INDIGENOUS PERCEPTIONS OF ENVIRONMENTAL CHANGE: LOCAL REALITIES AND COPING STRATEGIES IN THE COLOMBIAN AMAZON

by

ROCIO RODRIGUEZ GRANADOS

(Under the Direction of Nathan P. Nibbelink)

ABSTRACT

Subsistence livelihoods depend on the ability to read and predict the environment. Perceptions of environmental change mediate potentially adaptive behaviors and are related to culture (and knowledge), society, economy and the environment, and the opportunities they provide. Indigenous people of Puerto Nariño (Colombian Amazon) are ethno-climatologists who notice changes in their environment, and their adaptive capacity is linked to both deep and general knowledge of their contexts. Livelihoods are highly dependent on natural resources and are being threatened by contemporary changes. In Colombia, most of the work on climate change is done at the planning level, and does not consider local realities in a meaningful way. This dissertation seeks to translate into local realities, abstract scenarios of climate change. Using ethnographic tools (life histories, resource walks, semistructured interviews), and statistical tools (time series analysis), my goal is to understand how perceptions are influencing land use practices, creating new behavioral responses with consequences on the landscape. My objectives are to: 1) explore changes in river behavior since it is the key factor determining subsistence activities; 2) characterize local perceptions of environmental change and compare them with hydroclimatological data; 3) characterize livelihood implications of perceived changes in the environment and study the impacts of coping decisions. Results indicate that 1) environmental variables have been changing significantly in the region;

2) indigenous perceptions reflect the deep grounded knowledge that people have of their environment; and 3) livelihoods dependent on natural resources are profoundly affected by an unpredictable environment. I argue that adopted coping strategies paired with cultural transformations can reduce resilience over time. The absence of local data makes it difficult to determine trends in relevant hydroclimatic variables at local scales, and whether they are consistent with people's perceptions. This can result in poorly grounded adaptation plans that will increase communities' vulnerability. The government needs to address perceptions and design culturally sound management practices together with local communities to understand the effects of regional climate change on societies and their ability to adapt.

INDEX WORDS: perceptions of climate change, landscape use, livelihoods, northwestern Amazonia, coping strategies, adaptation, local livelihoods

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Para Emiliana, alma de purita belleza, ternura y amor... Pido al Universo que tu caminar sea seguro, libre, abundante, luminoso... Vuela libre, alto y llega lejos donde sólo tú quieras soñar!!!! Te Amo!

Al AMAzonas por las aventuras vividas y por vivir…

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Puede ser verdad que este loca, pero que aburrida es la cordura…

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CHAPTER 1

INTRODUCTION

> *"Los abuelos dicen que se están dando cambios muy rápidos por la contaminación, el cambio climático. La climatología de la región amazónica y la de todo el mundo está completamente desorganizada en comparación a tiempos pasados…"* (The elders say that very abrupt changes are taking place because of pollution and climate change. The climatology of the amazon region and of all the world is completely disorganized compared with the past…) Male, 26 yrs.

Change adaptation determines the ways in which people use and manage resources (Duerden, 2004). Working with indigenous communities from the Colombian Amazon, it is clear that they are noticing and responding to changes in the hydrological cycle, the key factor determining what, where and when subsistence activities take place (Pinilla Herrera, 2004). This research was done with the local indigenous groups of Puerto Nariño, Amazonas[1]. This dissertation addresses topics related to politics of knowledge regarding environmental change, which can be useful when communities plan adaptation strategies (Green and Raygorodetsky, 2010).

Current climatic data indicate that hydrological cycles are changing in Colombia's Amazonia. Likewise, temperatures have been increasing at a steady rate and affectations in precipitation have also been recorded (IDEAM et al., 2015). The baseline for public perception of climate change is affected by the amount of climatic variation in relation to the human life span. The goal of this research is to

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understand indigenous peoples' perceptions of climate change, and how these perceptions are influencing subsistence strategies in the municipality of Puerto Nariño, Amazonas, Colombia.

I have worked with this community for over 14 years, and I have been noticing changes that are also being reported by the people in the area. For this reason, I decided to further explore questions related to perceptions of environmental change, as well as analyzing real data to see if observed trends match human perception. I also want to understand potential impacts of the future scenarios for the area in terms of livelihood affectation. Finally how all these effects are translated in land use as changes that have an impact on the landscape of the region?

Most of the literature at community scale, relates local communities and climate change with respect to vulnerability, adaptation and resilience, as well as understanding community perspectives on the local effects of global climate change. This dissertation contributes to that literature by addressing the transformations of subsistence culture and the cultural implications of global climate change, including the human-environment relationships that help maintain local landscapes. This dissertation additionally explores the local effects of global climate change and how this affects perceptions and assumptions about local territories and the support systems that are key to ecosystem health.

The majority of approaches to climate change responses reflect large landscape scales; however, such approaches often overlook the local realities and needs that occur in highly vulnerable places due to specific, contextual conditions. Such local conditions may, as in this case, be crucial areas for biodiversity and cultural conservation. Understanding how local communities manage natural resources is crucial when developing local conservation and development practices.

Most research regarding local communities has taken place in the Arctic (see Berkes and Jolly, 2001; Crate, 2009; Cruikshank, 2005; Duerden, 2004; Gearheard et al., 2010; Turner and Clifton, 2009) and much less has been done in tropical areas in the developing world. Research in these tropical regions is needed to understand how adaptation is occurring in these environmentally and socially fragile areas. This work addresses matters of scale, knowledge, and cultural perceptions of environmental changes, and enhances our understanding of how human communities are responding to change and the implications that this has on the cultural landscape.

As this research shows, there is much work left to do in comprehending how people respond to the different kinds of socio-environmental uncertainty to minimize the negative impacts of climate change. This is fundamental in creating long-term sustainable strategies that become part of adaptation plans that address local needs. The work presented here contributes to the understanding of changes in behavior and their translation into land use and other practices. With such goal, this dissertation explores translating into local realities abstract scenarios of climate change in terms of livelihood implications for indigenous communities of the Colombian Amazon.

The Amazon is a unique area given its importance for the world's hydrological cycle and climatic regulation, but is also one of the areas facing faster destruction. The implications of rapid deforestation are also felt worldwide, and in many cases responding to climate change can enhance such practices in the need for finding alternatives that guarantee local livelihoods.

The future of the Amazon and the indigenous peoples that depend on its natural resources grow even more uncertain as climate change manifests its effects. Colombian scientists have developed projections of climate change for the region, and some studies have been done in terms of fisheries; however, not much can be found regarding its impacts on overall livelihoods and on the water cycle of the region which ultimately determines what, where and when activities take place.

So far, climatic extremes have been faced with scarce and insufficient government aid, and no real work has been done aiming to analyze and make decisions related to adaptation strategies that reduce the vulnerability of indigenous communities. Traditional environmental knowledge used by previous generations to know when to carry out certain activities and maintain sustainable use of resources has lost validity with the increasing changes in the ecosystems. How are people dealing with this new uncertainty? How do they decide when and what activities should they engage into? How do they guarantee a livelihood for themselves and their families? These are some of the questions that motivated my research in the area that I have worked for an important part of my life: Puerto Nariño, Amazonas. I chose this place because I was captivated by the dependence of human livelihoods on natural resources.

In this research, my main goal is to understand how socio-environmental uncertainty is influencing land use practices and creating new behavioral responses that have consequences for the entire landscape. I am concerned with exploring the effects of variability and how it shapes subsistence practices in the region.

After doing a comprehensive literature review in chapter 2, in the course of three chapters, I pose and answer the following questions:

1) Have river levels become unpredictable and/or more extreme? Are there changes in maximum and minimum levels, or in the time of year when maximum and minimum levels occur? Are there changes in the duration of high waters or low waters? Are there changes in the patterns of river levels before maximum point is reached?

In chapter three, I determine whether changes in river behavior have occurred in the past 25 years, because this has proven to be the most important variable in terms of livelihoods for the region and also the key factor determining what, where and when subsistence activities occur.

2) What are local people perceiving in terms of environmental change? What do environmental data indicate about these variables? Do these trends coincide with what people are perceiving?

In chapter four, I analyze the main perceptions related to climate change for the area. Following what has been identified, I analyze the climatic data for certain variables to finally compare them with perceptions. The goal is to observe locally how regional scenarios are shaping and what happens on local levels as a result of climate change.

3) What are the livelihood implications of perceived changes in the environment? Consequently what are the coping measures adopted by local communities and what effect do these have on the overall landscape?

In chapter five, by using interviews and other sources of information, I explore how people are responding to these perceived changes. Framing these responses in the local context and analyzing potential implications of such processes, including topics that might result in maladaptation by enhancing vulnerability or reducing adaptive capacity of these local systems.

This research shows that behavioral patterns are undergoing significant changes to adjust to perceived climatic and social changes. It is an effort to translate work done at different scales to local realities where the implications are felt, and where people are actively responding to overcome difficulties that arise. This is important from a practical standpoint because governments are having problems translating climate change scenarios into local realities and even more, local information at the level of livelihood implications is rarely considered when developing local adaptation plans to climate change, resulting in wasted efforts that are not really useful in local contexts.

To overcome such challenges, it is necessary to use both qualitative and quantitative longitudinal datasets that can capture change in processes of resource use and extraction so that climate change plans reflect local realities and can address the problems that will determine human responses that can enhance or diminish local adaptive capacity. There is a need to understand the indirect effects caused by climate change and the way in which traditional systems are changing in the tropics, areas of high biological and cultural relevance. This research will provide an idea of how local indigenous communities are conceiving and responding to climate change.

CHAPTER 2

LITERATURE REVIEW - THE CULTURAL LANDSCAPES OF AMAZONIA

Forest, River and Flooded Forest Systems

The Amazon is the world's largest river basin and tropical humid forest, covering 40% of the land of South America (7,500,000 km^2; Sponsel, 1986) (Figure 2.1). The Amazon River runs for 6,275 km, from the Andes Mountains in Peru to the Atlantic Ocean in Belem, Brazil (Galindo et al., 2009) ranging from 1.6 to 13 km in width and an average depth between six and 12 m (Sponsel, 1986). It discharges 198,240 m^3 of water per second, close to 17 percent of all the water drained from all the continents (Galindo et al., 2009; Goulding, 1993; Herrera, 1989), and with a larger flow than the combined flow of the next ten largest rivers, hence its importance for the global hydrological cycle (Chen et al., 2010).

Depending on the area considered for the basin, different discharge and derived runoff can be established, reflected in the overall water budget; differences have been reported on the annual cycle of the water balance between the northern and southern sections of the basin (Costa and Foley, 1999; Marengo, 2006; Marengo et al., 2009; Marengo et al., 2001; Zeng and Neelin, 1999). The Amazon River flows exhibit a peak from May to June, different from the overall basin's peak that arrives later and reflects the required time for water to travel to the river mouth (Dai and Trenberth, 2003; Marengo, 2006). In general the amplitude of change in evapotranspiration (ET) and precipitation (P) is very low in northern Amazonia (Marengo, 2006).

The Amazon basin originated from ocean incursions that happened during the mid-Miocene (Goulding, 1993; Hamilton et al., 2001), and subsequent isolations that created fresh water systems in time, isolating several species (Hamilton et al., 2001). The Amazon has some of the earth's rainiest places (above the 2,000 mm/year) (Junk et al., 1989), which have remained with forest cover despite the drops of temperature that lead to savanna formations in other regions during the Pleistocene and Holocene. These served as wildlife refuges during these periods of time with some isolation that led to unique adaptations and that relate to the current endemism that account for the recognized biological diversity of the area (Herrera, 1989). Likewise, cultural diversity relates to these island effects that resulted in lack of contact between human groups and that partly explain the diversity of languages (Meggers, 1977, 1999).

The northwestern Amazon includes the Amazonas state in Brazil; the Amazonas and Putumayo Departments in Colombia; Cotopaxi, Los Rios, Morona-Santiago, Napo, and Pastaza Provinces and the Oriente Region in Ecuador; and the Loreto Region in Peru. A usual distinction between the different freshwater systems found in the area is based on the types of waters according to their biophysical and chemical composition. White waters have large quantities of sediments, black waters result from non-decomposed organic matter and are poor in nutrients, productivity, and species diversity (Goulding, 1993; Sponsel, 1986), and clear waters are greenish and carry insignificant amounts of suspended sediments and dissolved organic substances; despite being useful in broader terms, the properties of the water system in Amazonia changes seasonally (Gragson, 1992).

The Amazon region's oldest sediments were deposited during the tertiary when the area was covered by saltwater. In the uplands (above the floodline), soils can be 60 million years old with high acidity, aluminum toxicity, micronutrient deficiencies and low effective cation-exchange capacity (Sponsel, 1986). Erosion has resulted in a hilly landscape with larger mountains that resulted from the precambric period, while recent surfaces are formed by fluvial sediments that can be divided in three different levels with different landscapes and properties (Junk et al., 1989; Sponsel, 1986) including former terraces, varzeas or flooded forests and lower levels varzeas. Climate in the northwestern Amazon is highly humid, with overall high rainfall and seasonality marked by flooding of water bodies which is usually affected by ENSO events (Schwartzman and Zimmerman, 2005).

Amazonian varzea forests (Figure 2.2) are areas influenced by periodic floods of white waters and cover an area between 60,000 and 100,000 km^2 (Wittmann et al., 2004). These ecosystems are home to endemic plant and animal species and many trees that offer food resources for fish and other organisms particularly adapted for this kind of ecosystem (Padoch, 1999). Tree diversity diminishes the longer the period of the year that the area is flooded. Special adaptations to survive the anoxic conditions are required, including reduced metabolism during the aquatic phase, formation of hypertrophic lenticels and specific adaptations at the root level to the geomorphologic conditions (Wittmann et al., 2004). Flooding, natural forest succession, sedimentation, erosion and physical soil features determine the development of these areas that have been used since the pre- Columbian era.

Amazonia Cultural Landscapes

The main reason behind the success of humans as a species is the ability to adapt and colonize every single terrestrial habitat in the world, which we have achieved mainly by our ability to alter our means of subsistence by managing our habitat (ecological engineering) (Smith and Wishnie, 2000). Incorporating the idea of social landscape that includes land history analysis and social dynamics (Brosius and Russell, 2003) with the environment, gave rise to the notion of cultural landscapes. In the development of the field during the 1980s, it became recognized that humans had the ability to live in harmony with nature and the task of incorporating human history and influence in preservation began, valuing traditional ways of life and traditional values (Jacques, 1995).

Environmental determinism has been common in explaining human adaptation in the Amazon region viewing humans as agents that react to certain conditions; however, this view has been challenged and other authors argue for the recognition of humans as agents that transform the landscape actively (Balée, 1998; Denevan, 1966, 1996; Heckenberger and Neves, 2009; Heckenberger et al., 2007; Heckenberger et al., 2003; Woods and McCann, 1999). Most of the work by ethnologists question simplistic explanations in terms of single causes, emphasizing the complexity of variables related to cultural evolution in lowland South America, understanding how a multiplicity of factors influence subsistence practices (Jackson, 1975).

Amazon soils have been described as poor in nutrients (Meggers, 1977; Sponsel, 1986), except for varzea areas that are replenished by the periodical inundation of white waters. Framed in the availability of the Amazonian ecosystem to sustain human populations, two main views have shaped much of the research in the area (Rebellato et al., 2009); the first refers to environmental conditions as a limitation to social and cultural development given the easiness of soil depletion and difficulty in procuring protein (Gross, 1984; Meggers, 1971; Meggers, 1999; Steward, 1959), and the second views the Amazon as a cultural innovation center (Lathrap, 1970, 1973). According to the first, population size was limited by the environment (Meggers, 1971; Meggers, 1999), while the second argued that varzeas and adaptations as dark earths allowed for development and larger settlements than originally believed (Lathrap, 1970; Viveiros de Castro, 1996; Woods and McCann, 1999).

Livelihoods of indigenous peoples of northwestern Amazonia are dependent on the environment resulting in a very intimate relation, reflected in particular and detailed knowledge of local conditions and relations (Colchester et al., 2001; Cristancho and Vining, 2009; Davis and Wagner, 2003; Gadgil et al., 1993; Hames, 2007; Naveh, 1995; Nazarea, 1999, 2006; Sillitoe and Marzano, 2009; Turnbull, 2009). Amazonia as the romantic ideal of pristine ecosystems has been reconsidered, and currently it has been widely accepted that it is a product of human activity (Colchester, 2004; Colchester et al., 2001; Griffiths, 2004; Heckenberger et al., 2003). What is found today corresponds to millennia of human co-evolution with the natural environment. In the northwestern Amazon annual activities depend on the river levels and the influence it has on natural communities and physical processes and how human communities perceive their surroundings based on periodicity of the activities that make up social life (Harris, 1998).

The broad environmental history in the Amazon has had five phases (Bush and Silman, 2007) framed in the concept of domesticated forests- wild gardens:

I. Early human occupation based on fishing and foraging;

II. Subsequent intensification of land management for over 10000 years;

III. Depopulation triggered by the arrival of the Europeans with reforestation and secondary forest growth;

IV. Extractives and reoccupation of riverine ecosystems with population returns to pre-colonial levels (XIX and XX centuries);

V. Rapid environmental change after the war, mostly destructive and concentrated more in upland systems.

The cultural sequences exemplified by Roosevelt et.al. (1993, 1998), Willey (1971), Cleary (2001), Heckenberger (2009, 2007, 2003) show that early human evolution was not severely limited in humid tropical environments as compared with other systems (Adger et al., 2005). Human presence and environmental management have been recognized to exist for thousands of years in the Amazon, with estimates ranging from 4,000 to 10,000 thousand years (Heckenberger and Neves, 2009; Sponsel, 1986). There is difficulty determining dates due to a lack of preceramic horizon and the use of tools that degraded easily in the environment (Meggers, 1977, 1999).

Agricultural societies with complex organization appeared in several areas (around 8000 B.C.), and evidence of a dynamic trajectory of human adaptation is seen in these different studies, where Pleistocene foraging bands gave way to fishing villages along waterways in the early Holocene. Horticulture was adopted, and the use of pottery spread. Archaeological evidence suggests that Amazonian forests once thought to be pristine were settled, cut, burned, and cultivated repeatedly during prehistoric and historic times, and that human activities widely altered topography, soil, and water quality altering biodiversity patterning (Bush and Silman, 2007; Heckenberger and Neves, 2009; Heckenberger et al., 2007; Heckenberger et al., 2003).

In the Amazon basin, there are three major families that account for most of the languages found throughout the region: Arawakan, Tupi-Guaranian, and Caribbean, with isolated languages on the periphery of Amazonia. According to Meggers (1977) this could be the result of forest transgressions that originated in the southwestern region which resulted in over 25 distinct languages from different families with similar adaptations that can reflect cultural convergence providing a means to humans for food storage and transportation while more productive habitats were found (Meggers, 1977, 1999).

Going beyond the traditional explanations of optimal foraging theories and human behavioral ecology, kinship systems use descent as an explanatory principle where cosmologies become regulative and symmetric alliances are part of the social organization in the whole region (Viveiros de Castro, 1996).

For many of the Amazon groups, animals and plants have human characteristics that allow them to have similar capabilities and maintain relationships between them and their communities in a manner similar to humans (Vacas Mora, 2008).

Change resulting from Western contact has been sudden, rapid and deep, resulting in population decimation that accounted for reductions from 6.8 million people, mainly concentrated in the floodplains of the major rivers and the disappearance of chiefdoms consequence of disease, slavery and warfare (Dufour, 1990; Harris, 1998). Even to recent times this decimation continued, particularly during the rubber boom by the end of the 19th Century and beginning of the 20th Century when thousands of indigenous people were killed (García Jordán, 2001; Hemming, 2008).

Seasonality affects the biomass, productivity, species diversity, composition, structure and function of the plant and animal communities in the Amazon basin (Goulding, 1993; Wittmann et al., 2004), resulting in differences across the year to which humans have developed different adaptations (Sponsel, 1986). Seasonality determines human movements and the rhythms of social activities.

With river variations between 6m and 10m, these changes influence annual activities as people depend on the water levels that determine fish migration, animal movements, soil hardening, plant growth, etc., defining the periodicity of human activities (Harris, 1998). Although it is believed that settlement in the Amazon followed the rivers, according to Denevan (1996) these were mainly in higher grounds near rivers, but that were not seasonally flooded given the risks this would impose. Evidence for this is found in dark earths that appear to exist in higher grounds, while varzeas were mainly used for seasonal crops and for fisheries.

Livelihoods

Livelihoods mostly depend on hunting, gathering, fishing and some subsistence agriculture (Fajardo and Torres, 1986; Perez et al., 1999) based on shifting cultivation with manioc as the main crop (Andrade, 1988; Dufour, 1990; Sponsel, 1986). According to most authors, this way of life relates to low population density because it requires long periods of rest for the land and large areas per person for it to be productive, preventing high population concentration (Andrade, 1988; Meggers, 1999). Dark earths resulted from intentional and unintentional processes that involved the use of byproducts resulting from traditional subsistence practices (Heckenberger and Neves, 2009; Heckenberger, 2008; Rebellato et al., 2009) as fertilizers and have been associated with archaeological remains, considered evidence of intensive agricultural practices (Andrade, 1988).

Agriculture and horticulture take place in the *chagras* (farming fields) that are mainly established in firm land and in seasonally flooded areas (Figure 2.3), cleared for seasonal agriculture (Andrade, 1988; Wittmann et al., 2004). It has been argued that they allowed for larger human settlements with political centralization and economic specialization even more complex than contemporary groups (Viveiros de Castro, 1996).

Shifting agriculture uses environmental conditions and processes where the slash allows for more photosynthetic activity and the burn is believed to return soil nutrients; it has been shown that farming fields are usually used for long periods of time since even when no agriculture is taking place in them. They are still used as gardens for certain plant species and also to attract certain kinds of game (Andrade, 1988; Dufour, 1990; Harris, 1971; Sponsel, 1986). With western contact, the most significant changes in this type of agriculture were the introduction of steel replacing stone tools and the introduction of crops different from those traditionally known to the region (Andrade, 1988).

Fish are more abundant and productive than game, being more dependable. Indigenous groups in the area have become adapted to seasonality regarding fishing (Harris, 1998) (figure 2.4); the effect of the type of water on the distribution of fish is not as important as landscape and habitat changes. Fishing is the most important source of quality protein, particularly in the dry season when water level concentrates fish and because more people can take part in this activity (Sponsel, 1986)

Fishing techniques are varied in order to exploit the diversity of fish. Differences between fishing and hunting relate to life histories of the species used and their status, although the number of species captured by human groups depends more on natural history and procurement decisions. When the water levels increase, the flooded forests open a new niche for fish where they feed on other fish, fruits and leaves, insects and other materials (Gragson, 1992).

Trading is frequent inside and between tribes and involves the circulation of people and resources. Nomadic societies were common until recently, with groups as the Maku of the northwestern Amazon or the Kayappo in Brazil that relied on nomadic foraging (Dufour, 1990; Sponsel, 1986).

Traditional Ecological Knowledge and Conservation

Traditional ecological knowledge has been defined as the "…cumulative body of knowledge and beliefs handed down through generations, by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Gadgil et al., 1993, p. 151; also similar definition in Brosius 1997). It is critical for environmental sustainability and human adaptation (Posey et al., 1984). For some authors it includes mainly two domains; a theoretical realm for the ability to name species or uses of species and a practical realm for the ability to associate names with organisms or the ability to use that knowledge (Godoy et al., 2006).

Traditional knowledge is collectively owned and is seen through stories, songs, folklore, proverbs, cultural values, beliefs, rituals, community laws, local language, and agricultural practices, being mainly practical in nature (UNEP, 2007). Recognizing its importance is understanding that local cultures know their biophysical world intimately and are experts on managing them in order to meet day to day requirements and make the most of occasional opportunities (Davis and Wagner, 2003; Nazarea, 1999, 2006).

Accordingly particular ways of life are developed in a framework of collective property (Zuluaga Ramírez, 2005) and that relates to decision making connected to natural resource management, nutrition, health, education, and community organization for many indigenous communities on a local level (Warren et al., 1995).

Northwestern Amazonia exhibits seasonality based on precipitation regimes, river levels, winds and temperature fluctuations. Research on seasonality study the relationship between environment and society from two main perspectives: as the strict determinant or generating complex dependency. Periodicity has been seen as intrinsic to life in the responses of people and embedded in their particular environment where in many cases the passage from one season to another is marked by rituals and reflected in productive cycles that modify social structures (Harris, 1998).

In northwestern Amazonia, survival depends on detailed local environmental knowledge and technical expertise (Harris, 1998; Stearman, 1994) to be able to manage transitions appropriately depending on the seasonal changes and the technical skills required for each of the different activities that take place (Harris, 1998).

Aboriginal cosmologies and myth structures coupled with the derived ritual behavior represent ecological principles that result in a system of social and economic rules with highly adaptive value maintaining the equilibrium between resources and society's demands (Reichel-Dolmatoff, 1976; Reichel, 1999). Totemism (the belief of humans having a connection with other physical beings) affects nature "by raising certain species to prominence, by serving to consign others to relative obscurity by down-grading them, and by shifting pragmatic attention to other less salient forms through restrictions attached to the more salient." (Ellen, 1993 p. 175). Food taboos create laws and restrictions that modify environmental exploitation efficiency allowing for long- term adaptation based on sustainability in time (Reichel-Dolmatoff, 1976; Ross et al., 1978; Sponsel, 1986).

Indigenous knowledge as part of a conservationist discourse has been used with two meanings mainly; one objectivist and one environmentalist that reflect indigenous understandings, interpretations and uses of the environment. The objectivist form deals with adaptation and utilitarian uses of knowledge (Brosius, 1997). Among the many discourses affecting conservation relevant for the northwestern Amazon, probably one of the most important is the construct of the noble savage, which is a stereotype based on the idea that native peoples lived in harmony with the environment (Forero, 2002; Hames, 2007) and are defenders or guardians of nature concerned in maintaining ecological processes (Stearman, 1994).

It has been recognized that indigenous people know of several uses of biodiversity and of the adequate manner to forage for the resources (Gadgil et al., 1993). This sustainable use and management of resources and habitats by small-scale societies has been linked with spirituality and practical understanding of the environment (Smith and Wishnie, 2000).

Local knowledge and cultural memory serve as storage for alternatives of cultural and biological diversity that are crucial for biodiversity conservation and reflect the sophisticated knowledge that results from living in a particular environment and dealing with its constraints over time, creating practices that allow local people to have a wide variety of species and varieties in their home gardens and their fields (Davis and Wagner, 2003). This idea was reinforced by authors as Rappaport and Meggers who presented cultures or populations as units of selection with stable population control mechanisms (Hames, 2007) and with cosmologies that allowed for a sustainable use of resources (Reichel-Dolmatoff, 1976; Ross et al., 1978). Despite the outcome, it was argued that this couldn't be accounted for as conservation.

The need to differentiate conservation from sustainability and management (Hames, 2007) was addressed. Sustainability science is concerned with "issues such as self-organizing complexity, vulnerability and resilience, inertia, thresholds, complex responses to multiple interacting stresses, adaptive management, and social learning, and is committed to place-based and solution-driven research encompassing local, regional, and global scales" (Wu, 2006, p.3). In the Amazon it is believed to be the result of low human population density, low demand for resources and limited technology (Smith and Wishnie, 2000).

Conservation is divided into intentional and epiphenomenal (side effect); the latter is very similar to what is understood by sustainability (Hames, 2007). Intentional conservation implies design and cost and it should yield measurable results that demonstrate the prevention of resource depletion, use or degradation (Smith and Wishnie, 2000).

Intentional conservation is outside of the preconceived notions of indigenous peoples (Stearman, 1994) and very rare in small-scale societies; it is recognized as a western construct (Smith and Wishnie, 2000). Many authors argue that not recognizing indigenous peoples as conservationists can have profound implications regarding basic rights to land, resources, and cultural practices (Hames, 2007; Smith and Wishnie, 2000).

The role of real causes behind resource depletion becomes relevant according to Hames (2007) and Smith (2001) for "real" conservation to occur, so that knowledge between the causes of resource depletion is part of the decisions made. For the authors portraying indigenous communities as noble savages has negative consequences as well since it depicts an idea of these groups being static in time (Hames, 2007; Smith and Wishnie, 2000) and doesn't really correspond with reality since it doesn't reflect their past or the entire diversity of native peoples (Brosius, 1999). This imposed ideal also conflicts with public expectations that perceive very negatively the use of indigenous groups of their resources with potential consequences on land rights topics (Forero, 2002; Stearman, 1994).

Cultural Diversity

Over 50 different indigenous groups can be found in the northwestern Amazon, being the Aruan, Arawakan, Kaxinaua, Yaminaua, and Amahuaca languages the dominant ones (Pollock, 2011). Amazonian societies exhibit different complex relationships that have been studied by several authors, many of whom believe that sociality is mainly about kinship or affinity (Santos Granero, 2007).

In some cases relationships go beyond kinship and underlie complex relations as trade and are believed to fulfill important pragmatic objectives including goods, knowledge and mainly security. These relations also offer an alternative to the mandatory kinship structures that can be conflicting, enlarging the network of safe relations for the individual and the group (Santos Granero, 2007). The diversity in languages and ethnicities in northwestern Amazonia mirror centuries of contact and exchange between cultures reflected in extensive trade networks (Sponsel, 1986).

Kinship relationships allow for multilingualism as is the case of the Eastern Tukanoan and Arawakan language families (Sorensen, 1967; Stenzel, 2005) or are determinant in maintaining power relationships and endo/exogamic relations depending on the rules the groups share.

Tikunas are the largest group found in the research area and are distributed throughout the Peruvian, Brazilian and Colombian Amazon. They are divided in clans clustered in two groups: the earth and air clans. The clans have a prescriptive marriage that favors the endogamous control of territories and settlements, and although the marriage system is denominated a hyper totemic exogamous moiety (each of two social or ritual groups), there is no significant exchange of females between villages (Oyuela Caycedo and Vieco Albarracín, 1999).

Loss of local knowledge research commonly relates this with age, gender roles, schooling, market integration, biodiversity loss and enculturation to western systems (Zent, 2009). The loss of traditional ecological knowledge results as time and resources invested in school deflect from investments in folk knowledge provided that people cannot learn two things at the same time (Godoy et al., 2005). Until recently, science had been resistant to the value of indigenous knowledge; however given current cultural transformation it has been recognized the amount of information that is being lost (Brosius, 1997).

If local knowledge is not being transmitted as it was in the past, then new generations are not as well prepared as their ancestors to cope with environmental variability (Duerden, 2004). Relying more on abstract learning, the gradual disappearance of the knowledgeable elder generation and young people's lack of interest in acquiring traditional knowledge, have resulted in a process of cultural transformation, or acculturation, in which rituals through which the knowledge was transmitted have changed (Cristancho and Vining, 2009).

According to Cristancho and Vining (2009), traditional ecological knowledge transmission is part of the socialization process and it is related to the transmission of values, knowledge, and skills from older to younger generations at various life stages that are intended to facilitate adaptation to the larger society and are crucial for the survival of those groups that depend directly on their local environments.

Most of the studies related to transformation in local knowledge can be placed under four areas that include social organization of knowledge, social position of knowledge as performance, transmission and learning, globalization and intergenerational changes (Zent, 2009). Studies agree that local knowledge is informally and unconsciously transmitted from very early ages in custom contexts through observation and experience (Sillitoe and Marzano, 2009); it usually comes from caregivers and is learner-directed. This knowledge is explicit and socially transmitted like scientific knowledge; however, conservation knowledge is not explicit and is mainly centered on restraints for resource use (Gadgil et al., 1993).

Current Conditions

Currently the Amazon region faces numerous threats that include population growth, resource over-exploitation, habitat degradation, deforestation, fragmentation and climate change (Armenteras et al., 2006; Costa and Foley, 1999). Governments have currently turned to economic development, integration, and national security with ideas of development based on different priorities such as hydroelectric and flood control projects that have significant effects on traditional ways of life (Sponsel, 1986).

Varzeas are currently disappearing in several areas as a result of selective logging and forests clearing to enable agricultural use (Wittmann et al., 2004). Animal husbandry has been a development axis lately in Amazonia, causing important environmental consequences related to soil degradation and ignoring traditional adaptation systems where indigenous groups are being absorbed into these new approaches (Andrade, 1988). In places like Colombia, another important source of deforestation comes from the establishment of illegal crops (Armenteras et al., 2006).

Physical changes related to climate change and global warming are already showing some effects. According to Chen et al (2010) terrestrial water storage show significant increases in the Northern lower Amazon basin as well as an increased inter annual variability that relates to this phenomena after 2002 and there is evidence that some of the recent major floods and droughts in the Amazon basin are related to El Niño and La Niña events (Chen et al., 2010) which are now more frequent and intense (Chen et al., 2010; Langerwisch et al., 2012).

Among human communities, contact with western civilization is having several effects. Some changes reported involve traditional production conversions as the Guayaki and Mura who abandoned shifting agriculture to specialize in hunting and gathering, or the Shiriana, Guaharibo and Macú, who changed from hunting and gathering to agriculture; traditional systems appear to be absorbed into introduced practices brought by other groups (Andrade, 1988).

With the Witoto and Andoke in 1977 marked differences were reported between crop composition of younger and older generations having the latest greatest crop diversity, while younger people tended toward homogenization (Andrade, 1988). This is having an effect on the quality of the indigenous diet and the decline in their nutritional and health status that has been reported parallel to cultural changes (Sponsel, 1986).

One impact of colonization was reflected in simplistic images of indigenous people as primitive and dangerous (Lauderdale, 2008). The Amazon region has been greatly affected by colonization processes that have led to severe deforestation, resulting in the loss of the majority of indigenous medicinal plants and the consequent impoverishment of their culture and their traditional medical system (Ramirez, 2007; Zuluaga Ramírez, 2005).

Landscape changes and overall habitat degradation affect local knowledge since terms and knowledge are forgotten as the objects of that knowledge disappear (Ellen, 1993). The Amazon region currently reflects the close relation between the destruction of tropical forests and other ecosystems and the decrease of biological diversity as well as cultural loss (Ramirez, 2007). *Colonos* (non-indigenous people living in the area) moving to areas historically inhabited by indigenous people have deepened transformations (Ramirez, 2007).

Indigenous peoples of the northwestern Amazon have varied land rights depending on the country; however, they all share a similar story of non-recognition of indigenous territories transformed into peasant social models that promoted colonization and finally to the modification of most constitutions granting indigenous peoples collective rights over the territories with local variations by country; however, this recognition hasn’t stopped the constant need of indigenous groups to protect their territories from encroaching, megaprojects, illegal crops and armed groups and private interests (Colchester et al., 2001; Griffiths, 2004).

In Colombia indigenous groups continue struggling for recognition of their territories and ways of life mainly with the government and armed groups that threaten their right to define and manage their environments independently from western ideals (Forero, 2002).

Making sense of how the world behaves has been oversimplified by science leading to a disconnection with nature, hence, the absence of the self-regulatory mechanisms that evolved in traditional societies as they faced resource limitations, and that led to biodiversity conservation as an indirect effect of maintaining the general productivity of a given habitat (Gadgil et al., 1993).

The scientific and industrial revolutions had profound consequences leading to social, economic, and cultural transformations that resulted in modernity. It has been defined by great demographic growth, urbanization, the use of energy derived from fossil fuels, the generation of nuclear weapons, the development of artificial intelligence, the accumulation of consumer goods and a radical cultural change that has resulted in large-scale homogenization of cultures (Zuluaga Ramírez, 2005). The right for indigenous people to decide if they want to use and have access to information and communication technology needs to be acknowledged within the right to be informed in the current globalizing and hybridizing culture and economy (Forero, 2002).

Lauderdale (2008) defines globalization as changes on political, economic and cultural levels that increase interdependence, integration, and interaction between people and institutions on a worldwide scale and have resulted in ever larger trading and political relations. It has been recognized as one of the main causes for traditional knowledge loss (Berry, 2003). Change resulting from Western contact in the present is in the form of economic development, integration, and national security (Sponsel, 1986). Colonization has been facilitated by opening roads that have allowed access to previously isolated communities and have accelerated the process of cultural change (Colchester, 2004; Griffiths, 2004).

Local knowledge systems are not isolated since they incorporate and reinterpret features of Western knowledge into their own systems (Sillitoe, 1998). Symbolic processes can accomplish reorientations of social and economic relations (Wright and Hill, 1986) as people who participate in markets must acquire new language skills, attitudes, and values (Lane 1991, Bowles 1998, Lazear 1999 in

Godoy et al., 2005). One of the main effects of increasing integration into the market and population pressure, results in indigenous communities degrading natural resources (Godoy et al., 2006). Before, simple technology, low population growth and no market interests had maintained local populations. Currently most indigenous communities depend on agriculture and commerce with outsiders, changing the way in which they use natural resources as well as how local knowledge is distributed and valued (Godoy et al., 2006).

Climate Change: Variability and Uncertainty

Climate change is an alteration in the state of the climate that can be identified by variations in "the mean and/or the variability of its properties, and that persists for an extended period of decades or longer" (Hegerl et al., 2007, p. 667). It can be caused by naturally occurring external influences or by changes in the composition of the atmosphere. Such changes are distinct from natural variability, and occur on different time scales, a fact that increases the difficulty when distinguishing between the two. Even so, there is now general scientific consensus on the impact of human activities in recent global climate change (Hegerl et al., 2007). The difficulty to predict the effects of global climate change, paired with the difficulty to separate them from natural occurring variability and the fact that one of the effects is that this variability will be exacerbated (Marshall et al., 2008), has led to one of the major problems when doing research in the field: uncertainty. In practical terms one of the main problems with climate change studies lies in the increase in climatic variability and the occurrence of extreme weather events accompanied by a lack of knowledge of how this will be manifested on local levels (Duerden, 2004; Marshall et al., 2008).

The climate change field borrows several concepts from ecology. These concepts include resilience, vulnerability, adaptation and adaptive capacity. These terms are relevant in the biophysical and in the social fields, since they can lead to a better understanding and communication across disciplines (Gallopín, 2006). Ecological and social resilience may be linked through the dependence on ecosystems of communities and their economic activities linked by institutional structures that govern the use of natural resources (Adger, 2000).

Vulnerability is the product of the interaction of biophysical and human processes, stresses and shocks acting on the system (Brondizio and Moran, 2008; Eakin and Luers, 2006; IISD et al., 2003). It is a function of the capacity to foresee, prevent, react, cope with and recuperate from the impact of events implying the loss of tangible and intangible assets (Berkes and Jolly, 2001; Lampis, 2009) and the extent to which a natural or social system is susceptible to or unable to cope with the negative effects depending on how sensitive it is to environmental changes, its ability to adapt and the degree of exposure (IPCC, 2007). Resilience is defined as the capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks (Adger, 2000; Berkes and Jolly, 2001; Cumming et al., 2005; Walker et al., 2004), as well as the degree to which the system is capable of self-organization (Berkes and Jolly, 2001).

Social resilience is the ability of a community to withstand external shocks and stresses without significant consequences, as a result of the dynamic structures of livelihoods, access to resources, and social institutions (Adger, 2000) and the community's ability to build and increase its capacity for learning and adaptation (Berkes and Jolly, 2001).

Uncertainty has not been widely studied in social systems beyond the idea of how local systems and institutions respond to it (Adger, 2003; Berkes and Jolly, 2001; Crate, 2009; Dietz et al., 2003; Marshall et al., 2008). The concept is taken to another level in the recognition that human societies aren't passive and they respond and adjust to the current changes in climate that they perceive. Uncertainty is inherent in the responses leading to the difficulty of being able to predict how human communities are going to respond to the different changes (Crate, 2009; Duerden, 2004).

Human and natural systems have been able to respond to climate change in the past. The current state of these systems is what determines their overall vulnerability, resilience and adaptive capacity, since other sources of degradation (cultural and ecological) create a darker scene for both natural and social systems in their ability to respond and maintain their basic functions in a given context (Crate, 2009; Laurance, 1998; Marshall et al., 2008; Petit et al., 2008). As Petit et al. (2008) explain "…future extinctions of tree species in response to climate change are probable, especially if their geographic distribution or climatic range is already highly restricted." (p. 1451).

Amazonia and Climate Change

Amazonia has important functioning ecosystems of great relevance to both containing and adapting to climate change; including the largest tropical forest that works as an important carbon sink (Bunyard, 2007). Changes in the northwestern areas of South America include increases in temperature of 0.5 to 0.8°C during the last three decades (Costa Posada, 2007; Quintana-Gomez, 1999), for the Amazon these changes have also been recorded since 1960 (Victoria et al., 1998). Precipitation has also changed depending on the part of Amazonia that is considered. Precipitation is expected to increase together with changes in seasonality of rains (Bush et al., 2007; Christensen et al., 2007; IDEAM, 2010; IDEAM et al., 2015) while in the southern Amazon the seasonal precipitation index has decreased by 0.32 per decade since the 1970s (Li et al., 2008).

Climatic variability in the area is strongly influenced by El Niño Southern Oscillation (ENSO) that creates droughts and the delay of the rainy season as well in southern Amazonia, while floods (Figure 2.5) and changes in rain patterns occur towards the northwest (Sombroek, 2001). ENSO events have changes in asymmetry between different years, creating both El Niño and La Niña, which changes conditions, resulting in lowered predictability capabilities to plan accordingly (An, 2004; Magrin et al., 2007; Roncoli, 2006).

The main constant regarding predictions of global climate change for Amazonia is uncertainty, and different models reflect different results for an area that has a large variability depending on microclimates leading to impossibility to develop conclusive assessments of the regional changes expected for the entire area (Christensen et al., 2007; Magrin et al., 2007; Marengo, 2006).

Uncertainty regarding rainfall is also common, except for some consistency among models predicting increases in rainfall for northwestern Amazonia and decreased rainfall in the southeastern regions (Bush et al., 2007; Christensen et al., 2007; Marengo, 2006). Extreme precipitation is expected to create more intense wet days per year in south-eastern South America and central Amazonia and weaker precipitation in the northeastern area of Brazil (Christensen et al., 2007; Magrin et al., 2007).

Average air temperatures in the region are expected to increase linearly with time, but the magnitude of this increase is still in dispute, ranging from 1.8°C to 5.0°C between 1999 and 2080/2099, with a mean of 2.6°C to 3.6°C (Christensen et al., 2007; Magrin et al., 2007).

Changes in temperature and precipitation levels are expected to create major forest dieback, transforming large areas of tropical forest into savannahs and causing a related decline in net productivity and increase in carbon release (Magrin et al., 2007).

Land use changes resulting from the change in biophysical conditions for the region, together with the expected changes related to climate change are expected to have impacts including erosion, freshwater systems degradation, loss of soils, accelerated biodiversity loss, decreased agricultural yields, increased insect infestations and severe consequences on human health (Magrin et al., 2007; Nobre et al., 2005).

Water regime changes are expected and have actually already been observed (Echeverri, 2009; Kronik and Verner, 2010a; Kronik and Verner, 2010b; Ulloa et al., 2008) affecting flow, flooding, runoff and erosion (Carpenter et al., 1992). This affects essential aspects of people's livelihoods including fisheries, agriculture, basic water supply and transportation since in many cases the river is the main or only mean of access to many villages (Pinilla Herrera, 2004).

Indigenous peoples are ethno-climatologists that given their experience and knowledge can see that things are changing and are actively responding to the changes they perceive in their environment (Crate, 2009; Duerden, 2004; Green et al., 2010; Green and Raygorodetsky, 2010). Studies involving indigenous perception and observed changes in climate have been done mostly in northern latitudes (Berkes and Jolly, 2001; Crate, 2009; Cruikshank, 2005; Duerden, 2004; Gearheard et al., 2010; Turner and Clifton, 2009) in Asian-Pacific states (Green et al., 2010; Lefale, 2010), and in Africa (Ifejika Speranza et al., 2010; Orlove et al., 2010).

It is now well recognized that people are not passive victims and their high adaptive capacity is linked to their deep and general knowledge of their contexts (Crate, 2009; Cruikshank, 2005; Duerden, 2004; Nelson et al., 2009). The increase in climate variability has diminished or taken the ability of indigenous peoples of predicting weather and other environmental phenomena (Adger et al., 2009; Berkes and Jolly, 2001; Crate, 2009; Cruikshank, 2005; Duerden, 2004; Echeverri, 2009; Kronik and Verner, 2010a; Kronik and Verner, 2010b; Ulloa et al., 2008) threatening their adaptive capacity.(Cruikshank, 2005).

The importance of climate lies in the influence it exerts on ecological phenomena determining organisms distribution and activity, as well as physical characteristics of a given ecosystem, including its connections with other ecosystems and the spread of disturbances that determine the optimal functioning of specific processes and that result in having an effect on human population distribution and human land-use practices (Echeverri, 2009; Marshall et al., 2008). Perception of climate change is structured on activities and related knowledge and on the landscape and the opportunities it provides (Vedwan, 2006).

Elders and local experts are losing credibility as climatic conditions have become impossible to predict, which has resulted in status decline and in younger generations looking elsewhere for solutions to their problems, seeking other bodies of knowledge (Cristancho and Vining, 2009) and migrating as a response to the limitations of their traditional knowledge and ritual specialists in the face of the effects on the seasonal calendars (Kronik and Verner, 2010a; Roncoli, 2006).

Seeking constant and unchanged systems with fixed rules usually results in “mal-adaptation”, especially in systems that are facing the effects not only of climate change, but also of globalization, where customs and traditions are being transformed (Roncoli, 2006) and the connections between local knowledge and local environments is being lost. This can result in a diminished capacity to recognize and implement sustainable adaptation strategies to climate change effects (Salick and Ross, 2009).

In the Amazon in particular increased deforestation can change the water cycle and therefore the climate on the region and in the planet. This paired with climate change can accelerate the hydrological cycle, influencing precipitation by increasing evapotranspiration, which adds moisture to the atmosphere and if recycled, directly increases rainfall. It can also increase latent heating, which associated with this increased rainfall can drive an intensified circulation resulting in changes to the moisture convergence from remote sources (Marengo, 2006).

Misinterpretations and mistrust of climate predictions that result from a mismatch between the cognitive frameworks of users and producers of climate forecasts have been recognized; however, not much has been done to understand the cultural meanings and social life implications of this climate knowledge (Roncoli, 2006).

Meaning is grounded in locality, being considered valid only for the specific site where they are produced (Cruikshank, 2005; Nelson et al., 2009). Local perceptions have proven to be related to overall climate trends and in general livelihood strategies are changing in order to accommodate to these perceived changes by diversifying livelihoods and accommodating agricultural practices (West et al., 2008).

Figure 2.1. The Amazon basin covers 40% of South America.

Figure 2.2 Varzeas (Periodically flooded areas). *Photo by Rocio Rodriguez Granados (Puerto Nariño, Amazonas, 2012)*

Figure 2.3. Chagras (farming fields) and produce resulting from agriculture. *Photos by Rocio Rodriguez Granados (Puerto Nariño, Amazonas, 2013)*

Figure 2.4. Traditional fishing, net repair and catch obtained. *Photos by Rocio Rodriguez Granados (Puerto Nariño, Amazonas, 2013)*

Figure 2.5. Flooding and drought in Puerto Nariño. *Photos by Rocio Rodriguez Granados (Puerto Nariño, Amazonas, 2012)*

CHAPTER 3

RIVER LEVEL TRENDS OVER THE LAST 25 YEARS IN THE COLOMBIAN AMAZON[2]

[2] Rodriguez Granados, R., Prebyl, T., Hatt, J.L. and N. Nibbelink. To be submitted to Climatic Change

Female, 59 yrs. Old

"Pues doctora eso fue muy grande el invierno de este año, alcanzaron a tapar todas las semillas que teníamos guardadas en las chagras prendidas, palo de yuca. En ese tiempo alcanzaron a tapar todo y entonces por ese caso ahorita está escaso. Los palos de yuca se perdieron todos y ahorita pues hay poquito, poquito. Se consigue la semilla para trasplantar al rio, a la isla. Entonces ahorita pues se siembra es maíz, sandilla, zapallo, ese es que se siembra ahorita. Si generó muchos problemas, porque después de eso pues ya... a veces llega tan pronto el creciente. Rapidito crece y el sembrío en la baja arroces... ahí veces se pudren los arroces cuando apenas están espigando, todo eso le tapa."

… That was very large, the winter this year, it covered all the seeds we had in the chagras, the manioc clippings. In that time it covered everything and that is why right now it is scarce. The manioc clippings were all lost and know there is very little. You can find the seeds to plant in the river, the island. So now we are planting corn, watermelon, zapallo, that is what we are planting right now. It created a lot of problems because sometimes the flood arrives very early. It floods fast and the crops, the rice… the rice rots before they are ready, they are completely covered.

Abstract

River levels are essential for local livelihoods in the Colombian Amazon, but also for distribution and arrangement of ecosystems and the associated plant and animal communities. Although previous studies have considered variability in the region in terms of discharge and flow, the practical implications of river levels have not received the same attention. Water regime changes are expected and have already been observed affecting flow, flooding, runoff and erosion. This study examines the 25-year (1988 – 2013) variability of river levels registered by the Colombian Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) in a local station on the main channel of the Amazon River. Within this 25-year record, there is a statistically significant increasing trend in flooding levels which has an important effect not only in ecosystem distribution but also on river morphology dynamics. It is very likely that given higher floods, larger flooding periods will become more common as well. This trend reflects possible changes in water transport within the basin that can be the result of global climate change paired with land use changes in the region. This affects essential aspects of people's livelihoods including fisheries, agriculture, basic water supply and transportation since in many cases the river is the main or only mean of access to many villages. Despite uncertainty regarding climate change scenarios, the need to understand the implications of global, regional and national trends on a local level is demonstrated by this study.

Introduction

Amazonia Hydrology

Seasonal patterns in river level are not only critical for ecosystem function and species composition (Langerwisch et al., 2012) but also essential for local livelihoods in the Colombian Amazon (Echeverri, 2009; Pinilla Herrera, 2004). Water regime changes are expected and have already been observed affecting flow, flooding, runoff and erosion (Marengo, 2006). However, little is known about shifts in the magnitude and seasonality of peak water levels and flooding patterns, which are important for subsistence agriculture and fishing. To understand if and how these patterns are changing we evaluate 25-years of river level data of a limnographic station in the Colombian Amazon.

The Amazon basin is the largest in the world; it covers 40% of South America and includes six countries, with an area of 7,500,000 km^2 (Chen et al., 2010). The Amazon River runs for 6,275 km, from the Andes Mountains in Peru to the Atlantic Ocean in Belem, Brazil (Galindo et al., 2009). It ranges from 1.6 to 13 km in width and an average depth between six and 12 m (Sponsel, 1986). The mean discharge of the Amazon River is 198,240 $m^3\ s^{-1}$, it is responsible for 17% of all the water drained from all the continents (Galindo et al., 2009; Goulding, 1993; Herrera, 1989), with a flow larger than the combined flow of the next ten largest rivers. The northwestern Amazon basin, which properties differ significantly from those of the southern Amazon, corresponds to 14% of the Amazon basin and has a drainage area close to 878,300 km^2 with a mean discharge of 35,500 m^3s^{-1}. This area includes the lowland Amazonian and the mountainous Andean regions (Zubieta et al., 2015). It is among the rainiest regions of the world and an important source of water vapor (Salati and Vose, 1984) and contributes significantly to the global hydrological cycle (Chen et al., 2010). Costa and Foley (1999) reported a decrease in water vapor into the basin associated with large-scale changes in the general circulation of the tropical atmosphere.

River flow is not constant throughout the basin, with steeper slopes near the Andes resulting in higher flows (Langerwisch et al., 2012). Flow of the Amazon is subject to inter-annual and long-term variability in tropical precipitation (Marengo, 2006), and annual flooding in the region is highly influenced by snowmelt in the Andes and precipitation across the basin. Water levels vary between five to 15 m, submerging trees in certain areas up to 230 days $year^{-1}$ (Junk et al., 1989). In the western Amazon, river flows are at its highest between May and June (Marengo, 2006) and river levels reach the highest levels between April and May (Chen et al., 2010; Costa and Foley, 1999) and lowest level in the latter half of September (Figure 3.2). The variation between high-water and low-water range from a recorded minimum of 0.24m which took place in 2010, an exceptionally dry year, to maximum levels of 14.15m (recorded in 2012, the year with the highest recorded floods in the region).

Amazon Landscapes

Flooding patterns determine the distribution of vegetation (Langerwisch et al., 2012). Landscapes are dynamic and constantly transform as a result of periodic flooding and this translates into high unpredictability from year to year in the location and configuration of lowland territory. There are no boundaries between lakes, rivers, land and islands during high waters and people and natural communities have become adapted to these patterns that determine fish migrations, animal movements and agriculture (Harris, 1998).

Varzeas are landscapes that are strongly affected by flooding pattern seasonality. Varzea forests are seasonal floodplain forests inundated periodically by white waters, which are rich in sediments (Sponsel, 1986). In the Amazon, these forests cover between 60,000–100,000 km^2 (Goulding, 1993; Junk et al., 1989) and are only found less than 300 m.a.s.l. and with widths ranging between 20-100 km (Sponsel, 1986). Periodic flooding deposits nutrient dense sediments in these areas (Junk et al., 1989; Shorr, 2000; Sponsel, 1986), and riparian forests along river margins protect water quality and provide resources to aquatic fauna (McClain and Cossio, 2003). Varzeas are unique ecosystems with numerous endemic plant and animal species and provide critical habitat for aquatic fauna. Vegetation in these areas is influenced by the duration of flooding, which affects the physiology of the plants and results in particular adaptations to anoxic conditions and strong currents that occur during the flooding season (Wittmann et al., 2004).

The richness of varzeas has been historically recognized, resulting in one of the most used ecosystems, particularly for agriculture (Wittmann et al., 2004). Local livelihoods depend mainly on semi-intensive agriculture, slash and burn agriculture, gathering, fishing and hunting (Fajardo and Torres, 1986; Sponsel, 1986). Agriculture is mainly established in the uplands where the ground is dry year-round and on the lowlands where seasonal floods replenish nutrients, allowing continuous use of the *chagras*, or farming sites (Harris, 1998; Pinilla Herrera, 2004; Shorr, 2000). Agriculture in the varzeas has adapted to water levels and people have selected crops dependent on location and duration of flooding (Shorr, 2000).

Hunting and gathering typically occurs in the drylands where established forests serve as sources of different species including fruits, medicinal plants, woods and plants (Fajardo and Torres, 1986). Hunting also takes place in the *salados* (mineral licks), although it has become rare given the scarcity of animals. Fishing is the most reliable and preferred source of animal protein in the region and occurs in all water bodies, depending on the time of year (Sponsel, 1986). This activity is contingent on the water levels since fish movement coincides with changing levels, with adjustments in fishing techniques and locations. Fishing is harder with increasing water levels because fish move into the flooded forests and more readily disperse in larger water volumes (Harris, 1998).

Water and aquatic resources are central for local communities. Native fisheries are key for protein intake and water is taken directly from rivers and lakes for human consumption, in many cases without any treatment. It is also used for cleaning purposes (Lavado Casimiro et al., 2011). Water bodies are crucial for local transportation as well (McClain and Cossio, 2003), as the only way to reach many isolated communities and the only means to access formal education and western health care.

Climate Change and the Hydrological Cycle

In the study region, the hydrological cycle determines timing and location of many activities of plant, animal, and human communities (Harris, 1998; Pinilla Herrera, 2004). The hydrological cycle is a product of the climate and the biogeophysical attributes of the surface exerting an influence on climate beyond the interaction between the atmospheric moisture, rainfall and runoff (Marengo, 2006). Climate in the northwestern Amazon is highly humid, with overall high rainfall and seasonality marked by flooding of water bodies which is usually affected by ENSO (El Nino-Southern Oscillation) events (Schwartzman and Zimmerman, 2005).

The Amazon is influenced by two interconnected climatic influences: land use change (affecting regional climate) and global climate change (Malhi et al., 2008; Nobre et al., 2005). Models predict that climate change will result in an overall increase of temperature with uncertainty regarding the effects on hydrological cycles (Li et al., 2006). The frequency and magnitude of extreme events is expected to increase (Langerwisch et al., 2012). Tropical South America expects temperature increases of 4°C, paired with a precipitation decrease in austral winter (Vera et al., 2006) and longer dry seasons with more severe droughts (Li et al., 2008). Recent precipitation trends appear negative for the overall basin (Marengo, 2006).

Climate determines structure and function of ecosystems (Carpenter et al., 1992; Nobre et al., 2005). For example, higher temperatures are related to more frequent droughts, which in turn limit biological activity and change ecosystem processes impacting land productivity and transforming species composition if sustained over time (Marshall et al., 2008). In the Amazon, higher temperatures will affect the water balance and this could lead to increased evapotranspiration, with forests replaced by savannahs in some areas and further release of CO_2 (Li et al., 2008; Marengo, 2006; Nobre et al., 2005). Temperature is critical to phenological processes and can lead to changes in species composition, as seasonality of ecosystem processes may favor species differentially (Marshall et al., 2008). In turn, changes in the distribution and structure of the vegetation influence climate as well (Nobre et al., 2005).

Climate change predictions for the northwestern Amazon region suggest increase in precipitation variability, which will likely affect river discharge and flooded areas (Langerwisch et al., 2012). Precipitation in the northwestern Amazon exhibits inter-annual and decadal variations linked to ENSO (Christensen et al., 2007; Marengo, 2006). It is also affected by the strength of the North Atlantic high, the position of the intertropical convergence zone (ITCZ), and sea surface temperatures in the tropical Atlantic (Costa and Foley, 1999). Terrestrial water storage has also been linked to ENSO, affecting river discharge significantly (Chen et al., 2010). Variations in total precipitation, extreme rainfall events, and seasonality will all affect the amount, timing, and variability of flow (Carpenter et al., 1992). Changes in frequency, magnitude and location of extreme events will disrupt ecosystems given temperature tolerances, species distributions and loss of water bodies (temporal or permanent) as a result of stronger droughts (Carpenter et al., 1992).

Hydrology and Land Use

The Amazon's hydrological cycle is a key driver of global climate. Uncertainty regarding climate change in the Amazon is high, particularly since detection of local effects is difficult given naturally occurring variability and the impact of other sources of change, such as land use, pollution, economic development and adaptation (Hansen et al., 2015). A warming and drying effect (IDEAM et al., 2015) combined with a decrease in evapotranspiration from plants will likely lead to a substantial decrease in precipitation, resulting in changes in ecosystem types and loss of species (Carpenter et al., 1992). Land-use change interacts with climate accelerating the loss of forests and even causing massive forest dieback (Betts et al., 2008; Christensen et al., 2007).

The Amazon River is significantly influenced by adjacent terrestrial ecosystems throughout the drainage network, given groundwater flows, surface and subsurface runoff, outflow from riparian zones and direct inputs of throughfall and terrestrial detritus (Dale, 1997). Riparian areas regulate water flow, particulates and solutes from terrestrial to aquatic ecosystems, shade streams and rivers, provide habitat and resources to different organisms, and constitute corridors for terrestrial fauna migration, which are critical for the maintenance of water quality and biological integrity (McClain and Cossio, 2003).

In the Amazon recycling of precipitation and evaporation are important parts of the water cycle (Marengo, 2006). Precipitation recycling is the contribution of evaporation within a region to precipitation in that same region, serving as a diagnostic measure for interactions between land surface hydrology and regional climate. Land use change affects ecosystems in the area with unintended negative consequences, particularly in frontiers where interventions may extend into surrounding ecosystems on which humans also depend (McClain and Cossio, 2003). Land use change results in variations in precipitation, increasing over deforested areas (Wang et al., 2000), as has been evidenced by a long-term shift in the seasonality of precipitation concurrent with deforestation; meaning that current land use changes have already affected the regional climate (Chagnon and Bras, 2005).

Deforestation greatly affects these watersheds because land cover influences hydrological properties of soils, the balance between rainfall and evapotranspiration, and consequently runoff responses. Deforestation reduces evapotranspiration (Chagnon and Bras, 2005) and results in higher stream flow (Neill et al., 2006) significantly affecting local and regional climate (Christensen et al., 2007; Costa and Foley, 1999). Deforested landscapes reduce water storage and recycling, resulting in local increases in temperature of almost 2°C (Christensen et al., 2007; Costa and Foley, 1999). Ultimately the effects of deforestation on climate depend on the scale of the deforested area (Marengo, 2006; Wang et al., 2000).

The aim of this paper is to determine if there are trends that signal changes in river behavior, since river levels have proven to be important for livelihoods in the region and are key to determining type, timing and location of subsistence activities (Pinilla Herrera, 2004). Using river level data for a weather station in the Colombian Amazon, this paper aims to answer the following questions:

1) Are there changes in trends for maximum and minimum river levels?

2) Are there changes in the duration of floods and droughts?

3) Are there changes in the time of the year when maximum and minimum river levels occur?

4) Are there changes in the rate of change each year for the period spanning 30 days prior to the maximum level, as well as the number of days in the same time frame when the river stopped increasing or decreased?

To answer these questions, we analyze the behavior of the Amazon's river levels using 25-years (1988–2013) of data gathered by the Colombian authority responsible for monitoring climatic variables (IDEAM, 2014). This data set was obtained directly from the IDEAM and includes daily river level values for the aforementioned time period. We hypothesize based on reported changes for the area (Echeverri, 2009; Kronik and Verner, 2010a), that river levels have become more extreme with stronger droughts and floods, but also with changes in seasonal peaks. Our first hypothesis is that there are changes to the maximum and minimum river levels, with more extreme events occurring more recently. For our second hypothesis, we expect that these changes will correspond to longer durations of floods and droughts. Finally, we hypothesize that there will be changes in seasonality and river behavior within this timeframe.

Methods

We examined a 25-year dataset (1988–2013) composed of daily river level measurement from Nazareth, Colombia in order to assess variability flooding/drought and timing of river level changes (IDEAM 2013). We used data from the Nazareth river station (Figure 3.2) due to the completeness of the data and the proximity to Puerto Nariño, where other research on effects of environmental variation on local communities was investigated. Data from this river station were strongly correlated with other nearby stations (Leticia – Pearson's $r = 0.95$ and Amacayacu – $r = 0.93$). There is not significant time lag in river levels on a daily basis between the three stations.

River level regime data were analyzed to identify shifts in the timing and magnitude of low or high flow events. River level values were used to characterize regimes in terms of magnitude, duration, frequency, timing, and rate of change. To explore changes in river behavior, we evaluated long term trends and inter-annual variability in river levels. Using the hydrological year (Oct 1 – Sept 30) we first determined "normal" behavior using average daily values across all 25 years. For all analyses, we evaluated statistical significance ($\alpha \leq 0.05$) using the statistical software R.

Maximum and Minimum River Levels

We conducted a time series analysis and used the Mann- Kendall test to evaluate the direction and significance of trends in river levels over the 25-year period (Yue et al., 2002). Analyses were performed on daily data and accounting for seasonality effects. For the remaining trend analyses, data were grouped into percentiles, to evaluate which values fell below a certain limit (first percentile) or above a certain limit (fifth percentile) and hence determine drought and flooding patterns respectively. To determine if river flooding extremes have changed, river levels in the fifth percentile were analyzed to identify trends as well as the significance of such trends, to explore if floods appear to be stronger over the last 25 years.

Duration of Floods and Droughts

We recorded the number of days during each year in which the river level was in the upper percentile of the 25-year dataset to test for changes in duration of floods. For this we used the 25- year data and selected the total days on the top 25% of river level values for all years. The number of these days per year was counted to determine whether the number of highly flooded days has significantly changed over time. We followed the same procedure to determine if the river was drying more than usual. We recorded the number of days each year during which the recorded river levels were in the first percentile. Following this, the Mann- Kendall analysis was performed to identify trends as well as the significance of such trends. The same analysis was used to identify if there are changes regarding the number of days in which river levels fell on the first percentile.

Changes in Seasonality

We used the day of the hydrological year where the maximum level was reached to determine whether there were changes in flooding patterns that could explain the perception of sudden floods (see Chapter 4) becoming more frequent. We used regression analysis to evaluate if the annual date of maximum river levels had significantly changed over time.

Changes in River Behavior

Finally, to determine how predictability of river behavior may be changing over the last 25 years, we evaluated the rate of change each year for the period spanning 30 days prior to the maximum level, as well as the number of days in the same time frame when the river stopped increasing or decreased. Linear regression of rate of change vs. year was used to determine whether there were any shifts in the timing of onset or decline in peak river levels.

Results

Time-series analysis showed a positive trend ($p<0.0001$), indicating that regardless of the season (low waters or high waters), river levels appeared to be increasing over time (Figure 3.3).

Concerning flooding extremes, a similar result was obtained for high waters, with river levels in the fifth percentile appearing to increase over time ($p<0.0001$, slope 0.017; Figure 3.4). Despite showing an increasing trend, there was no statistical evidence that supported that the number of days where the river was in the fifth percentile had changed over time (Figure 3.4). The same occurred when examining the low-water levels. Although there was no significant change in the timing of peak water levels, visual inspections of the trends suggested that it appeared to be arriving earlier over time (Figure 3.4).

For our analyses for low waters, there was no statistical significance to support changes in trends; there were no differences between river levels in the first percentile and number of days when the river was on the first percentile. In terms of predictability of the river, there was no statistical evidence that supported changes in rates in the 30 days prior to reaching the maximum level, nor the number of days in those 30 days when the river stopped increasing or decreased during the last 25 years.

Discussion

Our study demonstrated that water levels have increased in the northwestern Amazon in the last 25 years. Similarly, we found a significant positive trend in flooding extremes for this region. Though our analyses did not indicate number of flooded days annually had significantly increased, this could be a result of data sparsity or unknown local dynamics. Longer floods can result in the loss of riparian vegetation as current adaptations prove insufficient to longer anoxic periods or stronger flows (Carpenter et al., 1992). Shifting flooding situations will likely have an impact on land cover and this in turn will affect local climate change as a result of changes in water and carbon fluxes (Langerwisch et al., 2012). Terrestrial evapotranspiration will likely be reduced as a result of larger flooded areas; this paired with deforestation can reduce recycling of precipitation and enhance conditions for drought (Langerwisch et al., 2012). Given current scenarios and the lack of evidence for change in the absolute climate tolerances of local species in the region, future extinctions of tree species in response to climate change are likely, particularly if their geographic distribution or climatic range is already highly restricted (Petit et al., 2008).

Contrary to findings of other authors (Guimberteau et al., 2013; Magrin et al., 2014), none of the variables we examined pertaining to low waters exhibited a statistically significant trend. Reductions in flow during minimum discharges have been reported in the main tributaries for the Amazon River (Ucayali and Maranon) (Lavado Casimiro et al., 2011), paired with important reductions in the glaciers over high mountains from the nearby Andes (Lavado Casimiro et al., 2011; Magrin et al., 2014). Changes in river flow variability during the last 20 years have already been reported for other areas of the Amazon basin, although in many cases these trends do not coincide with the present study because they reported increased dryness for most of the river basins with no changes in the high flow (Guimberteau et al., 2013; Magrin et al., 2014). However, in this study, we could not find evidence that the river is drying more than is known historically or that droughts have increased in duration. Data were not enough to prove a statistical significant relation between river levels and ENSO events (Figure 3.5).

The western region of the Amazon basin is expected to suffer major changes as a result of climate change, with important consequences for the hydrological cycle of the region (Christensen et al., 2007; Guimberteau et al., 2013). Precipitation in the northwestern Amazon has been decreasing, particularly during dry seasons (Lavado Casimiro et al., 2011; Zubieta et al., 2015). Inter-annual terrestrial water storage has been linked to ENSO events and appears to be correlated with flooding in the area, although the results in this study don't support that. ENSO events appear to have become more frequent resulting in a larger number of extreme climate events in the region (Chen et al., 2010; Langerwisch et al., 2012). Recently intense droughts (2005 and 2010) and extreme floods (2009, 2012 and 2014) have been reported more frequently as a result (Zubieta et al., 2015).

Climate change has the potential to accelerate the hydrologic cycle, which coupled with changes in land use patterns from deforestation can ultimately influence precipitation, given that moisture is heavily affected by land use alterations and/or by climate change (Marengo, 2006). Increasing temperatures paired with precipitation variability (IDEAM et al., 2015) are expected to shift the flooding regime in the Amazon and, as a result, impact local ecosystems. It is likely that flooded area will increase in 33% of the basin, together with longer inundations (up to three months longer) as well as shifting in the times of highest and lowest river levels (Langerwisch et al., 2012). Expected increases in precipitation will increase high-flow discharge by 7% in the middle of the 21st century and even more by the end of the century (Guimberteau et al., 2013), as was observed in this study. As a result flooding will be more extreme and more frequent (also seen in this study) given the increase in discharge (Guimberteau et al., 2013) and the amplification of global trends on a local level due to regional deforestation (Malhi et al., 2008).

Expected changes to the flood regimes in the Amazon basin will likely reduce the duration and magnitude of the dry periods. The importance of the dry period in the Amazon region has been recognized for human and animal health, since endemic diseases are restricted by preventing the multiplication of vectors. It is also crucial for agriculture, both in the lowlands and the uplands, since it allows for a thorough burn of the fields, required for reducing pests and crop establishment. In the lowlands, without a dry season there are no temporary chagras where people harvest crucial crops for their subsistence (Sombroek, 2001). From a human standpoint, the potential effects of longer floods paired with shorter droughts will have significant consequences.

Zubieta et al. (2015) reported the northwestern Amazon streamflow availability relates to rainfall variability at seasonal and inter-annual time scales; however, reliable data regarding precipitation is necessary for analyzing extreme hydrological events given the importance of rainfall to the hydrological cycle (Hansen et al., 2015; Marengo, 2006). The same is true for quantifying and analyzing future trends in precipitation (Hansen et al., 2015; Marengo, 2006), particularly given the high spatial variability of rainfall in the Amazon, resulting from proximity to the Andes Mountains (Daly and Mitchell, 2000; Marengo, 2006; Zubieta et al., 2015). In developing countries, reliable ground-based data are often not available, and often insufficient for use in building a model to predict river levels or flows. Available model predictions have proven to have a low correlation with on-the-ground information (Zubieta et al., 2015).

Another important source of uncertainty is the effect of changes in land-use patterns throughout the basin and how this interacts with climate change (Lavado Casimiro et al., 2011). Climate and vegetation determine and influence each other reciprocally, and the biophysical characteristics of vegetation and soils are critical in the exchanges of energy and water between the land and the atmosphere. Tropical forests are recognized to be critical for climate regulation because of their role in evapotranspiration (Nobre et al., 2005). Given the dynamic nature of the Amazonian landscape, it is important to note that climate also affects erosion and sediment transport. Strong floods result in channel widening, which can be exacerbated by lack of vegetation in riparian areas lost from climate change and deforestation. Inundation extent and duration depend on climate and affect interactions between the river and the terrestrial ecosystems (Carpenter et al., 1992). This is important for local communities as it has been mentioned that hydrological cycles determine the activities they are able to carry out. In the Amazon basin, the determinants of runoff changes and ultimately river behavior are decadal and inter-annual variability at a regional scale, resulting in floods or droughts that have occurred recently, and this variability has been severely affected by climate change and thereafter deeply affecting human livelihoods in the region (Guimberteau et al., 2013). Climate change affects hydrological patterns, particularly the amount, timing, and variability of flow. As Carpenter et al. (1992) explain, “It is impossible to study the effects of climate change in isolation from the effects of land use change and direct human use of freshwater resources. Humans are an interactive component of aquatic ecosystems, responding to changes in freshwater resources and thereby causing further change.” (p. 133).

Conclusion

These analyses suggest that there has been an increase in precipitation for the northwestern Amazon basin, in agreement with regional climate change scenarios. This is concluded because river levels have increased over the last 25 years of available data, contrary to expectations had precipitation decreased given local hydrological dynamics. However, this river level trend can also be a result of glacier retreat in the Andes, since it has been shown that they contribute to the regional water cycle. Uncertainty in our conclusions reflects the lack of on-the-ground information, and also lack of understanding and consensus in the effects of the interactions of different variables on the hydrology of the region when evaluating potential future scenarios.

It is not clear yet the role that land use change has played on these observed trends, given the localized effects it has on climate. It is important to understand how river levels change the landscape dynamics, not only in a physical sense, but also through altering the ecosystem, species composition and human livelihoods, which vary in their resiliency and adaptive capacity. This paper aims to trigger a discussion of the implications of climate change scenarios on local livelihoods and landscapes, while recognizing inclusion of these crucial aspects and the need for more reliable information when developing adaptation strategies.

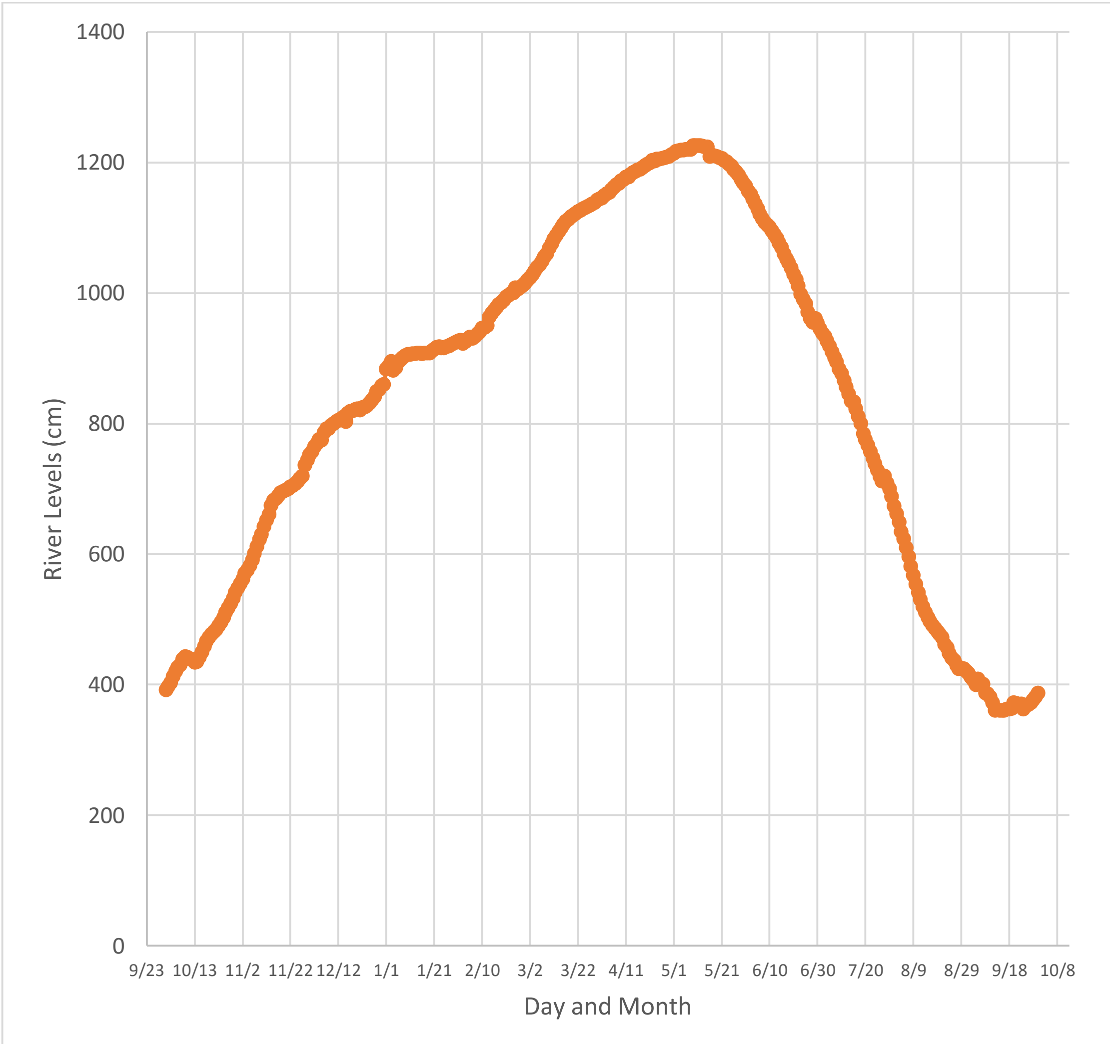

Figure 3.1. Average river levels (cm) in a hydrological year for the region

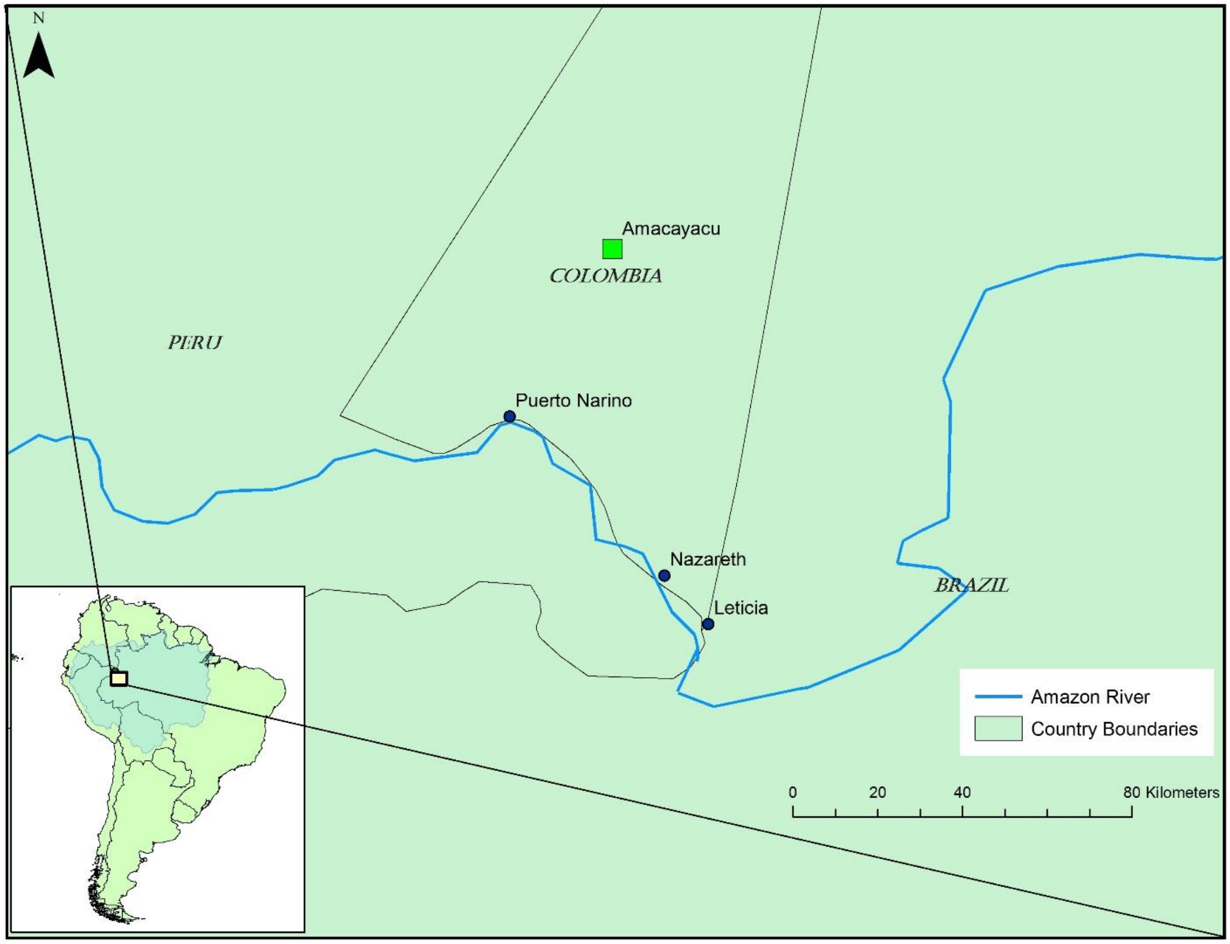

Figure 3.2. Study site and river stations reported in the study. Leticia, 84m.a.s.l., 04 11 37.90 S; 69 56 27.30 W. Nazareth, 119m.a.s.l., 04 07 12.70 S; 70 02 09.90 W. Puerto Nariño, 80m.a.s.l., 03 46 56.60 S; 70 21 51.50 W

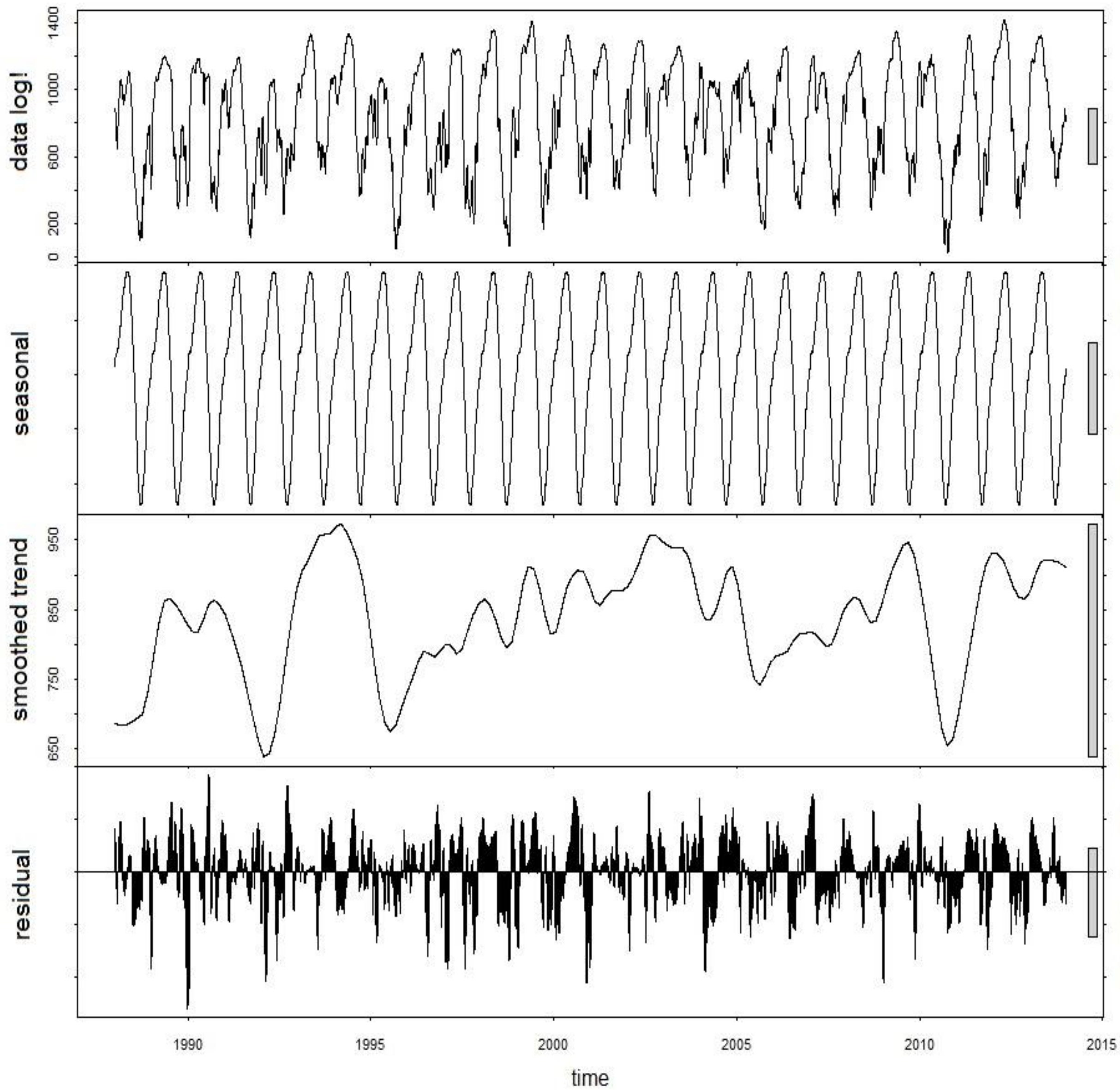

Figure 3.3. Time-series analysis for river level data of Nazareth

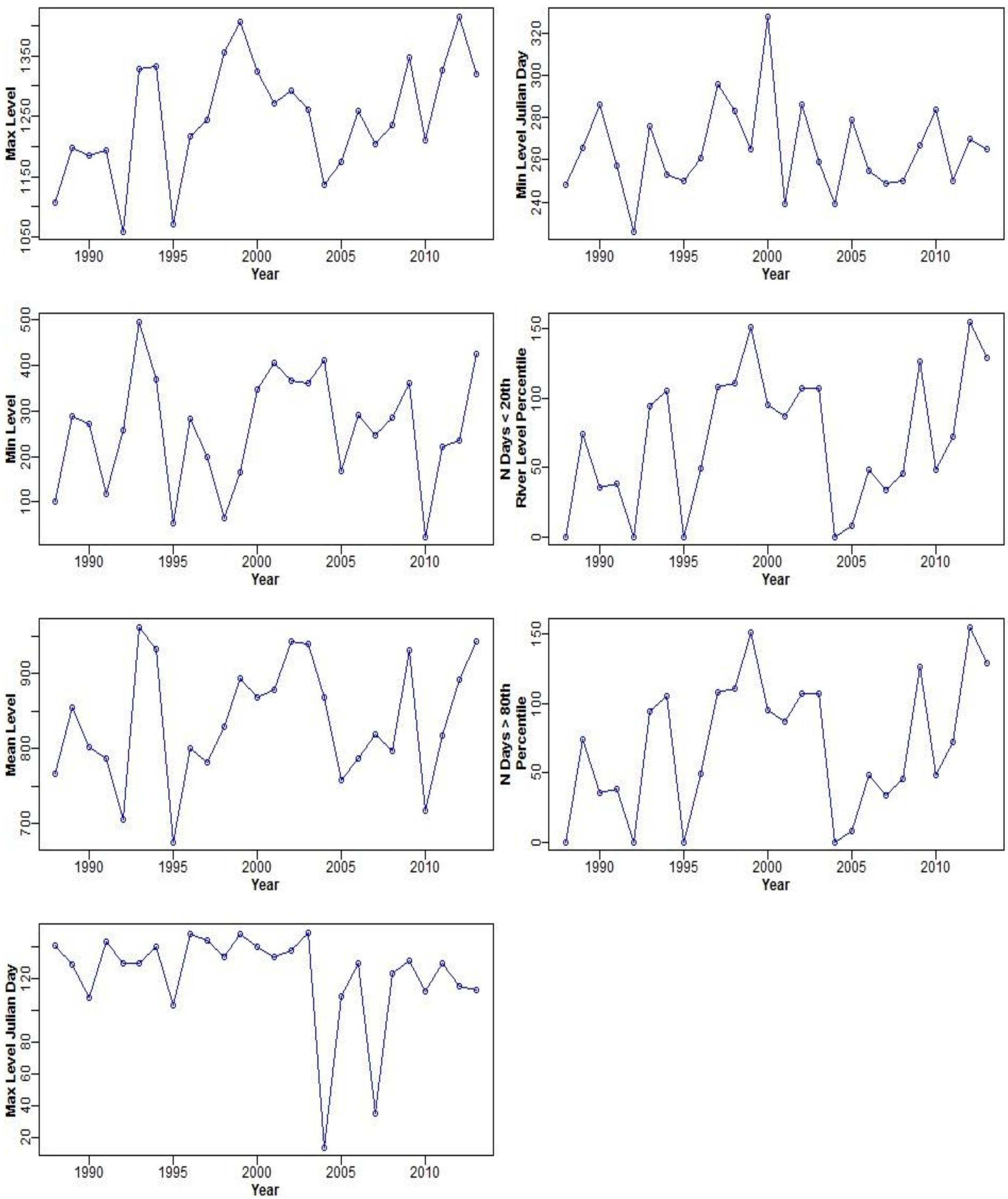

Figure 3.4. River behavior for Nazareth river station.

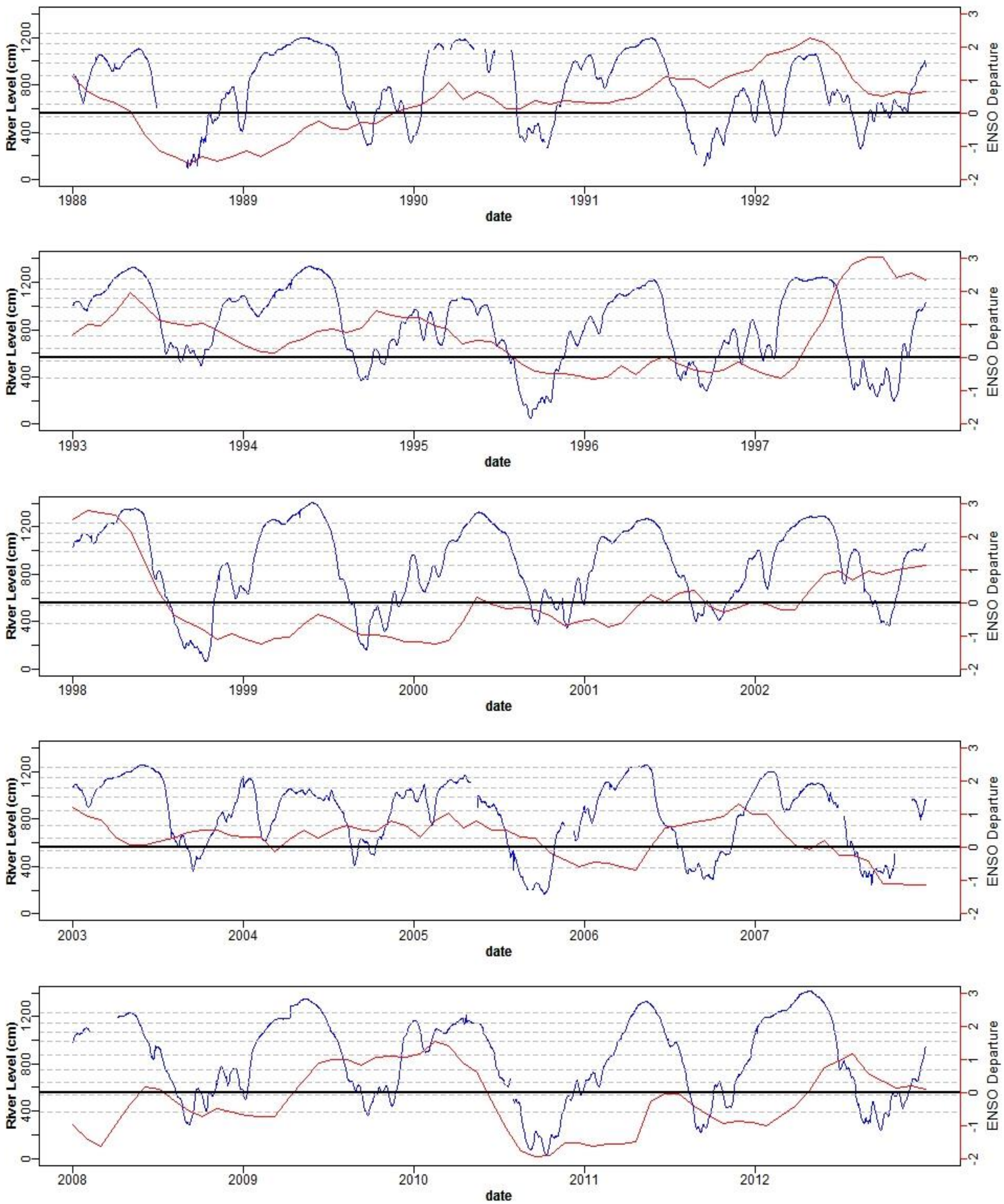

Figure 3.5. River levels for Nazareth (blue), compared with ENSO events (red)

CHAPTER 4

CLIMATE TRENDS AND INDIGENOUS PERCEPTIONS OF ENVIRONMENTAL CHANGE IN THE COLOMBIAN AMAZON[3]

[3] Rodriguez Granados, R., Hatt, J.L. and N. Nibbelink. To be submitted to Global Environmental Change

Male, 61 years

"Todos estos años casi no ha habido verano como las veces pasadas, como los años anteriores, porque yo me recuerdo que por allá del 60 al 70, cuando era tiempo de verano, era verano porque era verano mismo y cuando era tiempo de invierno también era invierno. Pero terminaba el invierno y cogía ahí el verano, por ejemplo en estos tiempos de mayo en adelante, ya no se sentía nada de lluvia y ahora estas veces es tiempo de mayo y eso está lloviendo cada rato. Hace poquito hizo un friaje. Nosotros llamamos un friaje cuando viene ese frio acá y hace frio, entonces nosotros tenemos una creencia que después del friaje, hace verano unos días y en estos días va a llover otra vez... está lloviendo casi todos los días y puede llegar al mes de agosto. El mes de agosto por allá en el 60 para que eso era, mejor dicho todo el mes de agosto era sol y la gente aprovechaba dizque a tumbar monte y aprovechaba a quemar para poder sembrar y ahora ya no"

All these years there hasn't been a real summer like in the past, like previous years, because I remember in the 60s and 70s when it was summer time it was summer, and when it was winter it was winter. Once winter ended summer came, from May on there was no rain and now even if it is May, it is raining all the time. Not long ago a friaje occurred. We call friaje when the cold comes, so we believe that after friaje there are summer days and in these days it will rain again… it is raining almost daily and August will arrive. August in the 60s was just sun and people used it to burn the fields for the crops, but not anymore.

Abstract

Local perceptions of environmental uncertainty and nature are key to understanding what lies behind resource exploitation. Cross-disciplinary research that combines science and local perspectives to create knowledge is fundamental to understanding the impacts of climate change, because the global problem of climate change generates local consequences. Considering how indigenous people conceive and use the land and how related knowledge changes with time is crucial to create sound adaptation processes. In this study, we examine how indigenous perceptions of environmental change agree with observed data trends in a specific locale, Puerto Nariño (Colombian Amazon). Semi-structured interviews and oral histories about perceptions of environmental change serve as the basis for comparisons with the Colombian government's climatic data for this area. Our findings support four main perceived changes to climate including temperature changes, changes in friaje (incursions of polar air masses towards the equator during the austral winter; Dantas Ricarte et al., 2015), changes in river behavior, and changes in seasonality of rainfall. Results show that local perceptions have proven to be related to most climate trends where data were available for comparative analyses. Although Colombia has done much to enhance adaptation to climate change, this study reflects the lack of local data to understand how trends are occurring on local scales and mirror people's perceptions. There are currently no mechanisms to locally monitor the impacts of climate change and it is important to recognize that local experiences do not necessarily reflect what has been defined on a national level.

Introduction

Studies involving indigenous perception and observed changes in climate have been mostly conducted in northern latitudes (Berkes and Jolly, 2001; Crate, 2009; Cruikshank, 2005; Duerden, 2004; Gearheard et al., 2010; Turner and Clifton, 2009) in Asian-Pacific states (Green et al., 2010; Lefale, 2010), and in Africa (Ifejika Speranza et al., 2010; Orlove et al., 2010). Indigenous peoples are ethno-climatologists, meaning that from their experience and knowledge, they can detect and are actively responding to the changes they perceive in their environment (Crate, 2009; Duerden, 2004; Green and

Raygorodetsky, 2010). How people adapt to change, particularly environmental change, is important to understand how they are using and managing resources (Duerden, 2004), and local perceptions of environmental change are key to understanding the drivers of resource exploitation. As the main objective of this study, we compare local perceptions with climatic trends in the Colombian Amazon. We believe this comparison is important given the close relationship that people have with their environment and the recognized breadth and depth of local knowledge upon which these groups have based their livelihoods.

The Amazon is the world's largest river basin and tropical humid forest, covering 40% of the land of South America (Sponsel, 1986). It has some of earth's rainiest places (above 2,000 mm $year^{-1}$; Junk et al. 1989) that have remained with forest cover despite drops in temperature that led to savanna formations in other regions during the Pleistocene and Holocene. These forests served as wildlife refuges during these periods of time with some isolation that led to unique adaptations and gave rise to the current endemism that account for the recognized biological diversity of the area (Herrera, 1989). Likewise, cultural diversity relates to these island effects that resulted in lack of contact between human groups and partly explain the diversity of languages found in these areas (Meggers, 1977, 1999). Amazonian climate is highly humid, with overall high rainfall and seasonality marked by flooding of water bodies which is usually affected by ENSO events (Schwartzman and Zimmerman, 2005). Amazon soils have been described as poor in nutrients (Meggers, 1977; Sponsel, 1986), except for varzea areas that are replenished by the periodical inundation of "white waters" which carry rich sediments (Wittmann et al., 2004). These areas are home to endemic plant and animal species and organisms particularly adapted for this kind of ecosystem (Padoch, 1999).

Amazonian Landscapes

Environmental determinism has often been used to explain human adaptation in the Amazon region, where humans are viewed as agents that react to certain conditions (Meggers, 1999). However, this view has been challenged and other authors argue for the recognition of humans as agents that transform the landscape actively (Balée, 1998; Denevan, 1966, 1996; Heckenberger and Neves, 2009;

Heckenberger et al., 2007; Heckenberger et al., 2003; Woods and McCann, 1999). Amazonian forests once thought to be pristine were settled, cut, burned, and cultivated repeatedly during prehistoric and historic times, and human activities widely altered topography, soil, and water quality altering biodiversity patterning (Bush and Silman, 2007; Heckenberger and Neves, 2009; Heckenberger et al., 2007; Heckenberger et al., 2003). It has been widely accepted that the Amazon is a product of human activity (Colchester, 2004; Colchester et al., 2001; Griffiths, 2004; Heckenberger et al., 2003) and what is found today corresponds to millennia of human co-evolution with the natural environment.

Seasonality affects the biomass, productivity, species diversity, composition, structure and function of the plant and animal communities in the Amazon basin (Goulding, 1993; Wittmann et al., 2004), resulting in differences across the year to which humans have developed different adaptations (Sponsel, 1986). Seasonality also determines human movements and the rhythms of social activities. With river variations between five and 15m , these changes influence annual activities as people depend on the water levels that determine fish migration, animal movements, soil hardening, plant growth, etc., defining the periodicity of human activities (Harris, 1998).

Indigenous Livelihoods

Livelihoods of indigenous peoples of northwestern Amazonia are dependent on the environment resulting in a very intimate relationship, reflected in particular and detailed knowledge of local conditions and relations (Colchester et al., 2001; Cristancho and Vining, 2009; Davis and Wagner, 2003; Gadgil et al., 1993; Hames, 2007; Naveh, 1995; Nazarea, 1999, 2006; Sillitoe and Marzano, 2009; Turnbull, 2009). Livelihoods have been mostly dependent on hunting, gathering, fishing and some subsistence agriculture (Fajardo and Torres, 1986; Perez et al., 1999) based on shifting cultivation with manioc as the main crop (Andrade, 1988; Dufour, 1990; Sponsel, 1986). This type of agriculture relates to low population density because it requires long periods of rest for the land and requires large areas per person for it to be productive, preventing high population concentration (Andrade, 1988; Meggers, 1999).

Shifting agriculture uses environmental conditions and processes where the slash allows for more photosynthetic activity and the burn is believed to return soil nutrients; it has been shown that farming fields are usually used for long periods of time as even when no agriculture is taking place in them, they are still used as gardens for certain plant species and also to attract certain kinds of game (Andrade, 1988; Dufour, 1990; Harris, 1971; Sponsel, 1986). With western contact, the most significant changes in this type of agriculture were the introduction of steel replacing stone tools and the introduction of crops different from those traditionally known to the region (Andrade, 1988). Agriculture and horticulture take place in the chagras (farming fields) that are mainly established in firm land and in seasonally flooded areas, cleared for seasonal agriculture (Andrade, 1988; Wittmann et al., 2004). Fish are more abundant than game, therefore are a more dependable source. Thus, fishing provides the most important source of quality protein, particularly in the dry season when water level concentrates fish in certain areas (Sponsel, 1986). Indigenous groups in the area have become adapted to seasonality regarding fishing, largely affected by landscape and habitat changes. When the water levels increase, the flooded forests open a new niche for fish where they feed on other fish, fruits and leaves, insects and other materials (Gragson, 1992).

Currently the Amazon region and indigenous communities face numerous threats that include population growth, resource over-exploitation, habitat degradation, deforestation, fragmentation and climate change (Armenteras et al., 2006; Costa and Foley, 1999). Governments have prioritized economic development, integration, and national security to include hydroelectric and flood control projects that have significant effects on traditional ways of life (Sponsel, 1995). Varzeas are currently disappearing in several areas due to selective logging and forests clearing to enable agricultural use (Wittmann et al., 2004). Recently, animal husbandry has become a development strategy in Amazonia, with important environmental consequences including soil degradation and ignoring traditional adaptation systems where indigenous groups are absorbed into these new approaches (Andrade, 1988). In places like Colombia, the establishment of illegal crops often results in deforestation (Armenteras et al., 2006).

Environmental Change

Human and natural systems have been able to respond to climate change in the past. The current state of these systems determines their overall vulnerability, resilience and adaptive capacity, because other sources of degradation (cultural and ecological) threaten the ability of natural and social systems to respond and maintain their basic functions in a given context (Crate, 2011; Laurance, 1998; Marshall et al., 2008; Petit et al., 2008). As Petit et al. (2008) explained "…future extinctions of tree species in response to climate change are probable, especially if their geographic distribution or climatic range is already highly restricted." (p. 1451). Social resilience is the ability of a community to withstand external shocks and stresses without significant consequences, as a result of the dynamic structures of livelihoods, access to resources, and social institutions (Adger, 2000) and the community's ability to build and increase its capacity for learning and adaptation (Berkes and Jolly, 2001). Uncertainty has not been widely studied in social systems beyond the idea of how local systems and institutions respond to it (Adger et al., 2003; Berkes and Jolly, 2001; Crate, 2009; Dietz et al., 2003; Marshall et al., 2008). Accounting for the fact that human societies are not passive and respond and adjust to changes in climate that they perceive increases uncertainty, and is inherent in the responses which leads to difficulty in predicting how human communities respond to different changes (Crate, 2009; Duerden, 2004).

Uncertainty underlies predictions of global climate change for Amazonia. This is because of large variability related to microclimates that lead to challenges in developing conclusive assessments of the regional changes expected for the entire area (Christensen et al., 2007; Magrin et al., 2007; Marengo et al., 2009). Uncertainty regarding rainfall in this region is also common, except for some consistency among models predicting increases in rainfall for northwestern Amazonia and decreased rainfall in the southeastern regions (Bush et al., 2007; Christensen et al., 2007; Marengo et al., 2009). Extreme precipitation is expected to create more intense wet days per year in south-eastern South America and central Amazonia and weaker precipitation in the northeastern area of Brazil (Christensen et al., 2007; Magrin et al., 2007).

Climatic variability in the Amazon basin is strongly influenced by ENSO (El Niño Southern Oscillation) causing droughts and the delay of the rainy season as well in southern Amazonia, while floods and changes in rain patterns occur towards the northwest (Sombroek, 2001). ENSO events have warm and cold phases (referring to eastern tropical Pacific Ocean sea surface temperature), creating both El Niño and La Niña, which changes conditions (An, 2004; Magrin et al., 2007; Roncoli, 2006). One of the main challenges of studying climate change is an increase in climatic variability and the occurrence of extreme weather events accompanied by a lack of knowledge of how this will be manifested on local levels (Duerden, 2004; Marshall et al., 2008). According to Chen et al. (2010) terrestrial water storage show significant increases in the northern lower Amazon basin as well as an increased inter annual variability and there is evidence that some of the recent major floods and droughts in the Amazon basin are related to El Niño and La Niña events (Chen et al., 2010), which are now more frequent and intense (Langerwisch et al., 2012).

Temperatures are expected to increase linearly with time, but the magnitude of this increase is still disputed, ranging from 1.8°C to 5.0°C between 1999 and 2080/2099, with a mean of 2.6°C to 3.6°C (Christensen et al., 2007; Magrin et al., 2007). Changes in the northwestern areas of South America include increases in temperature of 0.5 to 0.8°C during the last decades (Costa Posada, 2007; Quintana-Gomez, 1999), for the Amazon these changes have also been recorded (Victoria et al., 1998). Precipitation levels have also changed and vary depending on the part of Amazonia that is considered. Precipitation is expected to increase together with changes in seasonality of rains (Bush et al., 2007; Christensen et al., 2007; IDEAM, 2010) while in the southern Amazon the seasonal precipitation index has showed a decrease of 0.32 per decade since the 1970s (Li et al., 2008). Amazonia has important functioning ecosystems of great relevance to both containing and adapting to climate change, including a significant area of forest cover that works as a large carbon sink (Bunyard, 2007). However, changes in temperature and precipitation levels are expected to create major forest dieback, transforming large areas of tropical forest into savannahs and causing a related decline in net productivity and increase in carbon release (Magrin et al., 2007).

The case study presented here takes a socio-ecological systems approach (Berkes and Jolly, 2001; Brosius, 1999) and an individual-focused analysis to: 1) Determine specific environmental changes people perceive, 2) Explore the trends for these changes according to Colombian government data, and 3) Evaluate if reported perceptions agree with observed data. To that end, we focused on data gathered by the Colombian government for the last 35 years and using observational and ethnographic data we compared perceptions with observed trends. It is our primary goal to see how reality matches people's perceptions. We used content analysis, regression models and time-series analysis for this research. Results emphasize the value in using multiple research approaches that operate at different levels to complement parametric models.

Hypotheses, Data, and Methods

Study Site Background and Hypotheses

Colombia exhibits high cultural diversity concentrated in the Amazon region. In this region, people depend directly on natural resources for their livelihoods, employing diverse subsistence strategies across the landscape. In Colombia, the Amazon department (local political districts) is located in the south covering a total area of 109,665 km^2 and has the lowest population density of the country. The main and largest city is the capital, Leticia, located on the borders of Peru and Brazil. The second most important municipality is Puerto Nariño. Puerto Nariño has a total area of 154,160 hectares, with the urban area located on the margins of the Loretoyacu River, 87 km north of Leticia and only accessible by boat. Most of the populace in Puerto Nariño is comprised of the Tikuna indigenous groups, which hold special land tenure rights constituting the *resguardo* (indigenous territory). There are twenty indigenous communities within the resguardo that account for 94% of the municipality (Alcaldia de Puerto Nariño, 2008). It has a population close to 7,500 people (DANE, 2007), which includes the Tikunas, Cocamas and Yaguas ethnicities. Several of the human settlements in this region can only be reached by river.

This study uses an inductive approach—drawing on information from research conducted by the Colombian government—combined with an empirical approach—recording indigenous observations of environmental change and the related changes in their livelihoods (Duerden, 2004). In this paper we use the Colombian Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) data to evaluate patterns and the statistical significance of trends for the main variables identified from content analysis of interviews conducted that reflected perceptions of change. Through our evaluations, we aim to answer the following questions:

1) What environmental changes are people perceiving?
2) What are the trends for these changes according to Colombian government data?
3) Do perceptions agree with observed data?

Our main hypothesis is that people's perceptions should agree with observed trends, given the close relationship that local human communities have with their environments and their dependence on knowledge and predictability of their surroundings in order to support their livelihoods.

Survey Instrument and Informants

During preliminary research in the Colombian Amazon, people reported noticing and responding to changes in the hydrological cycle, which determines what, where and when subsistence activities take place. Using this experience and in order to evaluate human perception of their environment, we designed and conducted semi-structured interviews lasting between 30 minutes and one hour, depending on the amount of detail given by the informant. Fifty interviews were completed, and these interviews explored themes concerning people's perceptions of change and extreme events that had recently occurred. Interviews also explored ideas of climate change and other local explanations given to observed events. All informants identified as indigenous from the main groups known from the area and were willing to be filmed and recorded for the study. All 50 interviews took place in Puerto Nariño between May and August of 2012 and 2013. An inductive approach to content analysis (Elo and Kyngäs, 2008) was used to examine the local interview data and the main topics regarding perceptions of change were identified (Table 4.1). Analysis of data (words) was conducted manually and involved substantive coding (Fernandez, 2004). Substantive coding led to the identification of main themes and categories through an inductive approach (Elo and Kyngäs, 2008).

Measured Environmental Conditions and Comparison to Perceptions

IDEAM (Institute of Hydrology, Meteorology and Environmental Studies) is the local authority responsible for collecting climatic data in the country. IDEAM has ten stations in the region (Table 4.2), but the only gauge is located in Leticia (87 km from the study site). Data collected at the Leticia station cover the longest data timespan of the seven stations and with the fewest gaps through time. For these reasons, we used daily data from Leticia because they showed high correlation values with local temperature data in Puerto Nariño (Pearson's r = 0.8). While precipitation data from Leticia was poorly correlated with local precipitation data (r = 0.27), we still examined these data from Leticia for evaluation of regional trends because local data did not exist for the whole timeframe. Temperature data were available from 1978 and obtained in May 2014. Precipitation (rainfall) data were available from 1970 until the end of 2013.

Using R as the statistical software, time-series analyses were conducted for daily average temperature and daily total precipitation trends for the available years (1970-2013). Regarding friaje events, average temperatures and standard deviations were used instead of minimum temperature data to exclude outliers. Friaje are incursions of polar air masses towards the equator during the austral winter (Dantas Ricarte et al., 2015). These were identified using days where the average temperature fell three standard deviations (3.98°C) or more below the median (25.88°C). We conducted a regression analysis on these data to determine if there had been changes in the number of friaje events per year since 1970.

Using the same dataset, a time-series analysis was conducted to determine if the amount of rain had increased in the months of July and August (dry months). The number of days with precipitation for the dry months were also analyzed. In addition to analysis of overall changes in mean temperature and precipitation and to compare with additional perceived environmental changes, data were temporally organized to correspond to specific notable events. These datasets were then analyzed to identify trends and compare to perception information. Finally, river data and corresponding time-series analyses (see Chapter 3) were contrasted with local perception data.

Results

Using a combination of quantitative information, ethnographic and observational material was a central goal of this project. Fifty interviews were completed, 25 men and 25 women. The informants reported basic demographic information (Table 4.3) and their interviews were also recorded for later analyses. Informants were asked to describe environmental conditions when they were young, or share information they may have received from their parents concerning historic conditions. Most of the patterns described were consistent between informants (Table 4.4).

Overall perceptions of environmental change is detailed in Figure 4.1. Age appeared to have little bearing on the reported information. Only the more salient topics (those that were more frequently reported) were compared with available climate data in order to compare perceptions and trends for the region. In the end, the climate events that we compared with perceptions were: increase in average temperature, changes in river behavior, changes in friaje and changes in seasonal precipitation. Each of these observations was analyzed separately in order to compare it with observed trends in IDEAM data.

Increase in Average Temperature

Eighty percent of informants reported feeling hotter, the sun being harsher or feeling that the heat has become more extreme daily. In some cases they related this observation to droughts, simultaneously stating that they have also become more frequent, but since there were no data to examine drought patterns in the area, we could not explore this explanation. However, daily average temperatures from the Leticia station indicated a statistically significant increase ($P < 0.001$) in a period of only 33 years of approximately 0.02°C $year^{-1}$. Though we cannot conclude that the findings from this short term dataset are attributable to climate change, these trends agree with descriptions for the region in the Third Communication for the IPCC (IDEAM et al., 2015), where temperatures are projected to increase by 1.5°C by 2070. The increase is linear and shows a positive trend (Figure 4.2a). These trends appear to correspond with local perceptions.

Because many informants reported that "el sol esta calentando mucho" (the sun is hotter than before), we also conducted a time-series analysis of maximum temperatures to determine if these were also increasing. The trend appears significant for maximum temperature (Figure 4.2b) ($P < 0.001$), with an approximate rate of increase of 0.013°C $year^{-1}$.

Changes in Friaje

The main perceptions regarding friaje relate to it becoming "less strong," with specific reference to the number of occurrences and degree of cold. Informants also reported a change to the seasonality. Primarily, they reported differences in arrival time, with a delay of three or more weeks from the historical timeframe. For the period 1978 to 2013, 108 friaje events were identified for this region. Temperature increases as indicated earlier in our results support the idea of warming temperatures, and correspondingly, reductions in friaje events. Trends in the number of friaje events per year (as assessed in our study) also support that these events are becoming rarer ($p= 0.0032$). However, it is important to note that there is not enough evidence to support the perception of changing seasonality, as most of the events continue to occur in July (Figure 4.3). July has typically been when the majority of these events take place and this has also been reported in other studies (Dantas Ricarte et al., 2015).

Rain Seasonality

Nearly 60% of informants reported changes in rainfall seasonality. They explained that rainfall patterns were very well established, with July and August as the driest months with minimal precipitation that would permit them to plant their fields. Informants reported that rain has become unpredictable, and months that used to be locally known as summer (given the lack of rainfall), are receiving substantial rains. The available climate data from IDEAM did not support these observations and no trends were identified that supported an increase in the number of rainy days or in precipitation amounts for these months. Our time-series analysis of precipitation data showed a weak tendency of diminishing rainfall, although it was not significant ($P = 0.67$; Figure 4.4). These results agreed with the Third National Communication for the IPCC (IDEAM et al., 2015) that predict a reduction in rainfall for the region of 12.47% by 2070.

Changes in River Behavior

Informants perceived general changes in the traditional ways in which the river behaves. These changes included: sudden floods, extreme drying of the river, more extreme flooding (longer and higher levels) and changes in currents that result in considerable erosion. Observed trends show that peak river levels are generally increasing. Trends detected from previous analyses of river data (Chapter 3; Table 4.5) agreed with some perceptions, particularly increases in maximum water levels (as related to flooding events).

Discussion

Our results demonstrate the current local perceptions are similar to observable trends in climate, specifically as related to increasing temperature and reductions in friaje events. Friaje events have been reported to be decreasing in recent years (Dantas Ricarte et al., 2015). These events are very important to the ritual life of the indigenous groups of the area. However, not all climate trends match the local perceptions. In particular, measurements of total amounts of rainfall and seasonality provided little evidence to support local perceptions of changes to these variables.

Local perceptions have been shown to be related to overall climate trends and livelihood strategies are adjusting to accommodate these perceived changes through diversification and incorporation of agricultural practices (West et al., 2008). Elders and local experts are losing credibility with their communities as climatic conditions have become impossible to predict (Cristancho and Vining, 2009; Kronik and Verner, 2010). This has resulted in status decline of elders and younger generations have begun to seek alternative sources of knowledge (Cristancho and Vining, 2009). These movements are largely a response to the limitations of their traditional knowledge and ritual specialists in the face of the effects of climate change on the seasonal calendars (Kronik and Verner, 2010; Roncoli, 2006; West et al., 2008).

Local temperature trends not only agree with local perceptions, but also with other reports from the region. Increases of 0.63 °C per 100 years have been reported (Victoria et al., 1998). Temperature perception was uniform with zero informants claiming steady or decreasing temperatures. Only 20% of the informants did not remark on temperature, and because this was a semi-structured interview, they were not directly asked about this variable. It is also important to note that increases in temperature have been reported in other studies of perceptions of environmental change (Hansen et al., 2012; Kempton, 1991; Silva, 2010; Smith and Oelbermann, 2010; Vedwan, 2006; Vedwan and Rhoades, 2001). Climate extremes were perceived to be more extreme as well, and although no evidence was found to support that minimum temperatures have decreased, but rather they are increasing, our results support that maximum temperatures have increased significantly over time, as has been found by other authors (Silva, 2010). Again, these data support the consistent impression among informants that temperature has become almost unbearable, particularly for outdoor work or daytime fishing.

Regarding friaje events, or temperature extremes that result from incursions of polar air masses towards the equator during the austral winter (Dantas Ricarte et al., 2015), our study suggested that the number of these events has diminished, as was recognized by the informants in this region. The reason for analyzing the decline in the number of events rather than declines in temperature was to allow for identification of changes in the overall aspect, because these historic anomalies may become a new "climate norm" as average temperatures increase. Although several studies have evaluated the process by which this phenomena is changing (Dantas Ricarte et al., 2015; Oliveira et al., 2004; Silva, 2010), very little has been quantified regarding the frequency of these changes. However, if average temperatures are increasing, it can be inferred that friaje events will consequently be affected as was reported. It is important to note that changes in ENSO patterns have also been documented (Chen et al., 2010), but these changes have not been linked to changes in friaje events (Dantas Ricarte et al., 2015).

Analyses of river data appear to confirm most of the local perceptions, except increased frequency and intensity of droughts. However, available data are limited, so we do not have enough information to corroborate people's perceptions. Perceptions of river behavior agree with results from the analyses, namely that flooding is becoming more extreme. It is likely that local perception matches these trends because their farming systems and infrastructure were adapted for different time frames and water levels. Maladaptive changes to water levels result in economic losses due to affectation of infrastructure. In particular, many houses found on the river margin as well as commercial establishments are more frequently affected by the floods. Moreover, earlier increases in water levels, invalidate long-established timeframes for their crops and may explain complaints about losing crops planted on the lowlands.

Precipitation changes were reported by the informants, but harder to confirm given the available measured data. For the region there is only one station with a long-term gauge and other regional stations have only been installed recently. Additionally, these stations depend on human data collection, which has resulted in incomplete data. Thus, it was not possible in the scope of this study to evaluate perceptions with local data to confirm differences in seasonality. However, the analysis of data collected in Leticia suggests a reduction in overall rainfall. Marengo et al. (2001) found differences along the basin, where tendencies seem to be opposing for the northern and southern parts of the Amazon basin. Precipitation reduction is harder to attribute to climate change as deforestation has appeared to result in dramatic changes in rainfall patterns, with apparent increases over deforested areas (Wang et al., 2000). Deforestation has also been linked to changes in long-term seasonality, with more rain accumulation toward the end of the dry season, which would support informant perceptions (Chagnon and Bras, 2005). ENSO is also an important source of climate variability in the region, and El Niño has been related to droughts in northeastern Amazonia, while in the southern region it appears to result in very humid conditions (Costa and Foley, 1999). La Niña appears to behave in the opposite manner.

Perceptions of climate change are affected by the degree to which change occurs relative to the human life span (Duerden, 2004). Misinterpretations and mistrust of climate predictions that result from a mismatch between the cognitive frameworks of users and producers of climate forecasts have been recognized; however, not much has been done to understand the cultural meanings and social life implications of this climate knowledge (Roncoli, 2006). Meaning is grounded in locality, and is considered valid only for the specific site where it is produced (Cruikshank, 2005; Nelson et al., 2009).

Colombia has accomplished a great deal in preparations and adaptation to climate change; however this study reflects the lack of local data to understand how changes are occurring on local scales and reflect the ways in which they relate to people's perceptions. This is important because local perceptions of environmental uncertainty and nature are key to understanding what lies behind resource exploitation. Without basic climate data it is very difficult to achieve sound analysis that allows tracking climatic conditions, which would allow us to better understand how local realities mirror regional trends and predictions. We have had the opportunity to return to the study site since the initial field phase of this research and people continue to notice the same changes, as well as reporting new ones. It is very complicated to attribute what is happening in the region to climate change given the lack of data taken by calibrated monitoring systems (Magrin et al., 2014).

Despite the fact that Colombia is monitoring its greenhouse gases contributions given the United Nations Framework Convention on Climate Change (UNFCCC) mandate, the approach to mitigating impacts of climate change on a national level is very different than would be taken at a smaller scale given local experiences (Hansen et al., 2015). The importance of climate to system organization and function lies in the influence it exerts on ecological phenomena in determining distribution and activities of organisms, as well as the physical characteristics of an ecosystem (Marshall et al, 2008). Furthermore, climate can influence connections between ecosystems and the spread of disturbances. The coalescence of all of these ecosystem components and activities ultimately determines the optimal functioning of processes and can result in specific outcomes, with influence on human population distribution and human land-use practices (Marshall et al., 2008). Our study is unique in its comparisons of regional climatic trends and local perceptions. Interdisciplinary studies help us understand how beliefs, knowledge and customs shape the way humans conceive and use the land. In this study, we gave special consideration to the role of indigenous people in this context and how such knowledge is employed and modified over time. Cross-disciplinary research that combines science and local perspectives to create knowledge is fundamental to understanding the impacts of climate change, since the global problem of climate change generates local consequences (Cruikshank, 2005; Naveh, 1995).

Table 4.1. Main categories for changes reported by informants after content analysis

Group Name	Reported Changes
Changes in average temperature	Higher temperatures
Changes in river behavior	River drying more than usual River out of synchrony Stronger flows
Changes in rain seasonality	Rains out of synchrony
Changes in friaje	Friaje out of time Friaje absent Milder friaje Shorter friaje
Changes in droughts	More frequent droughts
Changes in wind patterns	
Changes in minimum temperatures	Lower temperatures at night
Changes in temperature extremes	
No changes	

Table 4.2. IDEAM weather stations in the study area

Code	Name	Elevation (m.a.s.l.)	Latitude DDD	Latitude MM	Latitude SS	Latitude Dir.	Longitude DDD	Longitude MM	Longitude SS	Longitude Dir.
48010010	Leticia	84	04	09	00.00	S	70	21	56.20	W
48017010	Leticia	120	04	13	21.10	S	69	56	33.80	W
48015010	Apto Vasquez Cobo	84	04	11	37.90	S	69	56	27.30	W
48015020	Apto Vásquez Cobo	84	04	11	57.80	S	69	56	37.30	W
48017030	Nazareth	119	04	07	12.70	S	70	02	09.90	W
48015030	Parque Amacayacu	82	03	49	08.90	S	70	15	39.20	W
48017070	Parque Amacayacu	82	03	49	07.40	S	70	15	38.40	W
48010020	Pto Nariño	93	03	47	01.80	S	70	21	56.20	W
48015040	Pto Nariño	158	03	46	49.10	S	70	21	45.50	W
48017020	Pto Nariño	80	03	46	56.60	S	70	21	51.50	W

Table 4.3. Interview demographics

Gender	Age	Ethnicity	Time living in Puerto Nariño	Occupation	Schooling
Female	12-19 (n=5)	Tikuna (n=5)	Entire life (n=5)	Student (n=3) Housewife (n=1) Farmer (n=1)	High school graduate (n=2) Students (n=3)
	20-29 (n=6)	Tikuna (n=5) Cocama (n=1)	Entire life (n=6)	Student (n=1) Housewife (n=2) Informal employment (n=3)	Incomplete high school (n=2) High school graduate (n=2) Technical degree (n=1) Technical student (n=1)
	30-39 (n=3)	Tikuna (n=2) Andoque (n=1)	Entire life (n=3)	Student (n=1) Farmer (n=1) Informal employment (n=1)	Incomplete high school (n=1) Technical degree (n=1) Technical student (n=1)
	40-49 (n=6)	Tikuna (n=4) Cocama (n=1) Huitoto (n=1)	15-20 yrs. (n=1) Entire life (n=5)	Firefighter (n=1) Farmer (n=2) Employed (n=1) Informal employment (n=2)	High school graduate (n=2) Incomplete high school (n=1) Complete elementary (n=3)
	+ 50 (n=5)	Tikuna (n=5)	Entire life (n=5)	Farmer + artisan (n=4) Farmer (n=1)	Complete elementary (n=2) Incomplete elementary (n=1) No formal education (n=2)

Cont. Table 4.3.

Gender	Age	Ethnicity	Time living in Puerto Nariño	Occupation	Schooling
Male	12-19 n=5	Tikuna (n=4) Yagua (n=1)	Entire life (n=5)	Student (n=3) Unemployed (n=1) Farmer (n=1)	High school graduate (n=1) Technical degree (1) Student (n=3)
	20-29 n=5	Tikuna (n=4) Cocama (n=1)	Entire life (n=5)	Employed (n=4) Student (n=1)	High school graduate (n=2) Technical degree (n=1) Technical student (n=2)
	30-39 n=4	Tikuna (n=3) Cocama (n=1)	Entire life (n=4)	Firefighter (n=1) Governor (n=1) Artist (n=1) Employed (n=1)	Incomplete bachelor (n=1) High school graduate (n=2) Technical degree (n=1)
	40-49 n=6	Tikuna (n=4) Cocama (n=2)	10-15 yrs. (n=2) 15-20 yrs. (n=1) Entire life (n=3)	Employed (n=4) Informal employment (n=2)	High school graduate (n=1) Incomplete high school (n=1) Complete elementary (n=1) Technical degree (n=2) Technical student (n=1)
	+ 50 n=5	Tikuna (n=2) Cocama (n=2) Yagua (n=1)	Entire life (n=5)	Farmer +government official (n=1) Farmer + fisher (n=1) Informal employment (n=3)	Complete elementary (n=2) Incomplete high school (n=1) High school graduate (n=1)

Table 4.4. Regular environmental conditions in Puerto Nariño

Description of Usual Conditions for the Region
River used to start increasing its level around November, reaching the highest point in April and going down from May. September used to be the driest month. Between December and February there used to be "repiquetes" (sudden minor floods).
Friajes occurred at least once a year. The first one used to be in May and the second one in June.
Distinct seasons (summer and winter)
Sun was not as strong and we were able to work all day, even at noon.
Even on low waters there was always enough water in the tributaries for navigation. Severe droughts were rare, they occurred every 30 years.
The river was more stable; we knew how to "read" it.
By this time of year, (June) the river was already drying.
There used to be a big island across town, we used to cultivate there.

Table 4.5. River trends for the region

	Maximum Water Level	**Minimum Water Levels**	**Date of Maximum Level Reached**	**Number of days below the 20th percentile (Drought)**	**Number of days above the 80th percentile (Flood)**
Significant changes in trends	Yes	No	No	No	No
Tendency	Increase*	Increase	Earlier	Decrease	Increase

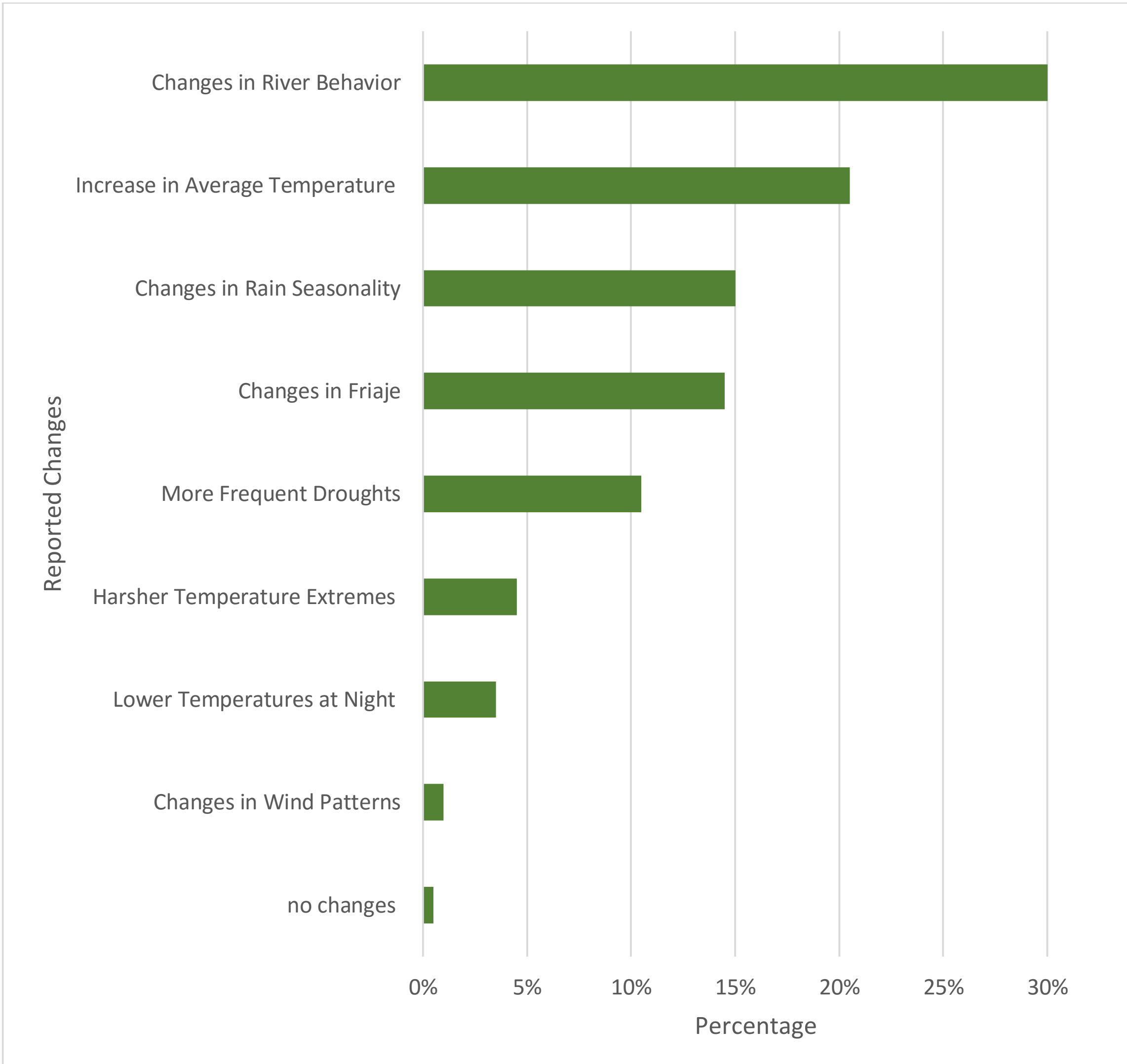

Figure 4.1. Percentage of Reported Perceived Changes in the Environment

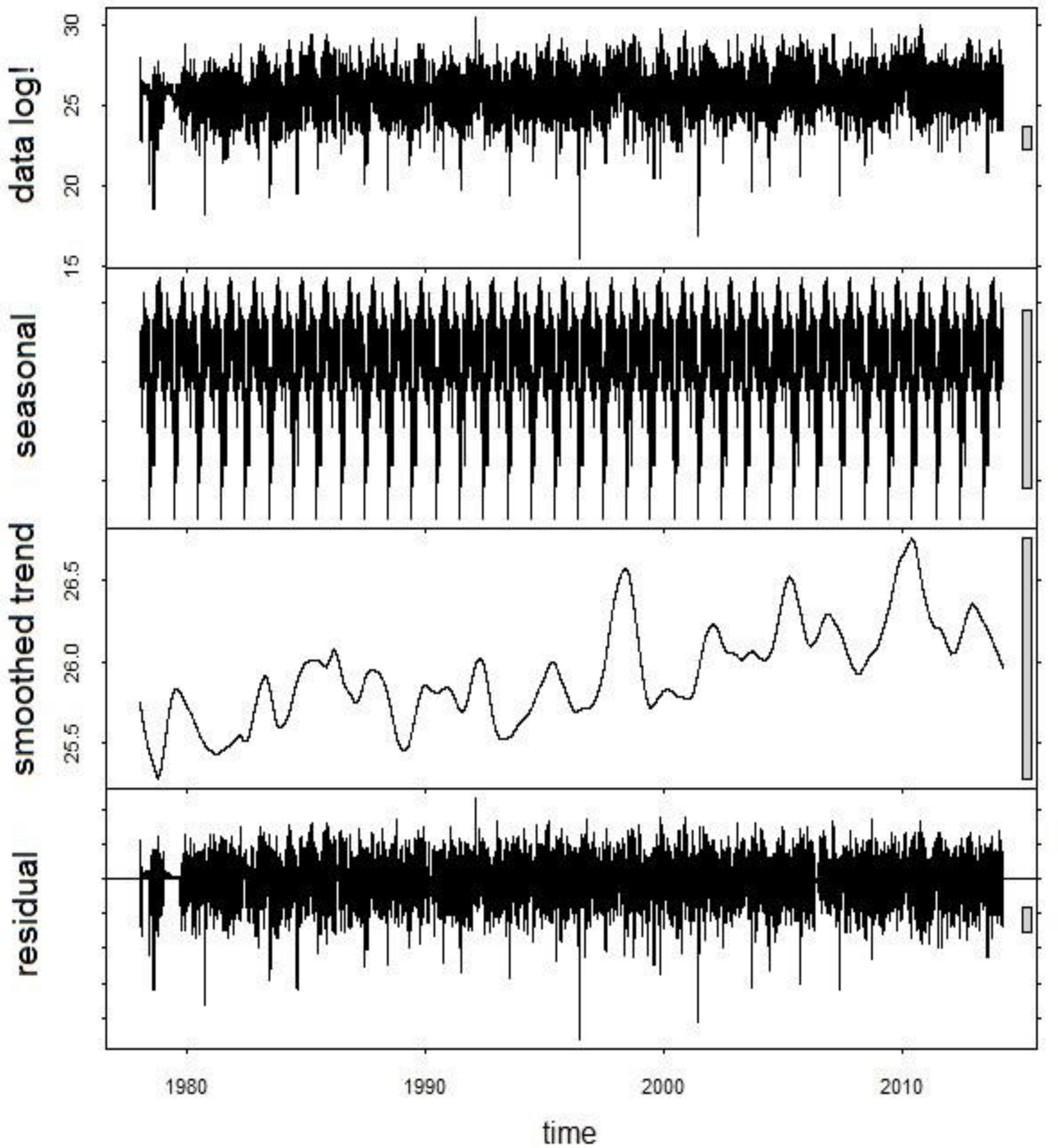

Figure 4.2.a. Time-series analysis for average temperature collected by Leticia's Airport gauge from 01/01/1978 to 12/31/2013

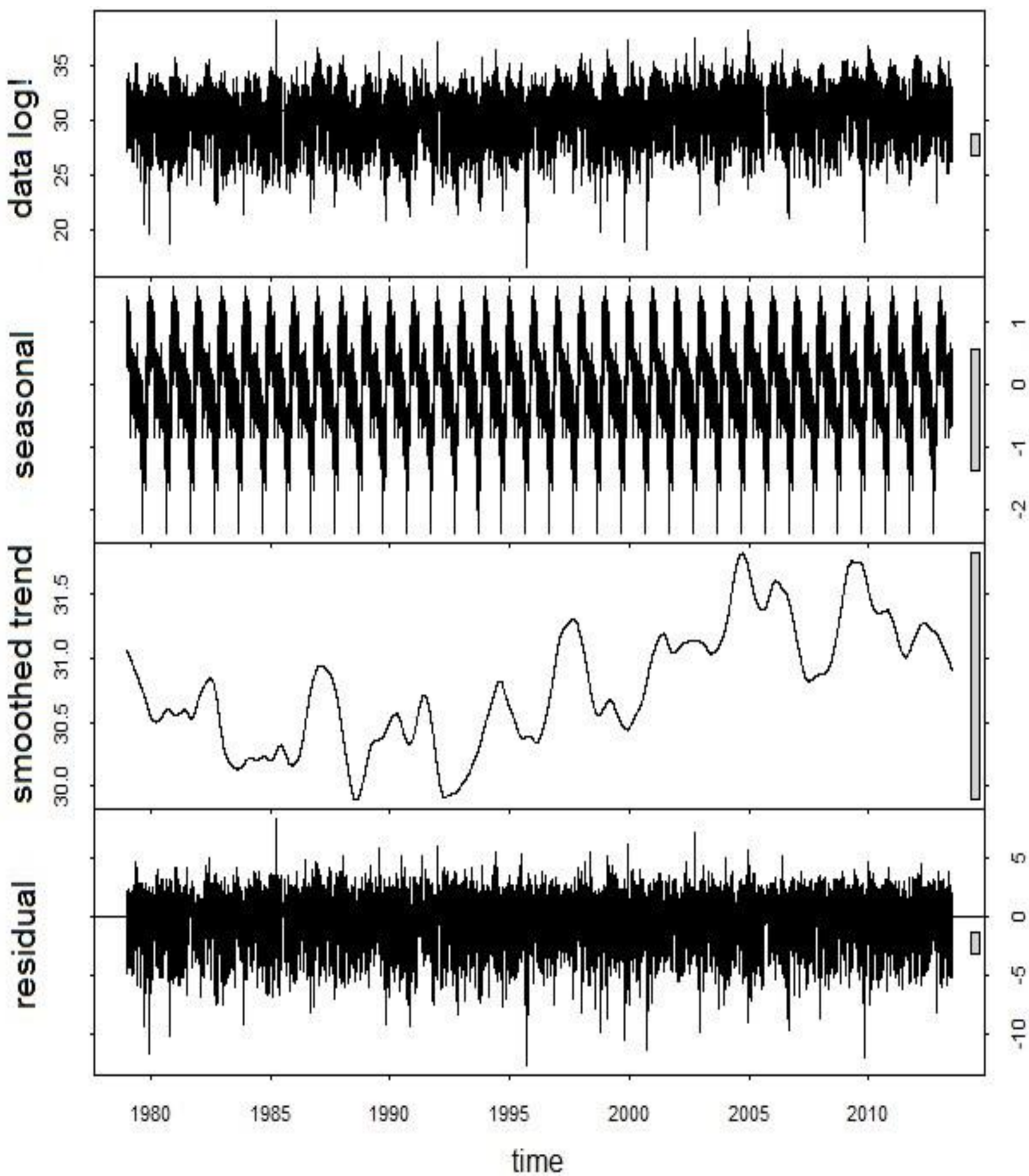

Figure 4.2.b. Time-series analysis for maximum temperature collected by Leticia’s Airport gauge from 01/01/1978 to 12/31/2013

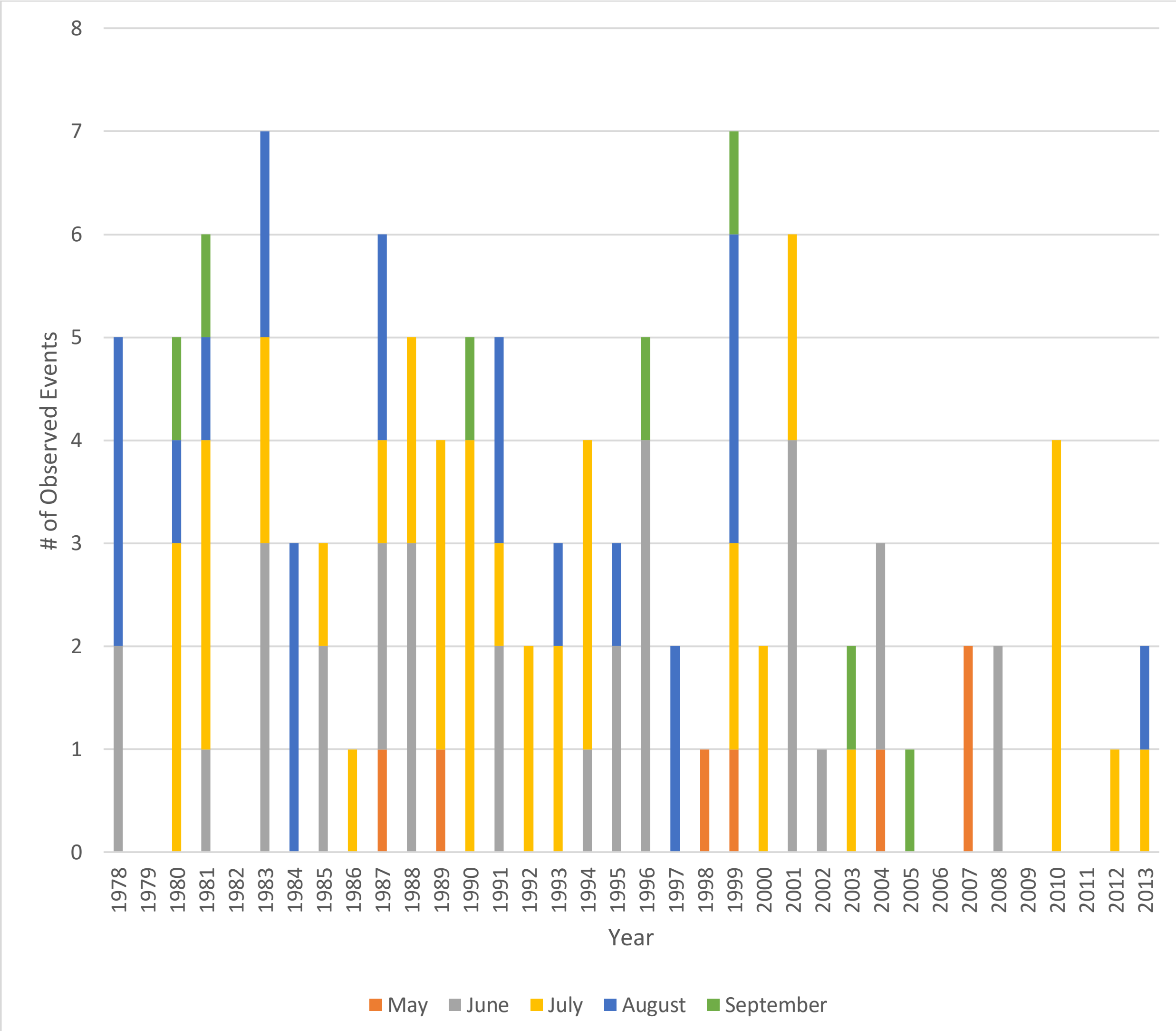

Figure 4.3. Number of friaje events per month and year for the austral summer (May – September) from 1978 to 2013.

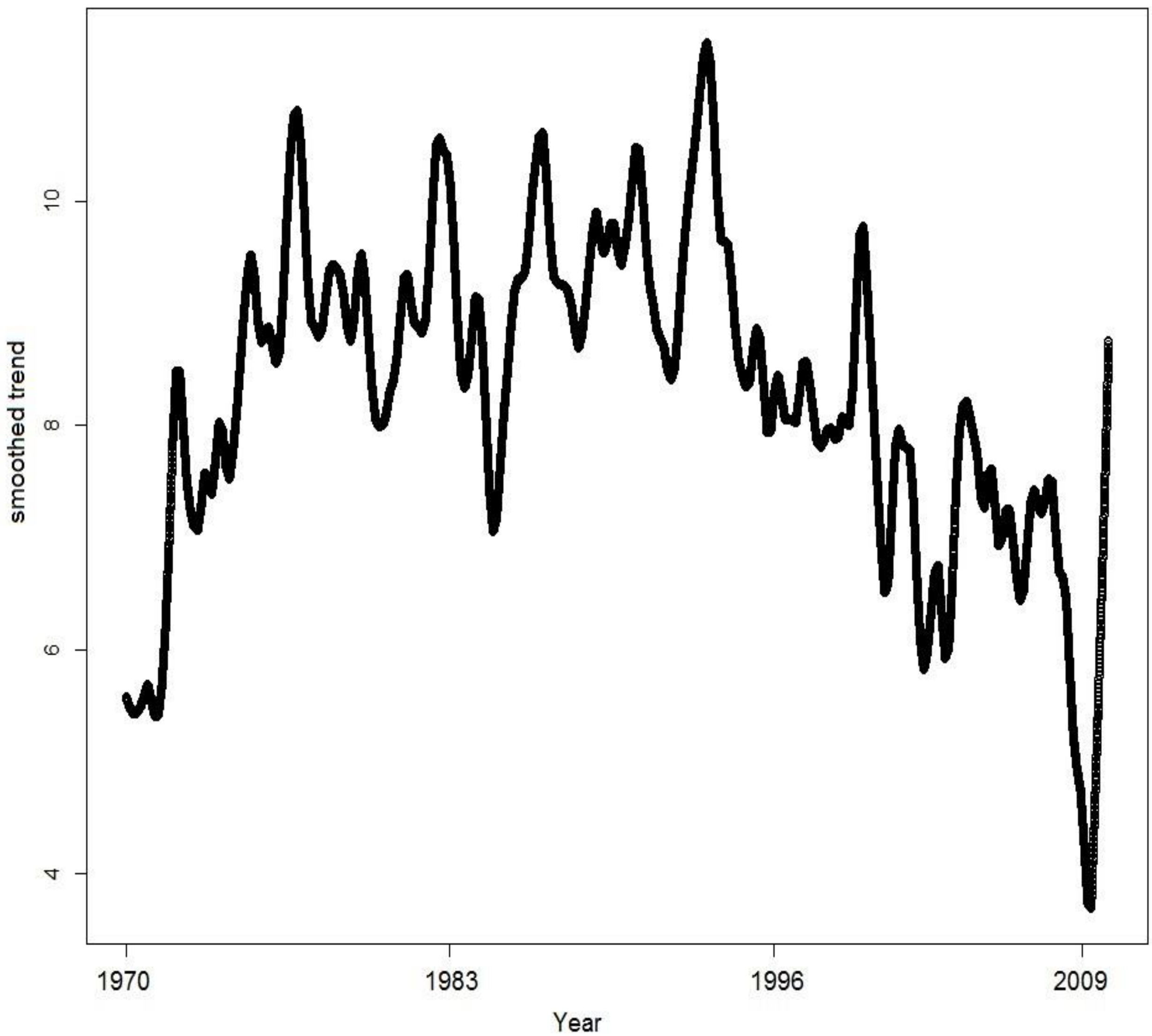

Figure 4.4. Trend in time -series analysis for precipitation collected by Leticia’s Airport gauge from 01/01/1970 to 12/31/2013

CHAPTER 5

LOCAL REALITIES AND COPING STRATEGIES IN PUERTO NARIÑO[4]

[4] Rodriguez Granados, R. and N. Nibbelink. To be submitted to Nature Climate Change.

Female, 26 yrs

"El calor afecta mucho porque les (a los abuelos) *toca ir muy de madrugada hasta máximo las 10 am a trabajar en las chagras. Después no se puede por el sol y en cambio antes no lo hacían y podían trabajar todo el día. Ahora la gente tiene chagra en tierra alta y en tierra baja, no dejan la de tierra baja pero si tienen una opción en tierra alta. Además es una costumbre muy marcada de los abuelos porque el agua es la rutina del pueblo Tikuna como tal."*

The heat affects a lot because they (the elders) have to go very early until 10 am the latest to work in the chagras. After it is not possible because the sun, before they could work all day long. Now people have chagra in the uplands and in the varzeas, they don't leave the varzeas but they have an alternative in the uplands. Besides this is a very important tradition of the elders because water is the routine of the Tikuna people.

Abstract

The importance of climate lies in the influence it exerts on ecological phenomena, determining organisms' distribution and activity. Climate also defines the physical characteristics of a given ecosystem, including its connections with other ecosystems and the spread of disturbances that determine the optimal functioning of specific processes. All of these have an effect on human population distribution and human land-use practices. Although Colombia has been addressing climate change through different strategies, most of the work has been done at the planning level and not considering local realities in a meaningful way. The government needs to address perceptions and design culturally sound management practices together with local communities in order to understand the effects of regional climate change on societies and their ability to adapt. In Puerto Nariño (Colombian Amazon), indigenous communities are perceiving important environmental changes that coupled with other sources of degradation (cultural erosion, overexploitation and population increase) are impacting several aspects of their livelihoods, mainly agriculture, fishing, navigability, infrastructure and health. Using ethnographic methods, we explored the practical consequences of perceived changes. For most of these, people have not found a coping strategy that helps them deal with the consequences. Regarding agriculture and fishing, people are responding by opening new farming fields, exploring new fishing areas or changing their livelihoods strategies. These are causing changes in the local landscape, where some areas overlap with Amacayacu National Park (protected area). Changes in land use in the Amazon contribute to climate change trends by affecting the hydrological cycle and increasing local temperature, therefore the approach that this community is taking is not necessarily adaptive in the long term.

Introduction

Amazonia Indigenous Livelihoods

The Amazon region displays a mixture of anthropogenic scenes and high biodiversity that have resulted from continuous occupation (Micarelli and Alexiades, 2009), with livelihoods depending importantly on natural resources (IISD et al., 2003). Indigenous communities of Puerto Nariño (Colombian Amazon) report that their livelihoods are strongly affected by the effects of climate change because their ways of life depend on their ability to interpret and act upon regular natural cycles (Kronik and Verner, 2010). There is a clear lack of alternatives and coping strategies for many of the problems these communities are facing, and these have to be addressed to allow a sustainable development and permanence of not only the biological, but also the cultural diversity of the region. The study reported in this chapter describes how indigenous peoples of Puerto Nariño are perceiving environmental change, how they feel their livelihoods are affected, and how they are responding to such affectations, framed in governmental approaches to adaptation to climate change.

Northwestern Amazonia exhibits seasonality based on precipitation regimes, river levels, winds and temperature fluctuations (Marengo, 2006). Periodicity has been seen as intrinsic to life in the responses of people and embedded in their particular environment where in many cases the passage from one season to another is marked by rituals and reflected in productive cycles that modify social structures (Echeverri, 2009). In northwestern Amazonia, survival depends on detailed local environmental knowledge and technical expertise (Harris, 1998; Stearman, 1994) to be able to manage transitions appropriately depending on the seasonal changes and the technical skills required for each of the different activities that take place (Harris, 1998). Subsistence decisions are done with large levels of uncertainty given the distribution of natural resources and the environmental changes to which human communities are not familiar (Betts et al., 2008; Brondizio and Moran, 2008; Echeverri, 2009; Nobre et al., 2005). In the northwestern Amazon annual activities depend significantly on the river level and the influence it has on natural communities and physical processes (Harris, 1998). Water and aquatic resources are central to local livelihoods. Most of the animal protein consumed locally comes from fisheries within the area; water for human consumption is taken without additional treatment from rivers and lakes and is also is used for cleaning and self-hygiene (Lavado Casimiro et al. 2011). Additionally rivers are the only transportation available, particularly for isolated communities along the tributaries.

Agricultural activities along the river margins of the amazon have taken place since prehistoric times (Meggers, 1977; Shorr, 2000); food production required an integration of cultivation in the interfluvial and flooded areas and not one or the other (Denevan, 1966, 1996). It has been described (Harris, 1998; McClain and Cossio, 2003) that riparian areas and flood plains have more fertile soils resulting from the seasonal flooding and subsequent nutrient replenishment, which is important for crops that do not do as well in the uplands (Shorr, 2000). Agriculture therefore is developed both in the seasonally flooded areas (Figure 5.1) and in the uplands, with the diversity and types of crops depending on the location where they are planted (McClain and Cossio, 2003).

Social life for Amazon indigenous peoples is related and developed through the environment (Harris, 1998). As Echeverri (2009) explains, seasonality in the Amazon is what determines ritual practices and agricultural cycles throughout the year. Events like friaje (incursions of polar air masses towards the equator during the austral winter; Dantas Ricarte et al., 2015) have the utmost importance since indigenous people believe it is the time of year when the land gets “impregnated” and fauna and plants reproduce. It is also believed that it arrives when water levels are at its maximum and defines the end of the rainy season. Friaje is followed by summer (dry) months when people use the conditions to clean the farming fields and burn the land to replenish its nutrients and kill local pests, preparing the ground for crops (Echeverri, 2009; Hammond et al., 1995) in the uplands.

Land Use Transformations

Amazonia is the iconic image for deforestation, degradation and climate change in the context of future scenarios (Betts et al., 2008; Malhi et al., 2008). More than 13% of the original area had been cleared by 2001 (Betts et al., 2008). Changes in land use generate consequences that are felt during the lifespan of a generation and they are fundamental in the study of environmental change (Duerden, 2004). Past forest cover transformations in response to past climatic change can help evaluate the outcomes of human induced climate change and biological invasions, and understand tree colonization, adaptation and extinction; however, there are important differences in the drivers of change that exist between the past and the present (Petit et al., 2008). Land use transformations resulting from the modification in biophysical conditions for the region, together with the anticipated changes related to climate change, are expected to have impacts including erosion, freshwater systems degradation, loss of soils, accelerated biodiversity loss, decreased agricultural yields, increased insect infestations and severe consequences on human health (Magrin et al., 2007; Nobre et al., 2005).

In the Amazon increased deforestation can change the water cycle and therefore the climate in the region and across the planet (Marengo, 2006; Magrin et al., 2007). This paired with climate change can accelerate the hydrologic cycle, influencing precipitation by increasing evapotranspiration, which adds moisture to the atmosphere and if recycled, directly increases rainfall overall (Carpenter et al., 1992; Marengo, 2006). It can also increase latent heating, which associated with this increased rainfall can drive an intensified circulation creating alterations in the moisture convergence from remote sources (Marengo, 2006). Deforestation also causes the release of large amounts of carbon dioxide into the atmosphere affecting the global climate (Betts et al., 2008; Daviet et al., 2007; Malhi et al., 2008). On a local level temperatures increase, moisture is reduced and the length of dry seasons are extended (Bush, 1996; Salati and Vose, 1984), so the local effect is felt as warmer and drier climate (Bush, 1996). Water regime changes have already been observed (Echeverri, 2009; Kronik and Verner, 2010; Ulloa et al., 2008) modifying flow, flooding, runoff and erosion (Carpenter et al., 1992). These changes impact essential aspects of people's livelihoods including fisheries, agriculture, basic water supply and transportation (Pinilla Herrera, 2004).

Knowledge Systems of the Amazon

It has been recognized that indigenous people know of several uses of biodiversity and of the proper way to forage for resources (Gadgil et al., 1993; Toledo, 2001). This sustainable use and management of nature by small-scale societies has been linked with spirituality and practical understanding of the environment (Smith and Wishnie, 2000; Toledo, 2001). Indigenous societies have important local ecological knowledge transmitted through language (usually unwritten) (Wyndham, 2010). Memory is essential for these societies, where knowledge is drawn from accumulated experiences over history, experiences shared within peers, experiences shared within households and personal experience (Nazarea, 2006). This knowledge is holistic because it is intricately linked to the practical needs of use and management of local ecosystems. Local knowledge encompasses structural aspects of nature, dynamics, relations and utilitarian dimensions of natural resources (Toledo, 2001). Landscape changes and overall habitat degradation impact traditional knowledge since words and knowledge are forgotten as the objects of that knowledge disappear (Ellen, 1993). The Amazon region currently reflects the close relation between the destruction of tropical forests and other ecosystems and the decrease of biological diversity as well as cultural loss (Ramirez, 2007).

It is important to recognize the evolution of knowledge systems and how they will be forced to adjust as a consequence of climate change, in order to understand how this is impacting the development and reproduction of local cultures (Kronik and Verner, 2010). Climate change is reflected in the diminishing ability of elders to predict what is happening (Crate, 2009; Duerden, 2004), creating a lack of trust from younger generations in these knowledge systems (Kronik and Verner, 2010). Contact with western civilization is causing traditional production conversions (Andrade, 1988), urbanites moving to areas historically inhabited by indigenous people have deepened these transformations (Ramirez, 2007). As climatic conditions have become impossible to predict, other bodies of knowledge are gaining importance (Cristancho and Vining, 2009) and migration has become common to look for other sources of income (Kronik and Verner, 2010; Roncoli, 2006). Loss of traditional knowledge is related to further degradation since the underlying values that govern the use of resources are lost together with the knowledge of these systems (Dietz et al., 2003).

Climate Change and Amazonian Livelihoods

Colombia's National Third Communication of Climate Change for the United Nations Framework Convention on Climate Change (UNFCCC) (IDEAM et al., 2015) predicts for the region temperature increases of up to 2.4°C toward the end of the century. Precipitation is expected to decrease, particularly in the municipalities of Leticia and Puerto Nariño (study site) (Table 5.1). Climate change is anticipated to have an effect on river flow as well as on phenology of flowers and fruits given the increases in temperature and the decreases in rainfall; it is also expected to cause an increase in pests (IDEAM et al., 2015). Human and natural systems have been able to respond to climate change and uncertainty in the past; however the current state of these systems is what determines their overall vulnerability, resilience and adaptive capacity, since other sources of degradation (cultural and ecological) create a complex scenario for both natural and social systems in their ability to respond and maintain their basic functions in a given context (Crate, 2009; Marshall et al., 2008; Petit et al., 2008). As Petit, et al. (2008) explain "…future extinctions of tree species in response to climate change are probable, especially if their geographic distribution or climatic range is already highly restricted." (p. 1451).

Climate controls phenology (Marshall et al., 2008), which has been shown to alter ecological calendars that are related to local communities' livelihood strategies (Ulloa et al., 2008). Biodiversity loss due to changing climate conditions affects ecosystem services, with the most severe impacts being felt by the poor and those who depend directly on natural resources (Green and Raygorodetsky, 2010; SCBD, 2010). Currently it is recognized that the effects of climate change will be distributed differentially, with certain areas facing the largest burdens where many of the resource-dependent communities are still located (Adger et al., 2003; Crate, 2009) as is the case of Colombia's Amazon.

Given the characteristics of Puerto Nariño, ecological and social resilience may be linked through the dependence on ecosystems of communities and their economic activities governed by institutional structures that oversee the use of natural resources (Adger, 2000; Holling and Gunderson, 2002). The scientific knowledge that local communities have related to climate change and its local effects reflects what Berkes and Jolly (2001) call a "grave mismatch" between global research to generate knowledge related to climate change and the information that local communities require to be able to respond to its impacts. The context of human research related to climate change should consider local biophysical conditions, together with "demographic trends, economic complexity, and experience with "change" in a broad sense" (Duerden, 2004, p.204).

Colombia has been recognized for its efforts in the climate change field. The role of the state is to promote social and policy learning, leading to the co-management of resources that encourage feedback across different levels so that learning and self-organization can take place (Adger, 2003; Berkes and Jolly, 2001). According to Colombia's latest Intended Nationally Determined Contributions (INDCs) (Gobierno de Colombia, 2015), submitted before the Paris COP 21, 11 territorial adaptation plans have been completed and 100 percent of the country will have plans formulated and implemented by 2030. Colombia's INDCs also intend a national system of adaptation indicators that will guide monitoring and evaluation of these adaptation measures, and water resource management tools for the country's priority water basins. Other commitments include adaptation planning for the six sectors of the economy, awareness and public education strategies, working groups on climate and agriculture; and an increase in protected areas by more than 2.5 million hectares (Gobierno de Colombia, 2015). A previous commitment involves achieving zero net deforestation in the Amazon by 2020.

Adaptation in Uncertain Landscapes

The disintegration of social capital, the erosion of resources, and the absence of viable livelihood options can occur when communities are less resilient (Adger et al., 2009). Vulnerability is the product of the interaction of biophysical and human processes (Brondizio and Moran, 2008; Eakin and Luers, 2006; IISD et al., 2003) and relates to the capacity to foresee, prevent, react, cope with and recuperate from the impact of events implying the loss of tangible and intangible assets (Berkes and Jolly, 2001; Lampis, 2009). For this reason, access to scientific information is important for decisions of resource allocation (Adger, 2003; Crate, 2009) related to ecological and social resilience given the dependence of communities and economic activities on ecosystems, linked by institutional structures that govern the use of natural resources (Adger, 2000).

Perception of climate change is structured on activities and related knowledge and on the landscape and the opportunities it provides (Vedwan, 2006). Indigenous peoples are ethno-climatologists that given their experience and knowledge can see that things are changing (Crate, 2009; Duerden, 2004; Green and Raygorodetsky, 2010). Perceptions of environmental change mediate behavioral transformations seeking adaptive processes and are related to culture, society, economy and the environment (Brondizio and Moran, 2008). It has been shown that more diversity related positively with adaptive capacity and given the multiplicity and dynamism of Amazonian communities, it is clear that they are seeking alternatives to cope with the perceived changes. In Puerto Nariño, natural cycles determine livelihood strategies including agriculture, fishing, hunt times and animal reproduction, river navigation, periods of droughts and floods, heat and cold waves and in general a change in the ecological calendar (Brondizio and Moran, 2008; Echeverri, 2009; Kronik and Verner, 2010; Ulloa et al., 2008). Indigenous perspectives and cosmologies that understand the role of human beings in the larger photo and how as a species is dependent on the health of the environment, recognize the importance of having reliable seasonal cycles that are threatened by climate change and are resulting in local responses that are as varied as the array of landscapes where they develop (Turner and Clifton, 2009).

Changes in precipitation, extreme rainfall events, and seasonality impact the amount, timing, and variability of flow in the Amazon, resulting as well in variability and timing of floods (Carpenter et al., 1992), already perceived by local communities. Predicted changes of decreased rainfall paired with increased temperature can also result in longer and more severe droughts, affecting seasonality which together with land use changes can result in further degradation of water systems, loss of productivity, loss of biodiversity and an increase in pests and diseases (Magrin et al., 2014). This will adversely impact subsistence agriculture particularly through drought; variation and duration of floods; and spread of accidental fire. The effect of these changes on livelihoods is direct and it is reflected in economic activities, land uses, livelihoods, residential patterns, dependencies on social networks and exposure to diseases (Brondizio and Moran, 2008). Changes in seasonality perception were found in chapters three and four for Puerto Nariño and have also been previously described by Echeverri (2009). Indigenous people agree in the changes of rainfall seasonality, diminishment of friaje events and unpredictability of river behavior. In chapter four it was found that there is a close correlation between people's perceptions and observed climatic trends for the region, which has been reported in other cases (West et al., 2008).

The increase in climate variability has diminished or taken the ability of indigenous peoples of predicting weather and other environmental phenomena (Adger et al., 2009; Berkes and Jolly, 2001; Crate, 2009; Cruikshank, 2005; Duerden, 2004; Echeverri, 2009; Kronik and Verner, 2010; Ulloa et al., 2008) threatening their adaptive capacity (Cruikshank, 2005). Seeking constant and unchanged systems with fixed rules usually results in "mal-adaptation," especially in systems that are facing the effects not only of climate change, but also of globalization, where customs and traditions are being transformed (Roncoli, 2006) and the connections between local knowledge and local environments is being lost diminishing the capacity to recognize and implement sustainable adaptation strategies to the consequences of climate change (Salick and Ross, 2009).

Berkes and Jolly (2001) use the term adaptation (any response that increases a population's probability of survival) differentiating between short-term responses to climate change or coping mechanisms and long-term adaptive strategies that involve cultural and ecological adaptations. For these authors these are found in a continuum of space and time, going from emergency responses (or coping strategies) to changes in livelihoods that modify local rules and institutions. Indigenous communities are not passive victims and their adaptive capacity is linked to their deep and general knowledge of their contexts (Crate, 2009; Cruikshank, 2005; Duerden, 2004; Nelson et al., 2009). They interpret and react to climate change impacts in creative ways, using local knowledge and developing new technologies including migration, irrigation, water conservation techniques, land reclamation, and agricultural practices paired with land use changes (Salick and Ross, 2009).

Adaptive strategies adopted by people depend on previous experience and overall knowledge which is context dependent and determines also individual responses that are time dependent and heterogeneous, with some individuals coping rapidly and others taking more time to change (Brondizio and Moran, 2008). One of the main problems with climate change studies lies in the increase in climatic variability and the occurrence of extreme weather events accompanied by a lack of knowledge of how this will be manifested on local levels (Duerden, 2004; Marshall et al., 2008). The study reported in this chapter describes how indigenous peoples of the Colombian amazon are perceiving their livelihoods are being impacted by environmental change and how they are responding to such affectations. It also discusses the governmental approach to adaptation to climate change in Colombia. To that end, this chapter answers the following questions: 1) What are the livelihood implications of perceived changes?; 2) Consequently what are the coping measures adopted by local communities and what effect do these have on the overall landscape? and 3) What are the implications (from a local and governmental stand) of adopted strategies in terms of enhancing vulnerability or reducing adaptive capacity of these local systems?

Research Site

In Colombia indigenous territories (resguardos) are recognized by the 1991 constitution that have been titled based on tradition and occupancy and are held by the cabildo or indigenous governing body of a community. The state recognizes full ownership of these areas and respects management practices within (Colchester et al., 2001). Puerto Nariño is located in the southern part of the country and is particularly vulnerable because many of the human settlements are isolated and depend greatly on natural resources for their subsistence. It was recognized as a municipality, therefore a political unit, in 1961. It is located 87 km from the main capital of the Amazon Department, Leticia and has a total area of 1,876 km2 (Figure 3.1). Human settlements have been reported in the area since 1936 and the first boarding school was established in 1957 by a catholic religious community (Alcaldia de Puerto Nariño, 2008). The total population for the area is of 7,338 inhabitants of which 5,416 are in the rural area and 1,922 in the urban area. Local rainfall averages about 3,150 mm per year with a mean monthly temperature of 26°C. The rainy season (invierno) is from October to June, and dry season (verano) from July to September. The highest river levels are usually in May, and the lowest levels can be seen by the end of September. Puerto Nariño overlaps with the 300,000ha Amacayacu National park. A protected area that allows for subsistence use in the overlapping extents, given the historical presence of these communities in the region.

Most of the people belong to the Tikuna indigenous group, but there are also Cocamas, Yaguas and colonos (settlers) (DANE, 2007). In the area there are two kinds of settlements depending on the organization and traditional social structure: indigenous settlement and multiethnic settlement. The former involves clear hierarchical structures and clan dominance; while in the latter there is no clear hierarchical organization since migrants from other regions and ethnicities live together and have given rise to other sources of conflicts (Pinilla Herrera, 2004). This is the case of Puerto Nariño.

Most of the economic activity for the municipality is based on subsistence strategies around fishing, small scale agriculture, lodging and tourism (Alcaldia de Puerto Nariño, 2008; Pinilla Herrera, 2004). Seventy percent of people base their livelihoods in subsistence activities planting manioc, corn and rice, fishing and hunting. Five percent are employed by the local government and 25% base their livelihoods in activities related to the touristic industry as are restaurants, hotels, stores and product (usually handcrafts) selling (Alcaldia de Puerto Nariño, 2008). For the agricultural fields (chagras) men select the place where these will be established and in a collective manner (mingas) cut down the trees. Women are responsible for burning down the area and keeping it clean from weeds. They are also responsible for most of the planting, care and harvest of the fields (Pinilla Herrera, 2004). Domestic animals are not very common but some families have chickens and pigs; however, recently colonos have introduced livestock to the area (Alcaldia de Puerto Nariño, 2008).

Fishing increases as the water levels decrease (Shorr, 2000) and is done both by indigenous groups and colonos as the preferred source of protein. Fishing is done individually and collectively in the area using both traditional methods as arrows or throw nets and nets, hooks, etc. Hunting is mainly a male activity that was traditionally done with arrows and traps (Shorr, 2000), but currently the use of firearms has become the main weapon. In the past this activity was done in groups but recently it has become an individual activity (Alcaldia de Puerto Nariño, 2008). Illegal trade has been identified mostly for colonos and is done with live fish, monkeys and birds, and with some animal skins as well (Maldonado et al., 2009).

Methods

We conducted fieldwork over two three months periods between 2012 and 2013 in the municipality of Puerto Nariño. For sampling, we drew elements from (Marshall, 1996) using stratification by age and gender and then selecting similar numbers of participants for each category by opportunity. Participants then were selected based upon their availability and disposition to be a part of this research. The total number of participants involved was 50, twenty-five for each gender and around 10 for each age group (12-19 years, 20-29 years, 30-39 years, 40-49 years and over 50 years of age). During preliminary research in the Colombian Amazon, people reported noticing and responding to changes in the hydrological cycle, which determines what, where and when subsistence activities take place. Using this experience and in order to evaluate human perception of their environment, we designed and conducted semi-structured interviews interviews, paired with resource walks and life histories, all carried out in Spanish. Interviews lasted 30 minutes to one hour, depending on the amount of detail given by the informant.

All participants consented to be involved in this research. All informants identified as indigenous from the main groups found in the area (Table 4.3). In the Results, we coded the source of quotations from interviews and workshops in a way that identifies gender and age group. During interviews and other approaches we initially sought perspectives on the ways in which perceived changes are impacting local indigenous livelihoods and the coping mechanisms that are being locally developed to deal with these effects. The main questions covered in the interviews for this chapter include:

- Why do people prefer to farm in the lowlands?

- What is the difference between farming in the lowlands and the uplands?
- Are there other issues that are affecting your livelihoods besides the identified climatic trends? If so, what are they?
- How are the perceived changes impacting you or the people you know?
- How are you or the people you know responding to these changes?

For research walks, male and female participants guided researchers to different areas and showed aspects of the landscape discussed during the interviews. We recorded data from interviews on video and data from life histories and resource walks was recorded by handwriting. We also recorded visual data, such as photographs and videos. Analysis of data (words) was conducted manually and involved substantive coding (Fernandez, 2004). Substantive coding led to the identification of main themes and categories through an inductive approach (Elo and Kyngäs, 2008). Following the theory of constructivism, we assumed that participants' perspectives are derived from their experiences of their physical environment and from social interactions with other members of the community and family.

Results and Discussion

Livelihoods

- Agriculture in the Lowlands vs Uplands

The main reason informants gave for planting their fields in the lowlands relates to the quality of the earth, previously explained by different authors (McClain and Cossio, 2003; Meggers, 1999). As one informant described in the uplands "La primera cosecha es buena pero la segunda ya no y por eso la gente prefiere chagras en bajas" (Female, 18 years old - the first harvest is good but the next is not, so people prefer to cultivate the lowlands). This has been previously reported in the literature (Andrade, 1988; Hammond et al., 1995; Herrera et al., 1992; Myers, 1992; Oliver, 2008; Shorr, 2000; Sombroek, 2001; Wittmann et al., 2004) as well. Another important reason for preferring the lowlands is that informants report that plagues are more frequent and resistant in the uplands, particularly ants (Atta sp.). Another common complaint reported repeatedly for the uplands is the lack of security. It has become common that people steal the harvests and there are no mechanisms to prevent this, other than “casting a spell on the thief” (Figure 5.2). Despite this, people farm the uplands, since the lowlands only allow to plant crops that can be harvested before the river floods these areas (Echeverri, 2009; Pinilla Herrera, 2004). Most of what they plant they report is for subsistence (Table 5.2), however, if there is any surplus they sell it in the local market for cash; this has been reported in other similar communities as well (Hammond et al., 1995).

In the lowlands the river determines cultivation and usually around June people start planting as the river starts to dry and continue doing so until all the beaches are exposed. They keep track of river behavior and harvest before the river floods and damages their produce. They report that they are able to cultivate in the uplands through the entire year and although they use climatic patterns for certain activities as well as certain beliefs for when certain species should be harvested, in general they do not have the pressure that the river imposes on the lowlands. Still crops need to be carefully cared for given the amount of thefts that take place and of course the plagues that exist. Informants explain that women hold primary responsibility for the farming fields, although men help at times and in many cases take care of the more physically demanding tasks as cutting down trees and cleaning the fields.

- Non-Climatic Stressors affecting Local Livelihoods

Most informants recognize that cultural change is the main problem they have when addressing non climatic stressors (Figure 5.3). The western education system has completely taken over younger generations, posing an important threat to local knowledge systems and cultural rules that used to regulate the relationship with nature (Brosius, 1997; Cristancho and Vining, 2009). Informants recognize the link between cultural diversity and biodiversity. In the region there used to be a sense of belonging with nature that contributed to respect, caring and sharing, acknowledging relationships with non-human entities that inhabit the system, such as plants, animals, spirits and gods (Pretty et al., 2008; Pretty et al., 2009).

People reported that youth are no longer interested in learning their traditions and practices, including how to fish, hunt or farm (Godoy et al., 2005). They report that now schooling and homework do not allow much time for them to acquire other kinds of knowledge (Cristancho and Vining, 2009) and that this has resulted in younger generations becoming more prone to steal since they cannot produce their own food. Interviewees report that youngsters just want to be a part of market economies and buy everything or get into unsustainable businesses or drug trafficking to procure their livelihoods. One informant reported “A los jóvenes nadie les enseña a sembrar o pescar y les da vergüenza. Hay mucha tierra pero nadie la quiere sembrar, quieren vivir como blancos, así se pierden los recursos, las historias, la cultura y eso es lo que permite el cuidado del ambiente. Cuando se te olvida todo eso no te importa nada.” (Female, 36 years old - No one teaches younger generations how to farm or fish and they are embarrassed. There is plenty of land but nobody wants to farm it, they want to live like the white man, this is how resources are lost, history is lost, culture is lost, and this is what allows that the environment is cared for. When you forget all that, you care about nothing).

The main source of protein stems from fishing despite the fact that it has also become harder. The reason for this is seen in overexploitation, habitat degradation and the use of unsustainable fishing methods including gill nets. Also because it became a commercial activity, resulting in depletion of the resource. There are several species that they report can no longer be found in the area. Men do most of the fishing, and although women fish too, they rarely used arrows and cast nets. Men also hunt, although it is not very common now since they report that animals have become scarce and that to be able to find game they have to travel inland for at least three days. They recognize that the reason for this is the overexploitation that took place (mainly for animal skins) as well as constant deforestation that results in habitat destruction. Fish and game reduction are blamed on the use of non-sustainable methods for fishing and hunting, as well as the need to take more each time in order to sell and obtain cash. Cash is used for other needs but also an increase in alcohol and drug consumption was informed. This has been reported by other authors in similar contexts (Freire, 2007; Godoy et al., 2005).

Government involvement (or lack of) was identified as well as a non-climatic stressor. It is interesting how assistance can be viewed as a negative process in terms of "making people lazy, which results in their reluctance to farm or fish." Also the recognition of the lack of governmental capacity in the area, which is reflected in initiatives that are poorly grounded in local realities and result doing more harm than good. People claim for assistance within their cultural traditions, and to prevent further cultural degradation.

Effects of Environmental Change

- Infrastructure

Informants reported that it is a part of their culture to deal with climatic variability and that they are used to the river levels changing throughout the year and from year to year. They explained that their livelihoods are "designed" to deal with variable conditions but recent changes challenge their knowledge and their ability to deal with the effects is not sufficient (Table 5.3). An example is that they have built their houses on sticks above the maximum river level. However, with more frequent flooding the current height is not sufficient, and in general higher water levels are creating hazards and economic losses for the people and also for the commercial areas in town (Figure 5.4).

- Agriculture

People report that they understand that the landscape is not constant. This awareness of transforming landscapes (Harris, 1998) has not prepared them for recent changes, since these are beyond the extremes they have become adapted to, and is challenging the knowledge they had of their surroundings. Reports of river currents that have become stronger and increased erosion were common. Informants described that a large island that used to be across Puerto Nariño has disappeared in just a couple of years. This island was used for agriculture and people lost their chagras.

Local people describe several natural signals they use to predict how the winter will be, including frogs singing or certain species of birds appearing at certain times. Many of these natural cues are being lost as a result of climate change (Kronik and Verner, 2010) and their ability to predict their surroundings is being lost. Planting decisions are impacted by predicted flood levels (Shorr, 2000), therefore the importance of being able to read the environment beforehand since chagras composition depends on how floods are expected. Shorr (2000) found that “in years of predicted low floods, more sweet-manioc is planted in the lower zones; in predicted higher flood years, watermelon is planted more exclusively. In expectation of a series of average or low flood years, bananas are planted extensively in the higher zones.” (p. 82). Losing the ability to predict seasons with natural cues, has affected agricultural planning, particularly because of river behavior unpredictability. Longer flooding periods in the lowlands impact their opportunity to plant and harvest mature crops, for there is not enough time for the plants to fully develop. These impacts have not been met by coping strategies because they have no previous experience of similar situations and in many cases they believe that these are temporal changes.

Informants are observing variations in seeds distribution and times for fruits to ripen. Also they report that an important effect of higher temperatures has to do with animals and plants becoming more susceptible to plagues and diseases or even dying, affecting their economy and resulting in a loss of work-hours. Friaje is an important environmental cue in this culture as it is crucial for agricultural planning, but it is also believed to be the period when the earth cleanses itself reducing diseases. It is a time during the high waters, where fishing is more abundant since fish get closer to the surface. It used to occur at the peak of the flood so it was a relieve for protein scarcity that results from fishing reductions typical of this time of year (Shorr, 2000). With the current lack of friaje, people have lost this, and the ability to determine the beginning of the dry season. This paired with changes in rain seasonality are reported to be impacting field preparations for farming since the burning of the chagras is impacted by constant rains (Sombroek, 2001). This results in the persistence of certain pests and further crop affectation.

- Water Resources

Overall environmental degradation is being recognized by local people, particularly local pollution. The importance of the river lies not only in determining what, when and where activities take place, but also in it being the main source of water for most of the families, so water quality is very important. It is also the means by which people move from the different communities to main areas including hospitals, schools, and cabildos. This explains the concern of river levels drying more than usual (Figure 5.6) as they are perceiving is occurring, because both water quality and navigation are heavily impacted.

The areas used for fishing change from high-water to low waters. In high waters they fish inside the flooded forests, where fruits from trees attract fish (Harris, 1998). In low waters they use lakes that become isolated, trapping fish and reducing fishing effort. Observed lengthening of floods creates problems because higher water levels make it more difficult to procure fish. When levels go under a certain limit, fish mortality increases polluting the water systems. Informants report an increase in the number of diseases when this occurs. River unpredictability has an effect on all the species that depend on the river for their different life stages. Sudden decreases have resulted in fish kill, and sudden floods are reported by informants to flood local turtles and birds' nests. They also explain that when the water is very low, salados (mineral licks) become scarce and animals have to become more visible to reach them which results in higher hunting rates, impacting game populations even more.

- Health

A reported effect of the various environmental changes has to do with health. Extreme weather events including floods and ENSO events have been related to outbreaks of vector-borne diseases such as malaria and dengue, infectious diseases such as cholera and meningitis and an increment in the incidence of water-borne diseases (Magrin et al., 2007). It was mentioned that stronger river currents are posing a risk for boats and canoes, causing an increase in the frequency of drownings. Effects on water quality due to extreme droughts or stronger currents creating more suspended particles are causing gastrointestinal diseases. The lack of season definition and constant rains was linked with more respiratory diseases. Heat is reported to cause skin complications, fatigue and headaches if work is done during the hottest hours of the day (10:00- 16:00).Overall the amount and diversity of diseases are reported to be increasing, posing the difficulty of dealing with the unknown and affecting mostly elders and children. As one participant said: “Ni la misma medicina tradicional puede controlar lo que esta pasando, tampoco las enfermedades porque están cambiando constantemente” (Male, 37 years - Not even traditional medicine can control what is happening because the diseases are constantly changing as well).

Coping with Change

Local perceptions have proven to be related to overall climate trends and in general livelihood strategies are changing in order to accommodate to these perceived changes by diversifying livelihoods and accommodating agricultural practices (West et al., 2008). Despite the advantages of the lowlands, recent changes have been met by many families considering or already planting in the uplands as well. This is a response to unpredictability in the river, since recently (in 2012) sudden floods destroyed most of their crops and this resulted in famine throughout the region. It is also a response to temperature extremes, because they argue that in the uplands trees mitigate climate extremes, and they do not feel the sun burning very bad or when temperatures drop low at night the plants are better sheltered that in the lowlands. Another important role that the informants reported for the uplands is providing a safe area where seeds are preserved for the following years. People in the area are used to having at least two chagras, so they are opening more than one per family in the uplands as well.

Despite opening new fields in the uplands, people still keep their chagras in the lowlands and in some cases they open new ones to account for the land loss to erosion in flooded areas. Informants admit that they will not leave the lowlands fields, not only because production is better, but also as one informant reported “…es una costumbre muy marcada de los abuelos porque el agua es la rutina del pueblo Tikuna…” (Female, 26 years old - It is a very important elder’s custom since water is the routine for the Tikuna people). Risk is then managed by having several chagras, both in the uplands and in the lowlands, particularly when they depend on their crops for an additional source of income. To reduce health affectations that result from increased exposure to high temperatures, especially in the lowlands, informants report that the number of hours when they can actually be outside has diminished importantly since the heat is unbearable between 10 am and 4 pm. This impacts work on the chagras and other activities such as fishing.

People reported that river unpredictability and longer flooding periods are affecting their ability to procure fish, and in order to get enough quality fish they are having to go to areas previously isolated. Recurring flooding of their houses has started to require temporary or permanent migration to the uplands or to other places. In some cases they have decided to go to Brazil where governmental aid is better or to cities where they have family and they can look for a "reliable" job. This results in further degradation of local cultural systems as knowledge is lost when migration becomes recurrent. Another solution that has an important effect on traditional systems is the transformation of local livelihood strategies into tourism. As a result the demand for chambira and yanchama (Figure 5.5) has increased, creating more pressure on these plants. Both come from the uplands, where yanchama is found and the palm of chambira is planted (*Astrocaryum chambira*). These were originally used for clothing but in time they have become the main materials for handcrafts which are an important source of income for many local families, particularly due to the recent increase in tourism in the region (Alcaldia de Puerto Nariño, 2008).

- Land use implications

Forests are becoming transformed into chagras or into pastures for livestock, without considering the influences that this has on surrounding land and aquatic ecosystems, and how the overall result conveys negative impacts for local communities (McClain and Cossio, 2003). So far the main coping strategy to deal with erosion, higher temperature extremes and unpredictable river behavior rely on opening new chagras in the uplands where mature forest can be found and that are the areas that overlap with Amacayacu. Opening new fields in the uplands in an area that overlaps and serves as a buffer for the most important protected area in the region will have important local consequences for wildlife and also for the local climate. Setting new chagras requires burning which creates further release of CO_2 and constitutes an important risk of uncontrolled fires that can be very disturbing for natural communities but that can also have an impact on ecotourism. Deforestation and intense agricultural production create an impact releasing greenhouse gases and depleting the soil's organic matter and carbon pools, further impacting soil fertility and crop productivity (Smith and Oelbermann, 2010).

Another consequence of changes in land use patterns has to do with disrupting water cycles and affecting precipitation regimes (Neill et al., 2006), which feeds into the processes of river flow alterations, seasonality changes, more frequent droughts, etc. Understanding this is crucial not only given the current threat that deforestation for small scale agriculture poses, but rather when projecting the idea of development for the region (Marengo, 2006). Another reason for deforestation increasing are changes in livelihood strategies, converting into the business of illegal wood exploitation.

Riparian areas are necessary for flow regulation, for providing habitat and resources for fauna, and for landscape connectivity (McClain and Cossio, 2003). They are crucial for water quality and biological integrity, help prevent erosion and provide multiple services in terms of fauna reproduction. However, deforestation is also increasing in the riparian areas of the region. Despite erosion and river predictability problems, people are setting new chagras in the lowlands as well. As McClain and Cossio (2003) explain "Riparian forests along river margins also provide valuable ecosystem services by protecting water quality and providing resources to aquatic organisms. Because inhabitants of the region rely on these aquatic resources, riparian deforestation may have unintended negative feedbacks on the health and well-being of rural communities."(p.242).

Local knowledge is the basis for local level decision making regarding natural resource management, nutrition, health, education, and community organization for many indigenous communities (Cristancho and Vining, 2009). The perception of crops being less productive because of the changes in temperature and higher infestations of pests, documented in other areas (Smith and Oelbermann, 2010), has resulted in more intensive farming to achieve required results. It may also start creating needs for the area that were covered before with traditional knowledge and can result in the widespread of chemicals to protect the crops. Consequences of the use of these substances in the southern Colombian Amazon have not been studied, but given the diversity, amount of rainfall and runoff and interconnectivity of ecosystems it can be presumed that the impacts would be important. Cultural degradation can also be reflected in crop diversity reduction, seeking to use only those that yield the best results, which is already observed in the lowlands given the reduction of time between flooding on farmable areas. Another situation that is currently observed and has an important impact on local biodiversity is the establishment of livestock. In several areas near and in Puerto Nariño, cattle can be found together with the clearing of very large areas of local vegetation. This further erodes local culture not only because of the intrusion of foreign species, but also because of the impact it has on local biodiversity and the required knowledge related to these livelihoods.

Fishing has also been impacted by the various environmental changes that informants are perceiving as well as by other factors that contribute to overall degradation. People report that in order to get enough quality fish they are having to go to areas previously isolated where lakes are found to capture fish, which can have an impact on the places that served as repositories of water fauna, particularly if the demand continues increasing to provide for the blooming local tourist industry. River unpredictability has an effect on all the species that depend on the river for their different life stages, affecting their overall ecology and particularly the reproduction periods which has been proven to impact populations dramatically. Sudden decreases have resulted in fish kill, and sudden floods are reported by informants to flood local turtles and birds' nests.

- Adaptation in time

Farming and land cover

Changing subsistence practices paired with cultural degradation (including the loss of their language) has resulted in the loss of local knowledge regarding the natural world (Cristancho and Vining, 2009). Change is also related to livelihoods that are transforming as people find alternatives that range from wood exploitation, to tourism. There is a clear lack of identified sustainable alternatives and coping strategies for many of the problems these communities are facing, and these have to be addressed to allow a sustainable development and permanence of not only the biological, but also the cultural diversity of the region. The lack of alternatives and adaptive strategies can result in the reduction of overall health as a consequence of food security being diminished given the reductions in productivity. Health will also be negatively impacted by aspects involving more vector-borne illnesses, gastro-intestinal diseases and human migration.

People are recognizing consequences related to overexploitation of resources, cultural degradation, overall contamination, population increase and lack of assertive government involvement in the region. This current situation, paired with potentially inadequate coping strategies, result in uncertainty regarding the future of local livelihoods. Deforestation seems to be increasing, despite efforts made by local institutions and more information on a local level regarding the need to preserve resources. It has actually become an adaptive strategy from different effects related to a changing climate, but also to the transformations in the local culture as well as market integration.

Deforestation is a transnational topic to address since together with climate change can result in major Amazonian forest dieback, and a subsequent release of carbon, turning the area from a sink to a source of greenhouse gases (Christensen et al., 2007; Malhi et al., 2008; Meehl et al., 2007). This results in a direct threat not only for the region but for the entire planet since the Amazon is not only an important carbon sink, but is home as well of over 10% of the world's biodiversity (Bennett, 1992; Sponsel, 1986). Puerto Nariño is a complicated area as it is immersed in the dynamics of invisible borders within three different countries that imply different policies and management strategies for each. It is an area where human interventions extend easily into surrounding ecosystems (McClain and Cossio, 2003) with no control from local, regional or national authorities. A regional approach would be more useful than a national one to achieve useful results in the area, particularly because one of the coping strategies that informants identified has to do with the easiness of migrating between the different countries and using resources across borders.

Hydrological resources

Hydrological resources are central in the region and human communities depend on them for every aspect of their livelihoods, which has resulted in them being labelled "amphibious communities." Water management is a crucial topic to address in any adaptation plan for the Amazon. It will be the most affected resource as water policy topics arise (Christensen et al., 2007), particularly for frontier zones. Changes are already taking place in terms of river behavior and it has been found that discharge from one of the main tributaries of the Amazon River exhibits a negative trend (Lavado Casimiro et al., 2011). Urgent topics that need to be addressed by local and regional governments have to do with water access for these communities, particularly during low-waters. These communities are very sensitive to degraded aquatic ecosystems given the many uses they make of the resource (Figure 5.6) (McClain and Cossio, 2003).

Conservation of human landscapes

Colombian Constitution recognizes indigenous territories and allows for use of protected areas in cases where they overlap. However, with cultural changes and population increases, the idea of indigenous communities as autonomously sustainable has been challenged. The positive links between indigenous peoples and biodiversity cannot be denied but it must be recognized that given current circumstances indigenous communities can be very disruptive for the ecosystems (Toledo, 2001). For Puerto Nariño this topic has to be addressed and sustainable development can be regained "as an endogenous mechanism that allows a local society to take (or retake) control of the processes that affect it."(Toledo, 2001, p.9) it is necessary to empower local communities and reinforce or give control of their territories coupled with real and effective access to information and technology (Toledo, 2001).

Further research is needed to understand the differential effects of all these changes on the local community. It is clear that elders and children are more impacted from diseases as has been reported above; however, what will the consequences of scarcer food production be for the different population groups? In Colombia indigenous communities in other areas are victims of malnutrition due to a lack of access to good food sources and drinking water. What is the scenario for these communities in terms of gender, since women are responsible for most of the agricultural processes? What will happen if migration continues, particularly from younger generations? Will local knowledge adapt and continue or will it fall into oblivion as its validity is lost given the changes in the environment and other social changes?

As stated in chapter four, it is necessary that continuous and reliable climatic monitoring stations are established in the region to understand the local translation of predicted regional trends that allow for better management approaches. Both in the Colombian amazon as in other countries, there is not enough comprehensive data to understand what is going in terms of rainfall trends in Amazonia (Magrin et al., 2014; Marengo, 2006). Appropriate information is critical to link social and natural data to be able to create models of land use change (Veldkamp and Lambin, 2001). Perceptions of climate and the environment define the ways in which people will respond, and therefore the importance of incorporating them into any strategy for mitigation and adaptation, particularly given that agricultural decisions and climate cannot be isolated from culturally constituted ways of seeing, knowing and valuing the world (Vedwan and Rhoades, 2001). It becomes necessary to ask how grounded in this reality are adaptation plans? How useful will they be for the poorest and most marginalized, including those in indigenous resguardos? How are they transforming the underlying circumstances that foster inequality? And, how are these feeding into new programs that aim to reduce vulnerability and enhance adaptive capacity?

Table 5.1. Climate change scenarios for Colombia's amazon (Adapted from IDEAM et al., 2015)

	2011-2040	**2041-2070**	**2071-2100**
Changes in Average Temperature (°C)	+0.7	+1.5	+2.4
Precipitation Changes (%)	-14.84	-12.47	-14.03

Table 5.2. Reported crops for the region.

Lowlands	**Uplands**
Manioc	Pineapple
Plantain/ Bananas	Corn
Corn	*Caimo*
Rice	*Guama*
Watermelon	*Copoazu*
Tomato	Plantain/ Bananas
Cucumber	*Chambira*
Cilantro	
Beans	

Table 5.3. Effects and coping strategies identified by informants for perceived environmental changes

Perception of Change	**Effects**	**Coping Strategies**
Higher Temperatures	Plants and crops dry	People are trying to cover crops with shadows People are setting new *chagras* in uplands near trees
	People cannot work during certain times of the day, affecting work in *chagras* and fishing	Work can only be done from very early until 10 am and/or after 4 pm People have to buy protective gear for the sun
	Animals die	No coping strategy
	More diseases	Use more traditional and western medicine
Extreme temperatures	Harvest reductions	Lack of fish and harvest have resulted in people changing activities to extract wood. Fishermen are also making their boats suitable for tourism. Women are changing to handcrafts.
	Fish die	
Changes in friaje	Agricultural planning is impacted	No coping strategy
	Fishing is affected since friaje allows for more fishing as animals go to the surface to breath	No coping strategy
Rain Seasonality	More diseases in humans and animals and plagues in crops	No coping strategy
	Agricultural planning is affected, including the ability to burn the farming fields to clean them for crop establishment	No coping strategy
	Changes in seeds distribution and time for fruits to ripen	No coping strategy

Cont. Table 5.3.

Perception of Change	**Effects**	**Coping Strategies**
River flooding longer/higher and unexpectedly	Loss of crops	Open new *chagras* in uplands
	Lateness to plant crops and not enough time for these to be ready	Open new *chagras* in uplands
	Infrastructure affectation	Displacement of people (temporary or permanent to uplands or other places) Raising the floor of the house with planks
	Economic affectation (food becomes more expensive, have to spend money on food)	No coping strategy
	Affectation on the commerce and closing of protected area that was a source of employment and income for local people	No coping strategy
	Increase of animals (snakes, mosquitoes, etc.)	No coping strategy
River drying more than usual	Fish die	No coping strategy
	Extreme drought impacts water quality	No coping strategy
	River navigation severely affected	No coping strategy
	More diseases	No coping strategy
	Salados are dry so animals have to go other places where they are being hunted	No coping strategy
River has stronger/ changing currents in high-waters	Erosion increased and the island disappeared	New *chagras* settled in lowlands
	Danger for canoes and boats	No coping strategy
	Drownings increase	No coping strategy

Figure 5.1. Seasonally flooded agricultural field. *Photo by Rocio Rodriguez Granados (Puerto Nariño, Amazonas, 2013)*

Figure 5.2. Curses imposed on those who try to steal crops from chagras in the uplands. *Photos by Rocio Rodriguez Granados (Puerto Nariño, Amazonas, 2012)*

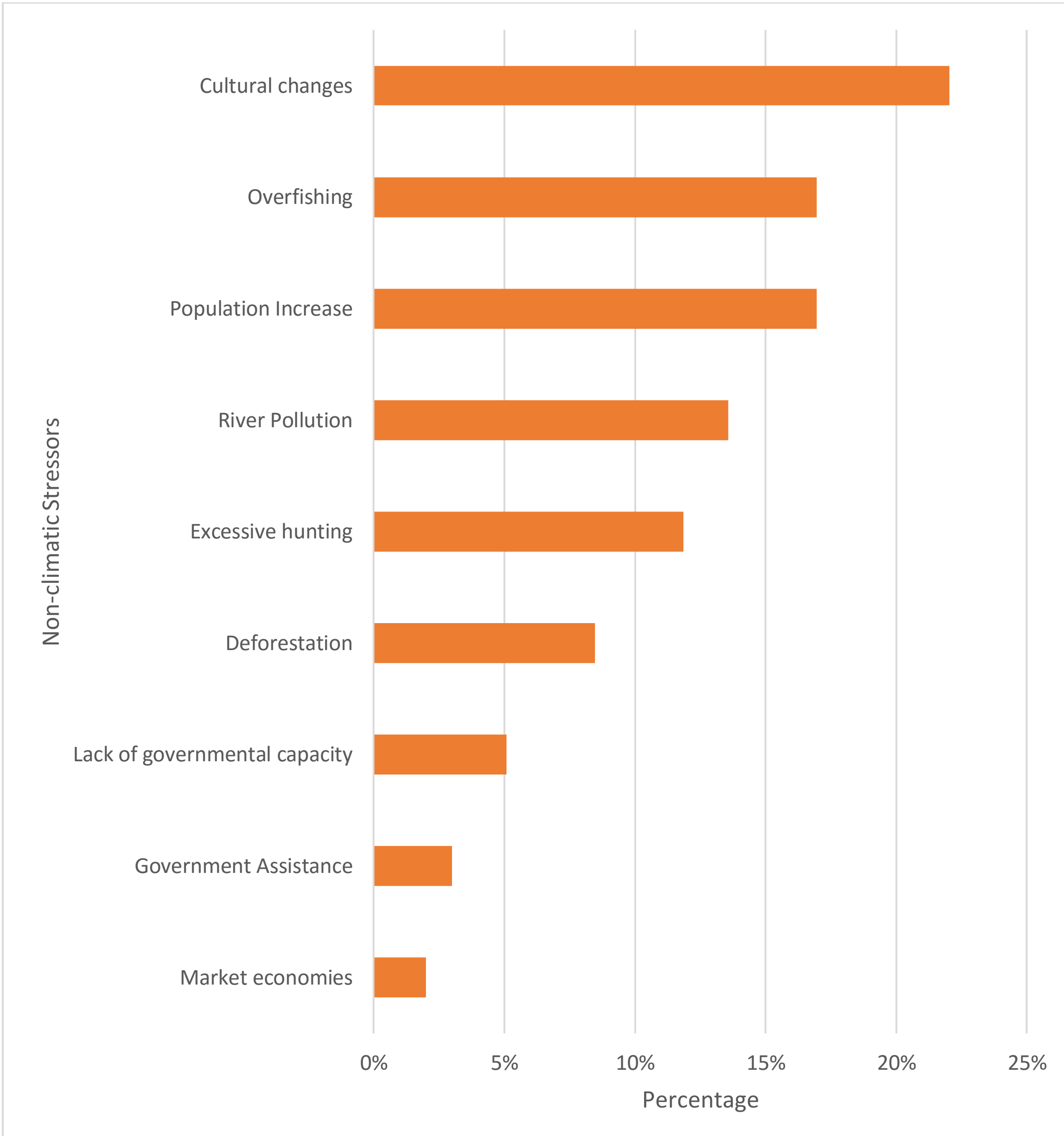

Figure 5.3. Factors identified as enhancing environmental degradation and affecting local livelihoods.

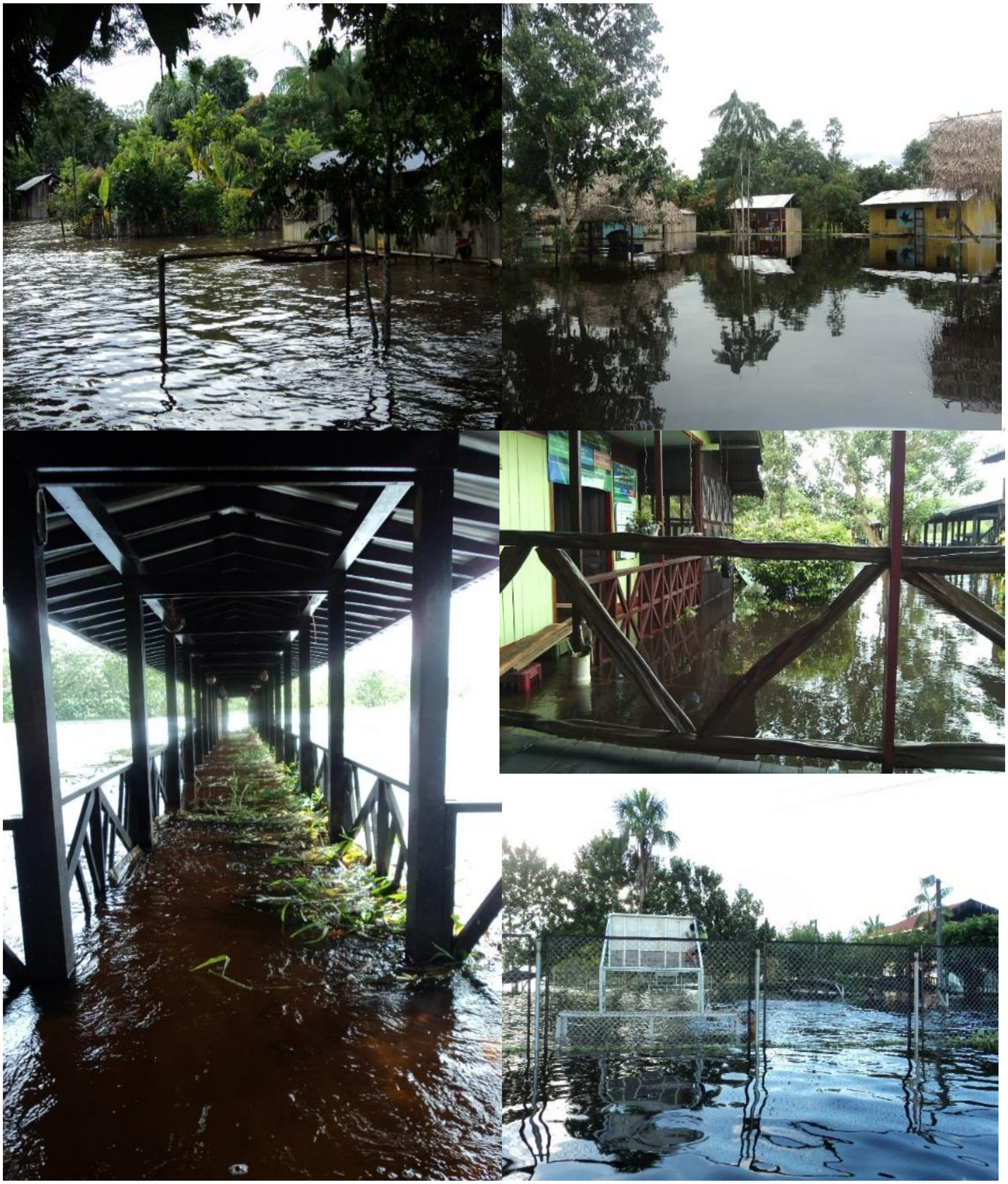

Figure 5.4. Infrastructure affectations resulting from higher flooding events in 2012. *Photos by Rocio Rodriguez Granados (Puerto Nariño, Amazonas, 2012)*

Figure 5.5. Handcrafts made of chambira and yanchama (top). *Photos by Rocio Rodriguez Granados (Puerto Nariño, Amazonas, 2013)*

Figure 5.6. Activities carried out in the rivers. *Photos by Rocio Rodriguez Granados (Puerto Nariño, Amazonas, 2013)*

CHAPTER 6

CONCLUSION

Summary of Findings

We relied on a combination of ethnographic and statistical tools to explore how perceptions of environmental change are affecting local indigenous livelihoods in Puerto Nariño. In chapter three we began by analyzing twenty-five years of available data for river levels in the Colombian Amazon to determine if the river has changed in terms of flooding behavior and drought. Results revealed significant changes in terms of maximum river levels reached. Floods appear to be higher and even in low waters, the results show that the levels in general have increased in the region. There was no evidence that showed changes in droughts, number of flood days and drought days, or date of arrival of river level peaks. Given the local environmental complexity of the hydrological cycle, we cannot explain the reason for observed increase in river levels, but it has important implications in terms of local ecology and effects on human livelihoods. The temporal availability of analyzed information made it difficult to be confident that this trend will continue as observed in the future; however, these results set the stage for the importance of continuous (and reliable) monitoring of hydroclimatic variables in the region, .

Chapter four also relied on climatological data gathered by the Colombian National Institute responsible for monitoring and tracking climatic information. However, this analysis proved even more difficult due to the scarcity and incompleteness of information for the Colombian amazon, except for data gathered by the gauge at the airport of Leticia. This proved to be a problem since the main objective of the chapter was to understand if local indigenous perceptions of environmental change are reflected in what the data show. This chapter relied heavily on the idea that perceptions guide human behavior and therefore are critical when trying to understand how a system will respond to climate change (Crate, 2009; Duerden, 2004). The ethnographic portion of this chapter was done in Puerto Nariño, Amazonas but when time to do the quantitative research arrived we discovered that the data available for Puerto Nariño was for a very short time frame, and incomplete. For this reason we decided to use Leticia's airport data, which despite being over 80 km apart from Puerto Nariño, still correlated highly in terms of temperature. Precipitation however, had a much lower correlation, likely due to the high spatial variability of rainfall in the Amazon, resulting from proximity to the Andes Mountains (Daly and Mitchell, 2000; Marengo, 2006; Zubieta et al., 2015).

This chapter then explored indigenous perceptions of change in the region, which basically translated into higher average temperatures, changes in river behavior, changes in rain seasonality and changes in friaje (incursions of polar air masses towards the equator during the austral winter; Dantas Ricarte et al., 2015). Perceptions appeared to corroborate gauge data with respect to increasing average temperatures, increased river flooding and friajes becoming less frequent. Data were not sufficient to conclude that rain seasonality has changed in the area. Results indicate that indigenous perceptions in Puerto Nariño reflect the deep grounded knowledge that people have of their environment. It is important to note that the absence of local data challenges options to determine trends at local scales and assess whether they mirror people's perceptions. There are currently no mechanisms to monitor locally the impacts of climate change and it is important to recognize that local experiences do not necessarily reflect what has been defined in the policy level. This can result in poorly grounded adaptation plans that will enhance communities' vulnerability instead of making them more resilient, particularly in areas where livelihoods are highly dependent on natural resources as is the case of Puerto Nariño.

Chapter five uses exclusively ethnographic methods to explore the implications of the perceived changes on local livelihoods and the ways in which these indigenous peoples are responding to the changes. People also reported that their livelihoods are being affected by other non-climatic drivers (cultural changes, resource overexploitation, population increase, river pollution, absence of government and market economies), that are affecting their adaptive capacity. The main findings of this chapter show that indigenous livelihoods of Puerto Nariño are profoundly affected by an unpredictable environment, particularly subsistence agriculture, water resources and health. While for most of the perceived changes people have not found coping strategies, they are actively responding by intensifying practices to account for potential losses and reductions in productivity. This has a direct effect on resources, causing deforestation through creation of new farming fields, a depletion in the fishing resource by expansion into new areas that are more difficult to access, and deepening cultural changes as a result of livelihoods transformations. The impacts of these changes are important in the area since it overlaps with Amacayacu National park, but also given regional trends and the effects that deforestation has on the climate. These coping strategies are not necessarily adaptive in the long term, reflecting the need for the government to address perceptions and design culturally sound management practices together with local communities in order to understand the effects of regional climate change on societies and their ability to adapt.

Theoretical and Methodological Implications for an Integrative Approach

Identification of coping responses to environmental change are critical for understanding how people use and manage resources (Duerden, 2004). Climate change creates a context in which communities are having to face many other issues that have an effect on their livelihoods. The Amazon in particular has been going through a cultural transformation resulting from market economies and globalization that is transforming local traditions and livelihoods and changing the ways local communities relate with nature. To understand the local realities and be able to create sustainable and sound management practices, knowledge has to be exchanged between local communities and governmental entities so that they all have the required information to make valid decisions in these fragile contexts. An integrative approach is the only way to move forward, since as this dissertation shows, hydro-climatological information is required to understand how local trends are manifesting climate change. This means that better data need to be locally produced. This material needs to reach local communities since their coping strategies are not grounded on information but rather a response to the climatic stimuli they perceive. Exchanging and understanding the complexity and dynamics of socioenvironmental systems can only be gained with an integrative approach that uses both qualitative and quantitative methods to answer to these questions related to biodiversity conservation and cultural transformations that result from climate change and are key for ecosystem health (Crate, 2009).

This dissertation also addresses the need to consider different scales when working on conservation, as has been stated by the integrative approach. Global climate change affects regional landscapes; this has important implications on local livelihoods. Coping strategies to deal with perceived changes, are reflected in the regional landscape, which ultimately have an effect on global climate. This is particularly true in frontier areas as Puerto Nariño, where human mobility is large; particularly since each country has its own laws and ideas regarding resource use. Besides, in Colombia it is necessary to understand the political environment on which decisions are made, particularly given current social processes that are taking place in terms of peace and development.

Limitations, Challenges and Opportunities

The main limitation for this dissertation is that regional datasets are incomplete. An important part of the analyses had to be based upon assumptions since we had no data to talk about local trends of rainfall variability. The fidelity of the data affects the validity of the conclusions in this respect and in the future this needs to be addressed through the use of better grounded models or other sources of data, for example weather stations from other countries but that are still within the area. Sample size might also play a role in replicability, however we have continued visiting the area and other informants have maintained similar responses. Overall this research proved a challenging but unique opportunity to understand the concept of integrative conservation through the recognition that conservation problems do not conform to disciplinary boundaries and require multiples fields of expertise, providing the opportunity of engaging many types of knowledge through different scales both spatial and temporal. This experience has also helped me become more comfortable in my interaction with different stakeholders from all kinds of backgrounds and moving between the worlds of academia and practice.

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