAN Fecha:________________________

Código de Hogar:__________ Nombre de Jefe:______________________________________

Nombre de Jefa:______________________________________

1. HOGAR

No	Nombre	Genero	Edad	Parentesco[57]	Situación[58]	Lugar de nacimiento	Educación	Niños

[57] En référencia al jefe o la jefa de familia.

[58] Viven de manera permanente, solamente el verano/invierno, cuando no hay trabajo …

2. HISTORIA/MIGRACION

¿Dónde vivían antes? ¿O cual es el origen de la familia? ¿Cuándo?

¿Cuál familias en este hogar dependen del jefe de familia económicamente? *(escribir números)*

¿Para que? Comida/ Casa/ Trabajo / Otro *(describir)* ____________________

2.3 ¿Porque vinieron a establecerse aquí?

3. ACTIVIDADES

3.1 ¿A que se dedican los miembros de este hogar? *(indicar quien en margen)*

[ ] Pesca Todo el ano / invierno / verano ¿frecuencia?_________________ Venta/ Consumo

[ ] Pesca esp. de camarón de laguna ¿frecuencia?_________________ Venta/ Consumo

[ ] Punchero, conchero Todo el ano / invierno / verano ¿frecuencia? _________________ Venta/ Consumo

[ ] Leña Todo el ano / invierno / verano ¿frecuencia? _________________ Venta/ Consumo

[ ] Socio o dueño de camaronera Todo el ano/ invierno / verano ¿Cual?______________________ Venta/ Consumo

[ ] Artesano (albañil, bolsas…) Todo el ano/ invierno / verano ¿Qué?____________________Venta/ Consumo

[ ] Venta (panadería, pulpería…) Todo el ano/ invierno / verano ¿Qué?____________________

[ ] Socio o dueño de finca agrícola, ganadera Todo el ano/ invierno / verano ¿Cuál?____________________ Venta/ Consumo

[ ] Comprador o financiero Todo el ano/ invierno / verano

____

[ ] Empleado en granja camaronera Todo el ano/ invierno / verano ¿Cuál?____________________ ¿Familial? SI / NO

[ ] Empleado en finca Todo el ano/ invierno / verano ¿Cuál?________________________________

[ ] Empleado en servicios (bus, maestro) Todo el ano/ invierno / verano ¿Cuál?________________________________

[ ] Cazador (venado, garrobo, otro…) Todo el ano / invierno / verano ¿frecuencia?________________Venta/ Consumo
¿Que?______________________

[ ] Otro________________________ Todo el ano / invierno / verano ¿frecuencia?________________Venta/Consumo

Informaciones adicionales:

Calendario Anual

¿A que se dedica su hogar en el ano (basado en el ano que paso)?

	Tipo de actividad 1	2	3	4	¿Quien participa con usted?[59]	¿Desde cuando esta involucrado en esta actividad?	Información adicional
Enero							
Febrero							
Marzo							
Abril							
Mayo							
Junio							
Julio							
Agosto							
Sept.							
Oct.							
Nov.							
Dec.							

[59] familia, socios y empleados

3.2 Actividades del pasado

	Tipo de actividad 1	2	3	4	Condiciones ambientales y socioeconómicas (en este tiempo)	Ingreso o producción	¿Como y Porque cambio?
1970-1980 (Somoza) Tormenta de 1982							
1980-1990 (Sandinista)							
1990-1995 (Violetta)							
1995-1998 (Taura)							
1998-1999 (Mitch-M.Blanca)							
2000-2002							
2002-2004							
2005-2006 (Hoy)							

3.3 Cambio ambiental

3.3.1 ¿Cuáles son los cambios ambientales, desde que vino a vivir aquí, que ha observado ud? (En que ano mas o menos)

3.3.2 ¿Cuáles fueron los cambios ambientales que le han impacto mas? ¿Cómo?

3.3.3 ¿Qué hizo ud para mitigar/disminuir el efecto de esos impactos? ¿Qué hizo para sobrevivir?

3.34 ¿Cuál es la importancia del manglar para su vivienda? ¿Cambio?

3.3.5 ¿Le influyen las inundaciones o huracanes del invierno? ¿Secia en verano?

3.3.6 ¿Qué piensan de la área protegida? ¿Cómo va a mejorar/impactar su vivienda?

3.3.7 ¿Cómo le impacto el Mitch en sus actividades, posesiones u otro?

4. TIERRAS, CONCESSIONES Y BIENES (Assets)

4.1 <u>tierras o/y concesiones</u>

Esta categoría incluye también tierras utilizadas de manera informal

ID	**Tipo** lugar y nombre	**Dimensión**	**Edad**	**Distancia** (tiempo y tipo de transporte)	**Estación**[60] (cuando lo utilizan)	**Usos** (cultivos, tipo camaronera, otro, no utilizada)	**Tenencia** Colectiva o individual?	**Acceso a la tierra/concesión** ¿Como ha obtenido esta tierra/concesión? **Formal (F)/ Informal (I)**	**Cobertura anterior**[61] Que había antes en este terreno? (otro cultivo, mangle, curumo, playón otro)

<u>Información adicional</u>

60 ¿Lo utilizan de manera diferente en el ano? ¿Cuales?

61 ¿Cuando empezó este uso de esta tierra? ¿La estaba utilizando de manera diferente antes?

4.2 Bienes

Indicar la unidad y el tiempo (un ano)

(PESCA)	**Cantidad**	**(CAMARONERA)**	**Cantidad**	**(CASA)**	**Cantidad**
Transmayo		Bomba		casa	
Simbra		Fertilizantes		Batería	
Bolsa		Alimento		Radio	
Tranca (o manga)		Cal		Maquina a coser	
Lampara		Larvas		Video/DVD	
Isladores				Televisor	
Ataraya		Empleados		Machete	
Bote		Asistencia técnica		Escopeta	
Motor		Gastos legales			
Gasolina/Aceite		Concesión		Perros cazadores	
Matricula				cerdo/chancho	
Permiso				pato	
		(OTROS)		vaca/buiy	
(TRANSPORTE)		Acopiado		peliguey	
Caballo		Maquina		cabro	
Motocicleta		Bodega		gallino	
Caro		Predio			
Caretta/Carreton		Venta		Refrigeradora	
Bicicleta				Cocina	

¿Alquila su(s) casa(s)? SI / NO ¿Precio? ¿Esta alquilando su casa? SI / NO ¿Precio?

¿Alquila su equipo de pesca? SI / NO ¿Precio? ¿Esta alquilando equipo? SI / NO ¿Gasto?

Consumo *Para un mes*

Productos	Produce (P) /compra (C)	¿Que frecuencia?	Precios (invierno/verano)	Información adicional
Granos básicos (frijoles, arroz, 'trigo')				
Tortillas o pan				
Azúcar, café, aceite, sal				
Limpieza (Jabón...)				
Huevos				
Pollo o carne				
Frutas y vegetales				
Electrizad				
Agua				

5. INGRESOS

5.1 Camaronera *(si hay mas de una incluir ID)*
(Presente)

5.1.1 ¿En que ano se formo esta cooperativa/colectivo? ¿En que circunstancia? ¿En que ano empezaron a trabajar esta granja?

5.1.2 ¿Sistema de producción? ¿Numero de cosechas al ano?

5.1.3 ¿Cómo obtiene ud las larvas para sembrar? ¿Cambio su fuente de larvas? SI / NO ¿Por qué?

5.1.4 ¿Qué numero de personas se dedican a este actividad? *(de su familia, socios y empleados; hombres, mujeres, edad)*

5.1.5 ¿Cuanto dinero han invertido el ano pasado para su granja (cada ciclo durante el ano pasado)?

5.1.6 ¿Cuál fueron los beneficios/perdidas del ano pasado? ¿Qué rendimiento?

5.1.7 ¿Tenia (n) que pagar interés o un crédito? ¿Cuanto? ¿Y a quien? O ¿Ha obtenido apoyo financiero de una organización?

5.1.8 ¿Cual fue su mejor cosecha? ¿En que ano? ¿Qué rendimiento? ¿Que paso?

5.1.9 ¿Cuál fue su peor cosecha? ¿En que ano? ¿Qué rendimiento? ¿Qué paso?

5.1.10 ¿Donde venden su producto? ¿A quien? ¿Distancia al mercado?

(Pasado)

5.1.12 ¿Que ano inicio su actividad camaronera? ¿Porque?

5.1.13 ¿Ha participado en proyectos camaroneros que no funcionaron? ¿Cuales? ¿Porque no funcionaron?

5.1.14 ¿Ha cambiado las condiciones ambientales (calidad agua, tasa de sedimentación, corrientes)? ¿Cómo impacto su finca? ¿Qué hicieron? ¿Cambiaron las practicas de su finca?

5.1.15 ¿Que son los riesgos mayores que identifica ud con la camaronicultura?

5.1.16 ¿Que ha hecho o hace para disminuir o prevenir estos riesgos?

5. 2 Pesca

5.2.1 General

5.2.1.1 ¿Cuál es la situación actual de la actividad pesquera en Morazán? ¿Cambio?

5.2.1.2 ¿Qué cantidad es dedicada al consumo y cual a la venta? *(un unas 15 dias)*

5.2.1.3 ¿Qué número de personas se dedican a la pesca en su hogar? *Familia, Socios, Empleados (hombres, mujeres, edad)*

5.2.1.4 ¿Qué tipo de material utilizan para la extracción del recurso?

5.2.1.5 ¿Dónde venden su producto? ¿A quien? ¿Distancia al mercado?

5.2.1.6 ¿Depende ud sustancialmente del financiamiento externo de algún organismo y/o préstamos privados para desarrollar el trabajo?

5.2.2 Producción *(a los 15 días)*

Estación	**Especias** (nombre)	**Distancia** (horas)	**Cuantidad** (libras)	**Consumo** (libras)	**Venta** (Córdoba/libra)	**Ubicación**
Invierno	Róbalo					
Verano						
Invierno	Tilapia					
Verano						
Invierno	Corvina					
Verano						
Invierno	Lisa					
Verano						
Invierno	Huiche					
Verano						
Invierno	Camarón					

Verano						
Invierno	Larvas de camarón					
Verano						
Invierno	Popoyote					
Verano						
Invierno	Guapote					
Verano						
Invierno	Sardinas (bubuchas)					
Verano						
Invierno	Punche					
Verano						
Invierno	Conche					
Verano						

Información adicional:

5.3 Trabajo de campo o otro

Persona del hogar	En que época	Duración	Ubicación	Tipo de trabajo/Para quien	Jornal

5.4 Producción Agrícola

Tipo/Distancia	Cultivos (manzanas)	Cantidad (quintal/manzana)	Estación	Consumo (córdobas/quintal)	Venta (córdobas/quintal)

5. 5 Otras Fuentes de ingreso

Comercio (venta), artesanía, reparaciones

5.5.1 ¿Qué vende? ¿Qué produce?

5.5.2 ¿Cual es el ingreso producido por su venta/trabajo en un mes? (invierno/verano)

5.5.3 ¿Quien participa a esta actividad de su hogar?

Lena

5.5.4 ¿Cosechan madera o leña? SI / NO ¿Frecuencia?
¿Cantidad *(al mes invierno/verano (en rajas))*?

¿Donde? *(invierno/verano) (mapa)*

5.5.5 ¿Compran leña? SI / NO ¿De quien? ¿Frecuencia?

Otros

5.5.6 ¿Además hay otras actividades ocasionales o frecuentas que no hemos mencionado que le ayudan a subsistir o forman parte de su ingreso? (ejemplo garrobo, casar venado o conejo, otro) (frecuencia, cantidad)

6. INVERSION

¿Al final del verano, donde invierten su dinero?	**Preferencia** *(pone preferencia de 1 a 11)*	**¿Al final del invierno, donde invierten su dinero?**	**Preferencia** *(pone preferencia de 1 a 11)*
Consumo (subsistencia)		Consumo (subsistencia)	
Educación		Educación	
Mantenimiento de la casa		Mantenimiento de la casa	
Mantenimiento de granja camaronera		Mantenimiento de granja camaronera	
Mantenimiento de material de pesca		Mantenimiento de material de pesca	
Mantenimiento de la venta o otra actividad productiva		Mantenimiento de la venta o otra actividad productiva	
Mejoramiento de la casa		Mejoramiento de la casa	
Mejoramiento de granja camaronera		Mejoramiento de granja camaronera	
Mejoramiento de material de pesca		Mejoramiento de material de pesca	
Mejoramiento de la venta o otra actividad productiva		Mejoramiento de la venta o otra actividad productiva	
Inversión en nueva actividad		Inversión en nueva actividad	
Compra de tierra/concesión		Compra de tierra/concesión	
Divertimiento		Divertimiento	
Otros ¿cuales?		Otros ¿cuales?	

7. CAPITAL SOCIAL
7.1 Apoyo de afuera (informal o formal)

7.1.1 ¿Ha recibido ud ayuda/apoyo de la parte de alguien que conoce afuera de la comunidad?
-(1) el ano pasado
- (2) después del Mitch 1998-1999
- (3) después de la Mancha Blanca 1999-2000
- (4) Otro evento

7.1.2 ¿Frecuencia?

7.1.3 ¿Que relación tienen con usted?

7.1.4 ¿Que fue el tipo de ayudo?
Dinero /Comida/ Contactos/ Material/ Crédito/ Otro

7.1.5 ¿Porque necesitaba ud ayuda?

7.2 Ayuda de la comunidad

7.2.1 ¿Puedes mostrar me en este mapa cuales son los hogares que forman parte de tu familia, aun que no viven contigo?

7.2.2 ¿Cuáles son los hogares con cuales tienes una relación de reciprocidad en el sentido que hacer trabajo o ayudas y ellos ayudan de otra manera? *((R) recibí ayuda y (A) ha ayudado)*

7.2.3 ¿Cómo les ayudas y como te ayudan? Labor/ Dinero/Comida/Ganado/Pollo/ Crédito/ Equipo/Material/ Uso de tierra/ Otro

7.2.4 ¿Porque ellos?

7.2.5 ¿Hay hogares a quien pediste ayuda en una situación excepcional? ¿Quien? ¿Por qué ellos? ¿En que situación?

7.2.6 ¿Hay hogares que ayudaste después de una evento excepcional? ¿Quien? ¿Por qué ellos? ¿En que situación?

7.3 Asistencia técnica y crédito

7.3.1 ¿Has recibido asistencia técnica antes? ¿De quien? ¿En que?

7.3.2 ¿Has recibido crédito antes? ¿De quien? ¿En que?

7.4 Asociación, cooperativa, colectivo

7.4.1 ¿Formas parte de una cooperativa? SI / NO

¿Cual?

¿Desde cuando?

¿Cuántos socios? *Nombres*

¿Asociación? SI/ NO

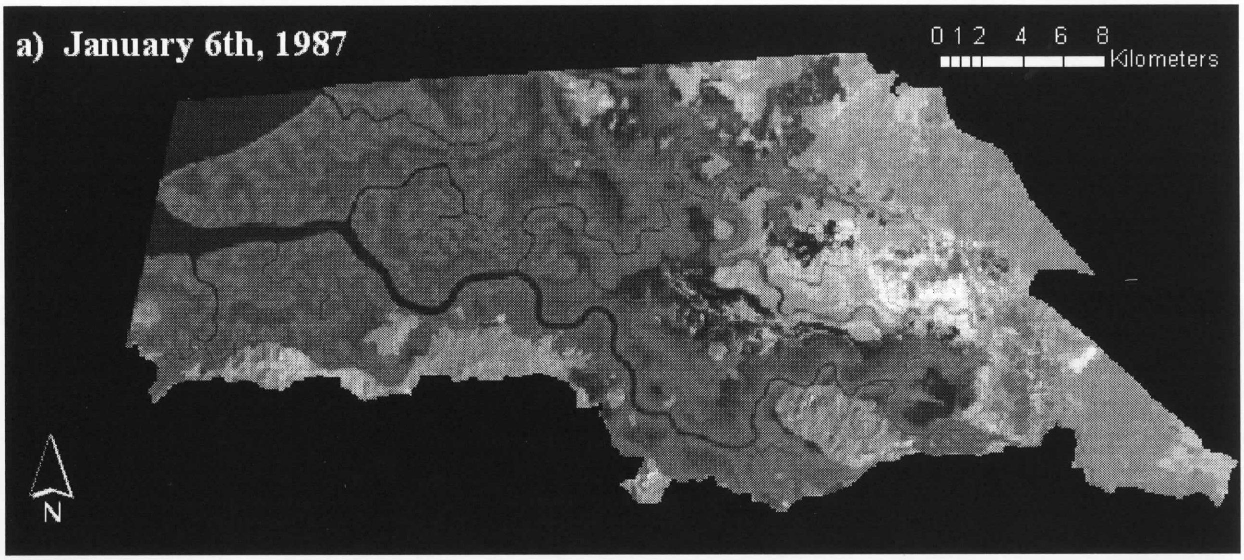
¿Cuál?

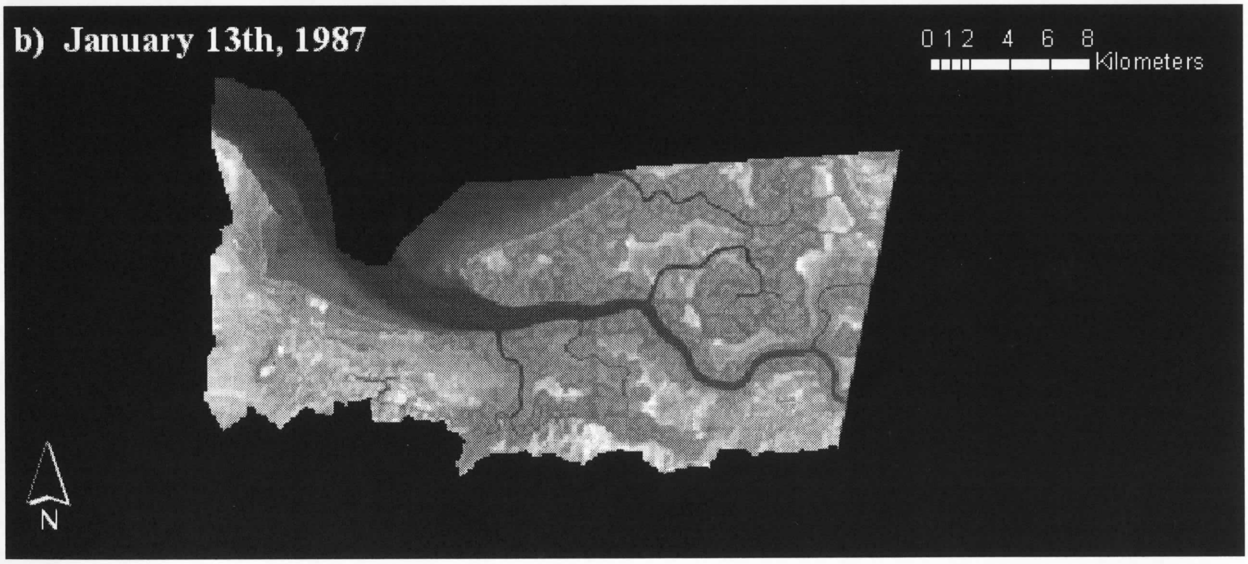
7.4.2 ¿Como eso le ayuda?

7. 5 Alternativas ¿En su opinión, como podría mejorarse su vivienda y ella del pueblo, aparte de financiamiento externo?

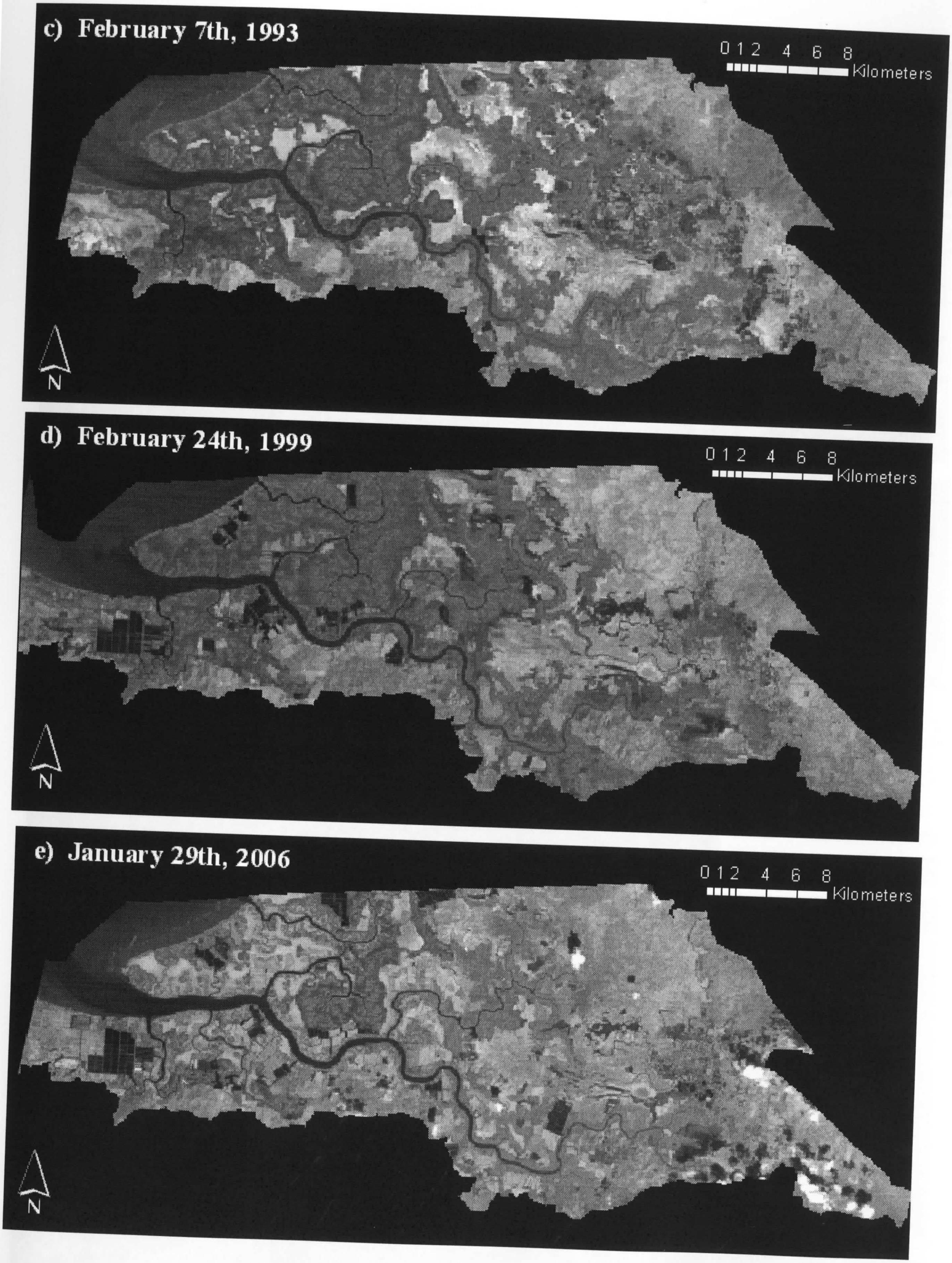
Appendix 3. Satellite image composites (3A) & classifications (3B) 1987-2006

APPENDIX 3A: Classifications 1987-2006 Landsat TM 5 for 1987, 1993 and 1999 and SPOT 4 for 2006

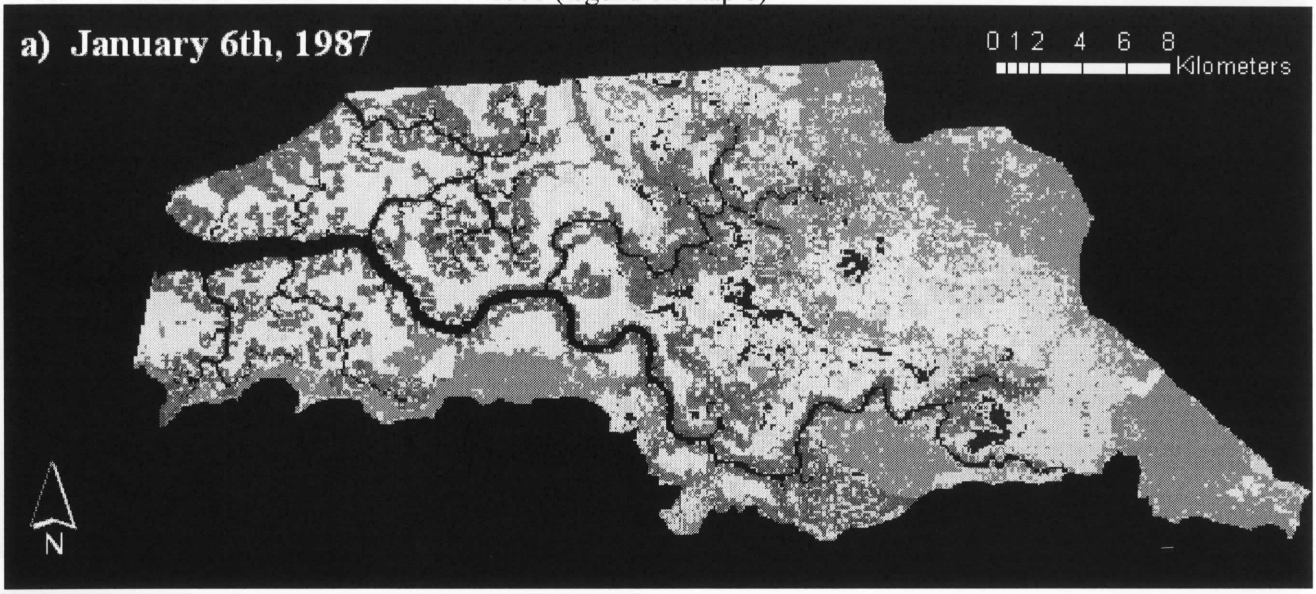


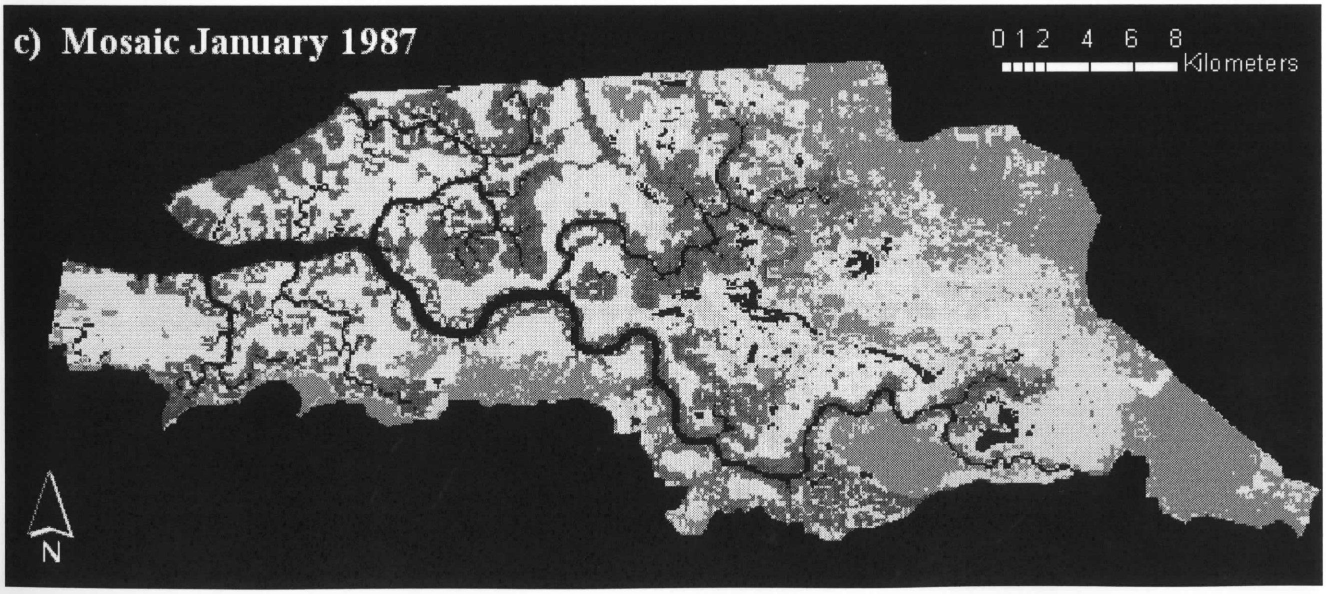


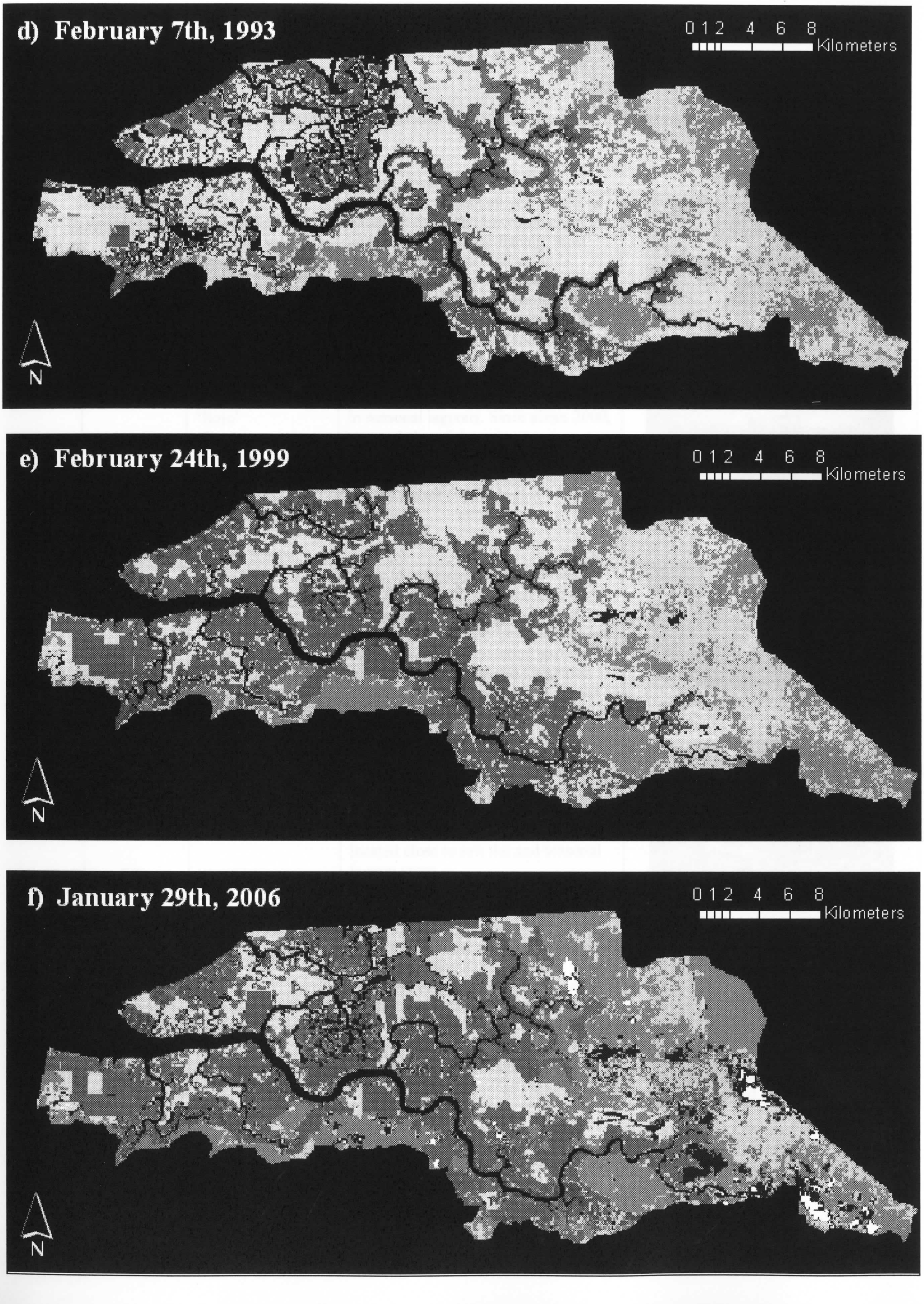
The images were graciously purchased by McGill libraries from USGS and SPOT for the purpose of this research.


c) February 7th, 1993
0 1 2 4 6 8
Kilometers
N
d) February 24th, 1999
0 1 2 4 6 8
Kilometers
N
e) January 29th, 2006
0 1 2 4 6 8
Kilometers
N

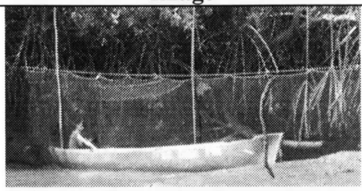
APPENDIX 3B: Classifications 1987-2006 (legend on map b)

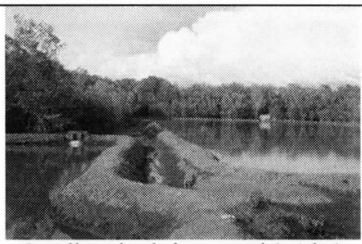
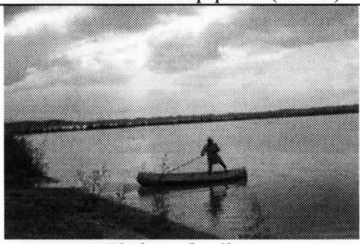
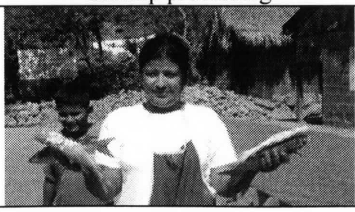





d) February 7th, 1993
0 1 2 4 6 8
Kilometers
N
e) February 24th, 1999
0 1 2 4 6 8
Kilometers
N
f) January 29th, 2006
0 1 2 4 6 8
Kilometers
N

Appendix 4. Description of livelihood activities in Puerto Morazán, Nicaragua

Activities	Description	Season, location & technology	Image
Fishing	Fishery targeting fish species including snappers (*Lujanus spp.),* snooks (*Centropomus spp.*) weakfish (*Cynoscion spp.),* tilapia etc.	Fish species present all year round in estuarine channels. However given the importance of shrimp fishing, most fishermen focus on high value resources such as shrimp, especially during the wet season. Fishing techniques are mostly *transmallo* and *manga* but also *simbra* and *ataraya*	 Example of *manga*
Shrimp fishing	Fishery targeting shrimp *spp.* incl. 'Rojo' (*Trachypenaues byrdi*) and *fievre* during dry season. 'Blanco' (*P.vannamei & ocidentales*) during the wet season.	Traditionally a wet season endeavor, shrimp fishing was mostly conducted in seasonal lagoons. Since about 2000, a new shrimp fishery is commercialized at the mouth of the estuary in the Gulf of Fonseca. Using mainly *bolsas* (with *plastico* in the lagoons).	 Example of *bolsa*
Shell fishing	Collection of shell *spp.* ie. mangrove cockles (*A.tuberculosa* and *similis*) and crabs (*Ucides occidentalis*)	Close to mangrove areas and flats. This fishery is of low value and does not generate considerable income. Used to be especially important before hurricane Mitch. Important species for subsistence however and a tradition during the holy week (easter). Based mainly on skilled labor with a paddle boat or by foot.	 *Punche* (crab)
Firewood sale	Firewood collection for sale.	Collection of firewood for sale to village and neighboring city dwellers. The mangrove collected for firewood is primarily coming from transitional mangrove spp. such as *A. germinans*, located close to salt flat and seasonal lagoon areas.	 Firewood processing
Hunting	Food, leisure and partly for sale; mostly iguanas	Dry forest areas and mangroves to a lesser extent. Iguanas are increasingly hard to find in the region according to local informants. Their value is relatively high but their small numbers make them hard to rely upon as a stable source of income. Additionally their collection is prohibited by law even though enforcement is weak.	 Sign located in a shrimp farm

Services	Shops, school, bus, pharmacy	Activities that do not directly rely on natural resource extraction, including shop vendors, food processing, school staff, bus drivers, boat and house repairmen. Located mainly in the community.	 Tortilla preparation for sale
Agriculture	Sorghum, maize, palm leaves mainly; for consumption or local housing. Minimally for sale,	Primarily subsistence agriculture or destined to the local market. Mainly on lands that belong to other than Puerto Morazán communities (or on the single hilly area in the community for two households) but that are linked to households through family/friend ties.	 Palm gathering
Aquaculture	Production of shrimp (*P. vannamei* mostly) for sale	Around the estuary mostly on salt flat areas. Wet season activity for small scale producers.	 Small scale shrimp pond (<1 ha)
Aquaculture (labor)	Labor necessary for shrimp pond maintenance and harvest	Dry and wet season with more employment given during the latter, mostly men	 Shrimp feeding
Shrimp processing	Extracting the shell from shrimp being caught or farmed.	All year round with more employment during the wet season. This activity is mainly done by women and children and constitutes an important source of income when examining gender income distribution.	 Shrimp processing
Shrimp trade	Sale of shrimp and fish.	All year round. Traditionally a woman's job but gradually including a significant amount of men as well. Usually contingent upon financing fishers and shrimp farmers in return to their goods.	

			Fish reseller
Household firewood	Firewood for food preparation	Collected in salt flats in areas occupied by *A.germinans* (transitional mangrove areas) for household own use.	 Firewood fuelled fire for cooking
Subsistence fisheries	Fish, shell and shrimp for consumption	All year round. Extremely important especially during the dry season but difficult to estimate precisely.	 Fish drying on a stand
Remittances	Revenues originating from household members that migrated	Migration plays an important role in the community especially for younger men and women. This migration occurs seasonally (during the dry season when livelihood activities are reduced) and also over longer time periods. Destinations of choice include urban centers, labor intensive agricultural areas in Nicaragua as well as other countries in the region (Honduras, Guatemala, Salvador) as well as the United States.	 Migratory birds (metaphor)
Other	Pension funds and other sources of revenue that are not generally part of a category (i.e interests from loans, donor funds)	Pension funds are an important source of revenues for older members of a household, especially if their ties to the rest of the family are weak. The importance of donor funds is hard to assess because they are usually constituted by idiosyncratic donations	 Toy provided by a French family that 'adopted' a child from Puerto Morazán