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# Envisioning adaptive strategies to change: participatory scenarios for agro-pastoral semi-arid systems in Nicaragua

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## ABSTRACT

Historically, the semi-arid socio-ecological systems of dry Centro American corridor have proven resilient to pressures. In the last century these systems, however, have experienced huge environmental and socio-economic changes that have increased the vulnerability of local livelihoods to shocks and perturbations. New approaches are needed to capture complex, uncertain, cross-scale and non-linear relationships between drivers of change and vulnerability. Therefore, to tackle this challenge the paper suggests applying a participatory and interdisciplinary methodological framework of vulnerability assessment to a case study in northern Nicaragua. We triangulated a range of information and data from participatory and scientific research to explore historical and current drivers of changes that affect system's components and indicators of vulnerability, represented in a three dimensional space in terms of ecological resilience, socio-economic individual ability to adapt to change and institutional capacity to buffer and respond to crisis. A projection of climate changes combined with a participatory scenario analysis helped, then, to heuristically analyze tendencies of vulnerability in the future and to explore which policy options might enhance the system's adaptive capacity to face new pressures. This study mainly contributes to the empirical understanding of key factors that influence vulnerability and learning of local strategies to adapt to change in semi-arid agro-pastoral systems in Central America. The paper also makes a methodological contribution by testing the use of multidimensional vulnerability framework as a way of stimulating discussion between researchers, local stakeholders and policy-makers.

Keywords: *vulnerability, conceptual model, participatory scenario analysis, dry tropical system, agro-pastoral farming system, Central America*

## INTRODUCTION

Dry-land regions provide livelihoods for almost half of the world's poorest people (MEA 2005) and are vulnerable to global changes including climate change (Eriksen and O'Brien 2007). For example, a 75% of dry-lands in South America, Central America and the Caribbean are seriously degraded and threatened by desertification (Scherr 1999; UNCCD 2004). In particular, in Central America region the "dry corridor", which stretches between Mexico and Panama (WFP 2002), remains largely unstudied, despite holding 25% of the region's population (Reynolds *et al.* 2005). In addition to the stress of climate change, the area's livelihood systems are also threatened by war, cultural and demographic changes, and political and economic instability (Martí i Puig 2004). Specifically, in the central-northern semi-arid region of Nicaragua 75 % of the farmers live on less than US\$2.0 per day (Marín and Pauwels 2001) and 27% of the population is undernourished (FAO 2004). However, there are no detailed empirical studies of how livelihoods in this region are vulnerable to climate change or how multiple threats interact.

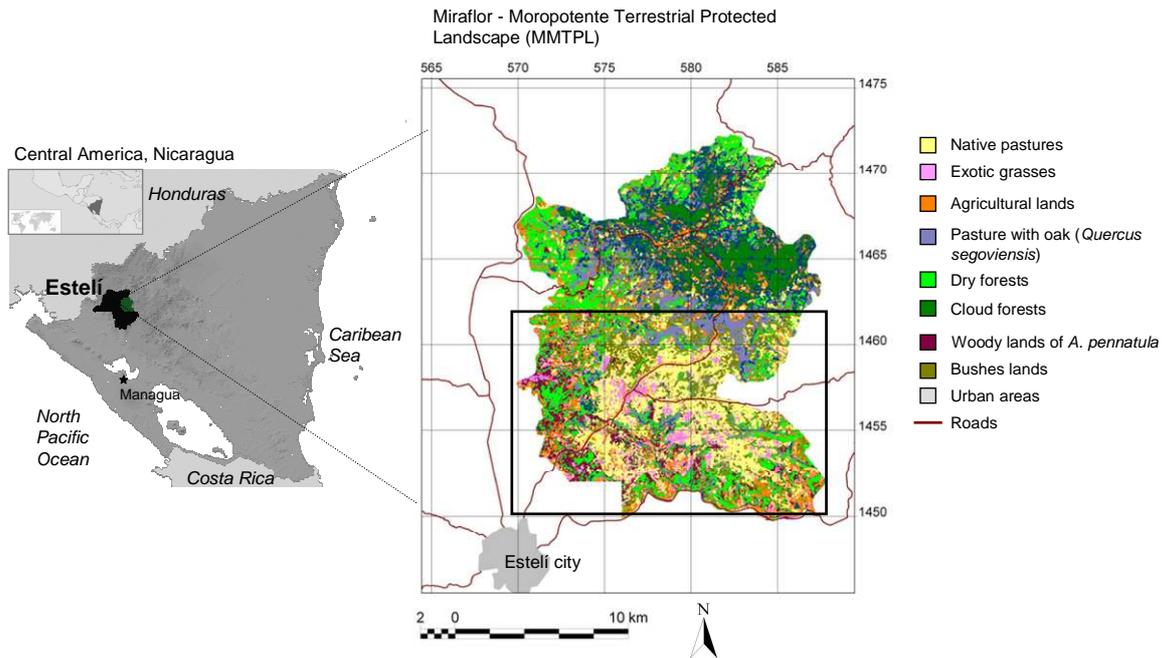
In general, there is an extensive body of literature that can be drawn upon to assess the vulnerability of livelihoods to both climatic change and other threats. Theoretical work draws on concepts like resilience and adaptive capacity (see Fraser *et al.* this volume; Gallopin 2006). More empirical approaches tend to use either top down quantitative biophysical modeling, which are criticized for lacking to integrate methods and missing key local factors that determine vulnerability, or bottom up qualitative case studies. These studies provide a vivid contextual understanding of people's adaptation strategies to face multiple stresses (Fussel and Klein 2006) and their future aspirations (van Aalst *et al.* 2008), but may be so context-specific that it is difficult to extract broader lessons. In light of the gap between top-down and bottom up vulnerability assessments, as well as the need to conduct detailed work on dry-lands livelihood systems in Central America, this paper has two objectives:

1. To evaluate how the multidimensional vulnerability of livelihoods to change in semi-arid agro-pastoral system in Nicaragua has been affected over time by multiple drivers.
2. To combine knowledge systems and participatory methods with climate models to develop scenarios of the future and link these scenarios with locally relevant adaptive strategies.

## STUDY AREA

### Bio-physiographic components

The case study area is located in Estelí department on a semi-arid plateau (13°09'N-86°14'W) in Northern Nicaragua. It is located in the Miraflor-Moropotente Terrestrial Protected Landscape (Fig. 1), which consists of three ecological zones: fluvial valleys, mountainous cloud forests and the intermediate semi-arid plateau that was dominated by tropical savannah, oak woodlands and dry forests in the 18<sup>th</sup> century.



**Figure 1.** Map of Miraflores - Moropotente Terrestrial Protected Landscape and land cover in 2008. The study area is located in the semi-arid zone (within the black box). Source: satellite images ASTER and LANDSAT-7; Garcia-Millan V. and More G., unpublished data.

### Climatic features

This semi-arid region's climate is influenced by the North America Monsoon System. Annual mean temperature is 23.5 °C and annual total rainfall about 770 mm, 90% of which falls between May and October. Rainfall is concentrated into convergence zones and is influenced by topography. This leads to extremely variable annual totals. The region is also exposed to droughts and floods related to the El Niño-Southern Oscillation (ENSO) and La Niña cycles (Appendix 1 for details).

### Governance system and socio-economic attributes

In terms of the socio-economic and political landscape, since 2003, when Miraflores-Moropotente was declared a protected area, a new co-management agreement has been in effect between local communities' associations, a group of medium-sized cattle ranchers, and the Minister of Natural Resources and Environment of Nicaragua. In the area, a minority of very large commercial cattle ranchers occupy 73% of the plateau area. One third of the population remains landless and small-scale and medium size mixed farming systems occupy 25% of the land and provide food, job and income for half of the rural population. Livestock is the most important component of local economy, and is used for food, as a capital, job resource and for social status. The local diet consists of maize and beans that are produced in both in first (*primera*) and second (*postrera*) growing seasons and these are supplemented with meat, local dairy products, vegetable and fruits from home gardens and wild fruit from the nearby dry forests. During the dry season the local availability of food declines and nearly half of the local population suffers from hunger and malnutrition.

## FRAMEWORK AND METHODS FOR ASSESSING VULNERABILITY

Three methodological steps were used to achieve the two objectives of this paper listed above. These steps are presented in following paragraphs and summarized in Figure 2. More details are provided in Appendix 2.

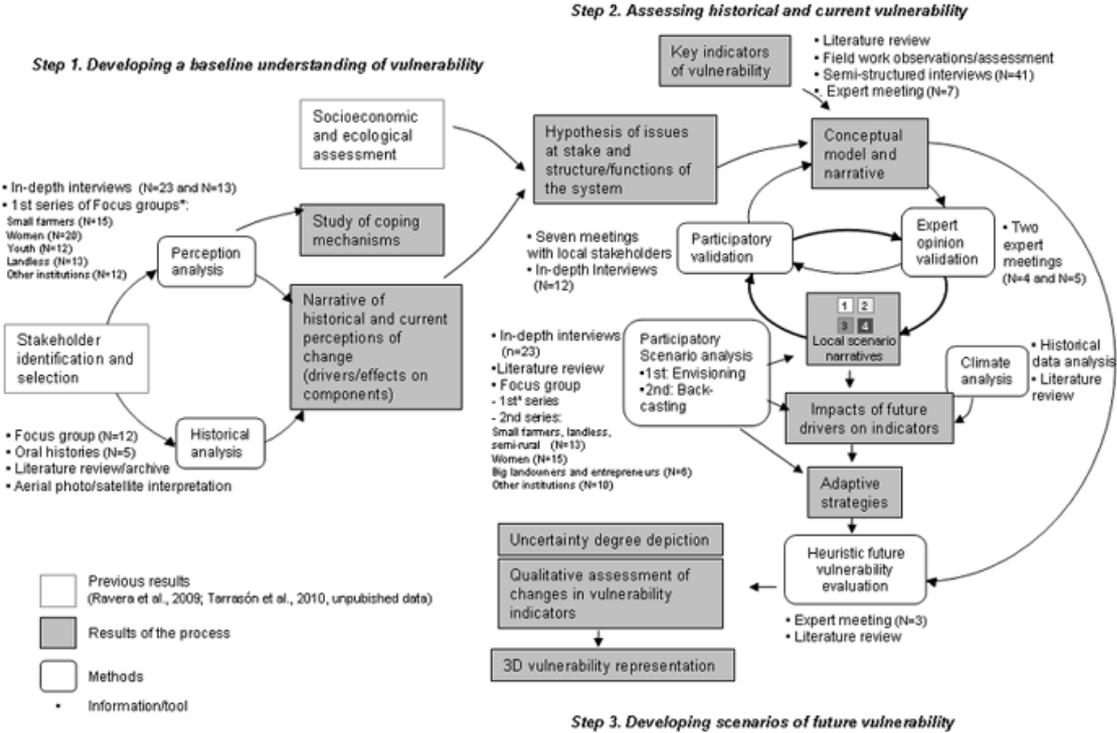


Figure 2. Methodological framework for assessing vulnerability to change.

**Step 1. Developing a baseline understanding of vulnerability**

The purpose of step one was to establish a series of preliminary hypotheses about how livelihoods were changing, to identify mechanisms currently used to cope with climate and socio-economic changes, to explore the values of ecosystem goods and services, and to discuss indicators of vulnerability. To accomplish this, we conducted a series of key informant interviews and a focus group with village elders. This information was triangulated with aerial photographs (1954, 1971, 1988, and 1996) and satellite images (2008) as well as through a literature review and review of archive material. Using the categories of relevant stakeholders identified by Ravera *et al.* (2009), we also conducted a perception analysis of local environmental and development issues through in-depth and semi-structured interviews, selected through snow-ball sampling, and a first series of deliberative focus groups.

**Step 2. Assessing historical and current vulnerability**

Interviews and survey data collected during step 1 were transcribed and analyzed using discourse analysis (Gee 1999). By following a grounded theory approach, researchers specifically looked for emergent variables and relationships that described the structure and functions of the agro-pastoral system (Sendzimir *et al.* 2007). The findings were organized into a conceptual model accompanied by a graphical representation that helped to incorporate diversity of knowledge and perceptions to reflect the multi-scale causalities and feedbacks expressed in the transcripts. In parallel, a qualitative narrative synthesized how local agro-

pastoral systems have become over time more or less vulnerable to perturbations. This conceptual model was then refined on through a further set of in-depth interviews with key informants, extended meetings with local stakeholders and a new series of experts meetings. To assess changes in vulnerability we followed Fraser (2007) who argues that livelihood multidimensional vulnerability is a function of three overlapping elements: (1) ecological resilience of agro-ecosystems that refers to the extent to which the agro-ecosystem is able to maintain or recover key functions (Holling 1986; Holling *et al.* 2001) that are essential for production (Walker and Abel, 2001); (2) socio-economic ability that refers to the extent to which the socio-economic system helps provide the resources or assets individuals and households require to reproduce, in the long-term, the productive system and sustain local livelihoods and thus to adapt to shocks (Scoones 1998; Sen 1991) without destitution (Corbett 1988); and (3) the capacity of local institutions that may provide either social buffer or safety nets (e.g. food security programs, risk alert systems) to protect livelihoods and help mitigate unexpected crisis (see also Fraser *et al.* this volume). Field research work (Ravera *et al.* 2009; Tarrasón *et al.* 2010) and literature provided the information to infer qualitatively indicators' performances of current vulnerability.

### **Step 3. Developing scenarios of future vulnerability**

The purpose of this step was to assess how climatic and socio-economic drivers may affect livelihood vulnerability in the future. This phase also allowed stakeholders to deliberate policy options. Three activities were undertaken. First, an exploratory exercise was developed to capture conflicting visions about future through collecting images (collages and metaphors) and storylines during in-depth interviews and deliberative focus groups. Second, a future climate scenario was developed using monthly observed temperature and precipitation for 1961-2007 from nearby meteorological stations with the same geographical and climatic characteristics of the studied area. To develop a temperature and rainfall scenario up to 2050, we projected seasonal changes and frequency of extreme events based on literature references (Christensen *et al.* 2007, Rousteenoja *et al.* 2003). Local impacts of these changes were, then, identified via the literature (Appendix 1 for details). Third, during a final series of deliberative focus groups, the conceptual model and climate scenario were used as the basis for a back-casting exercise. Each scenario (and its components) was overlapped to the conceptual model to infer future trends of changes in vulnerability indicators' performance. Moreover, using a 3D plan of the area and a list of questions about environmental, social and economic policies related to each envisioned future, researchers facilitated a discussion of short and medium term management and policy options. The alternative options were classified as either being (1) a current coping mechanism that needs to be reinforced (as defined by Osbahr *et al.*, 2008) or (2) a new adaptive strategies that needs to be implemented (as defined by Nayak, 2004). Secondly, each scenario and policy option was ranked according to the type of uncertainty being explored, such as incomplete knowledge, unclear tendencies and unpredictability of change, plurality of conflictive perceptions and ignorance. As result, each scenario was evaluated along the three dimensions of vulnerability, forming "vulnerability trajectories" in relation to the present (baseline).

## **RESULTS AND ANALYSIS**

### **Trends and Drivers in Historical and Current Vulnerability**

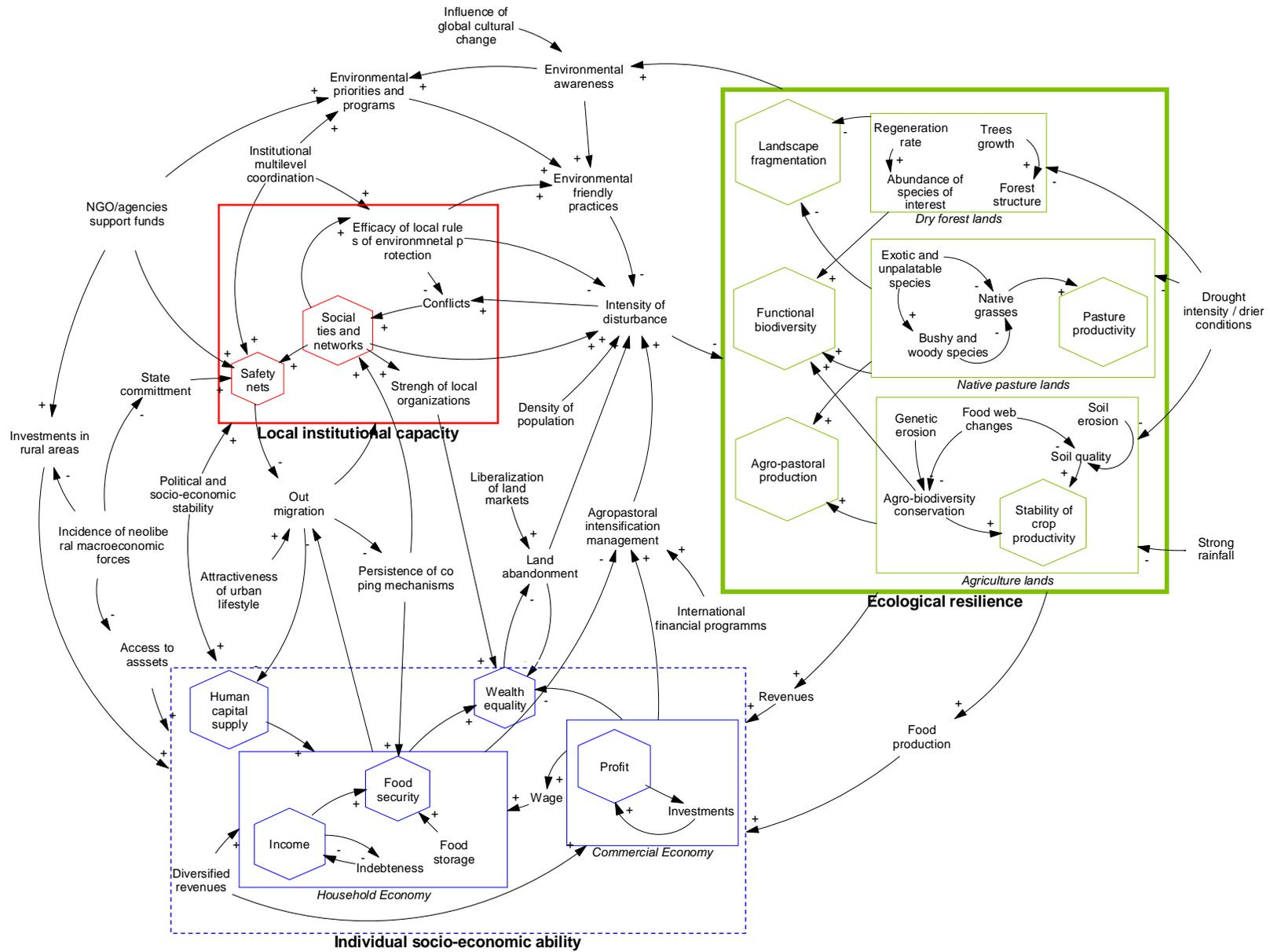
To analyze historical forces and patterns of changes in the study region, Nicaragua's history during the past century up to the 2006 elections is divided into four periods, summarized in Table 1.

**Table 1.** Historical drivers of change and vulnerability trends

Historical period	Multi-scale drivers of change		Local perception on historical trends in vulnerability		
	Socio-economic and political structure	Local land tenure, land use and natural resource management	Ecological resilience	Socio-economic individual ability	Institutional capacity of buffer
<b>Post-independence period (circa 1900-1936)</b>	<p>New agrarian rules:</p> <ul style="list-style-type: none"> <li>– expropriation of lands to communities</li> </ul> <p>Coffee-boom economy</p> <p>Polycentric system of natural resource management (NRM)</p>	<ul style="list-style-type: none"> <li>– <i>Latifundia</i> and patronage system coexist with communitarian system and medium size farms.</li> <li>– Traditional slash and burn practice and rotating systems</li> <li>– Fire/livestock management for weed and bushes control.</li> <li>– Mixed browsing/grazers</li> <li>– Transhumance</li> </ul>	<ul style="list-style-type: none"> <li>– High landscape connectedness</li> <li>– High resilience of pasture after shocks</li> <li>– Conservation of grain-crop native varieties</li> <li>– High soil quality</li> </ul>	<ul style="list-style-type: none"> <li>– Diversification of food production</li> <li>– Wide access to lands</li> <li>– Exchanges between ecological zones</li> <li>– Commercial economies growth</li> <li>– Persistence of coping mechanisms</li> </ul>	<ul style="list-style-type: none"> <li>– Strong sense of belonging</li> <li>– Strong social capital and governance system of natural resources within original communities of “ladinos”</li> <li>– Weak centralized institutional systems to mitigate effects of crisis</li> </ul>
<b>Dictatorial regime (1936-1979)</b>	<p>Strong State control</p> <p>“Capitalist modernization” and “livestock boom” (1950-1970)</p> <ul style="list-style-type: none"> <li>– Absence of poverty alleviation programs</li> <li>– Coffee crisis</li> <li>– Export-oriented agro-production</li> <li>– Import of food commodities</li> <li>– Technological modernization</li> </ul> <p>Political and economic decline started by 1970s</p> <ul style="list-style-type: none"> <li>– Migration of landowners</li> </ul> <p>Command-and-control of resources management</p>	<p>A centralized <i>latifundia</i> system administered by a few families</p> <ul style="list-style-type: none"> <li>- Intensification of agro-pastoral management (e.g., agrochemical and high-energy and water demand crops, opening pasture lands)</li> <li>– Fire/livestock management for weed and bushes control.</li> <li>– Mixed browsing/grazers</li> <li>– Transhumance</li> </ul>	<ul style="list-style-type: none"> <li>– Decrease of grasses cover by intensification (e.g. introduction of exotic grasses, division of paddocks)</li> <li>– Degradation of dry forest areas by reducing area and decreasing diversity and structure</li> <li>– Diffusion of agrochemical and high-energy and water demand crops and soil impoverishment</li> <li>– Landscape fragmentation</li> </ul>	<ul style="list-style-type: none"> <li>– Increasing patronage dependence and indebtedness</li> <li>– Loss of access to assets</li> <li>– Increasing on wealth distribution inequity</li> <li>– Diversified opportunities of activities/diet in humid areas</li> <li>– Technology and credit access for commercial economies</li> </ul>	<ul style="list-style-type: none"> <li>– Absence of safety nets programs</li> <li>– High conflictive confrontation and uncertainty between local actors (Fragmentation of social ties and networks)</li> </ul>
<b>Socialist period and the contra-revolutionary war (1979-1990)</b>	<p>Strong State control</p> <p>Nationalization policy, prices policies, Agrarian Reform, food security program</p> <ul style="list-style-type: none"> <li>– Hierarchical economic and social organizations’ system.</li> </ul>	<p>1980-1984: A cooperative specialized system under a subsidized economy.</p> <ul style="list-style-type: none"> <li>– Specialization of local economies for ecological areas</li> <li>– Loss of transhumance system</li> <li>– Agro-pastoral intensification export oriented (dairy products).</li> </ul> <p>1985-1989: Creation of productive-military cooperative</p>	<ul style="list-style-type: none"> <li>– Increasing deforestation and fragmentation</li> <li>– Diffusion of agrochemical and high-energy and water-demand crops and soil impoverishment</li> <li>– Substitution of crop varieties</li> <li>– Transition of native mature grasses to bushes</li> </ul>	<ul style="list-style-type: none"> <li>– Increase of land and NR access (households)</li> <li>– Increase of credit and information access</li> <li>– Disruption of value-added system production</li> <li>– Disruption of individual</li> </ul>	<ul style="list-style-type: none"> <li>– Strong safety nets programs (strong local organizations, hierarchical structure of monitoring and control, improved food processing for domestic and foreign markets)</li> <li>– Disruption of social ties and networks</li> </ul>

	<p>Command-and-control system of NRM</p> <p>Contra-revolutionary conflict and socio-economic crisis (i.e. high inflation rate)</p>	<ul style="list-style-type: none"> <li>– Decrease in cattle population and exports</li> <li>– Land abandonment during the war period.</li> </ul>	<p>and woody cover</p> <ul style="list-style-type: none"> <li>– Landscape fragmentation</li> <li>– Recovering of dry forestry patches</li> </ul>	<p>networks</p>	<ul style="list-style-type: none"> <li>– Failure of protectionist mechanisms</li> </ul>
<p><b>Economic liberalization (1990—2006)</b></p>	<p>Peace Accords and democratic elections</p> <ul style="list-style-type: none"> <li>– Neoliberal State reforms, structural adjustment and poverty alleviation programs, hampered by International Financial Funds (weak State commitment)</li> <li>– Crisis of organizations</li> <li>– Absence of investments in rural areas and stagnating economic situation</li> <li>– Market volatility</li> <li>– De-concentration process and disempowered local governments</li> <li>– National Development Plan prioritizes agro-exports and import of food commodities</li> <li>– Absence of food security programs</li> </ul> <p>International conservation funds encouraged new environmental priorities and regulations.</p>	<ul style="list-style-type: none"> <li>– Land reallocation schemes (from cooperative to private land system) and land concentration/abandonment</li> <li>– Loss of transhumance</li> <li>– Agro-pastoral intensification</li> <li>– New rules and mechanisms within protected areas and co-management plans</li> </ul> <p>Demographic change:</p> <ul style="list-style-type: none"> <li>– population growth, returns and refugees resettlement schemes</li> <li>– young people out-migration (ageing population)</li> </ul>	<ul style="list-style-type: none"> <li>– Transition of native mature grasses</li> <li>– Increasing fragmentation of dry forestry patches</li> <li>– Disappearance and degradation of patches</li> <li>– Diffusion of agrochemical and high-energy and water-demand crops</li> <li>– Slow recovering of trees density and natural regeneration areas</li> <li>– Diffusion of <i>A. pennatula</i></li> <li>– Landscape fragmentation</li> </ul>	<ul style="list-style-type: none"> <li>– Loss of the financial and material assets and pauperization process</li> <li>– Loss in human capital (access to school, health systems etc.)</li> <li>– Loss of land and NR access</li> <li>– Progressive increasing on wealth distribution inequity</li> <li>– Stagnating economic situation of commercial economies</li> <li>– Fragmentation of individual networks</li> </ul>	<ul style="list-style-type: none"> <li>– Weakness of safety nets programs</li> <li>– Weakness of social programs for food security.</li> <li>– Increasing of aid programs as safety nets</li> <li>– Increasing conflicts over lands and Natural Resources Management</li> <li>– Increasing conflicts between local organizations for the control of the protected area management</li> <li>– High fragmentation of familiar networks</li> </ul>

The following narrative links historical drivers with current trends of change and is organized based on Fraser's (2007) three dimensions of vulnerability of livelihoods. Key factors and interrelationships that influence the indicators of vulnerability are summarized as a conceptual model in Figure 3.



**Figure 3.** Overall conceptual model of the agro-pastoral system, showing the main drivers, variables and causal loops that affect vulnerability in terms of: a) ecological resilience of agro-ecosystem (large green bold box) b) individual socio-economic ability to adapt to change (large blue hyphenated box) and c) local institutional capacity to buffer and respond to crisis (large red box). Small blue boxes within the large blue hyphenated box point out both economies of the area (commercial and household economy); small green boxes within the large green bold box point out ecological processes in the main land uses (dry forest, native pastures and agriculture lands). Hexagons refer to main criteria/indicators used to evaluate the final effect on the three dimensions of vulnerability.

### *Ecological resilience of the agro-pastoral system*

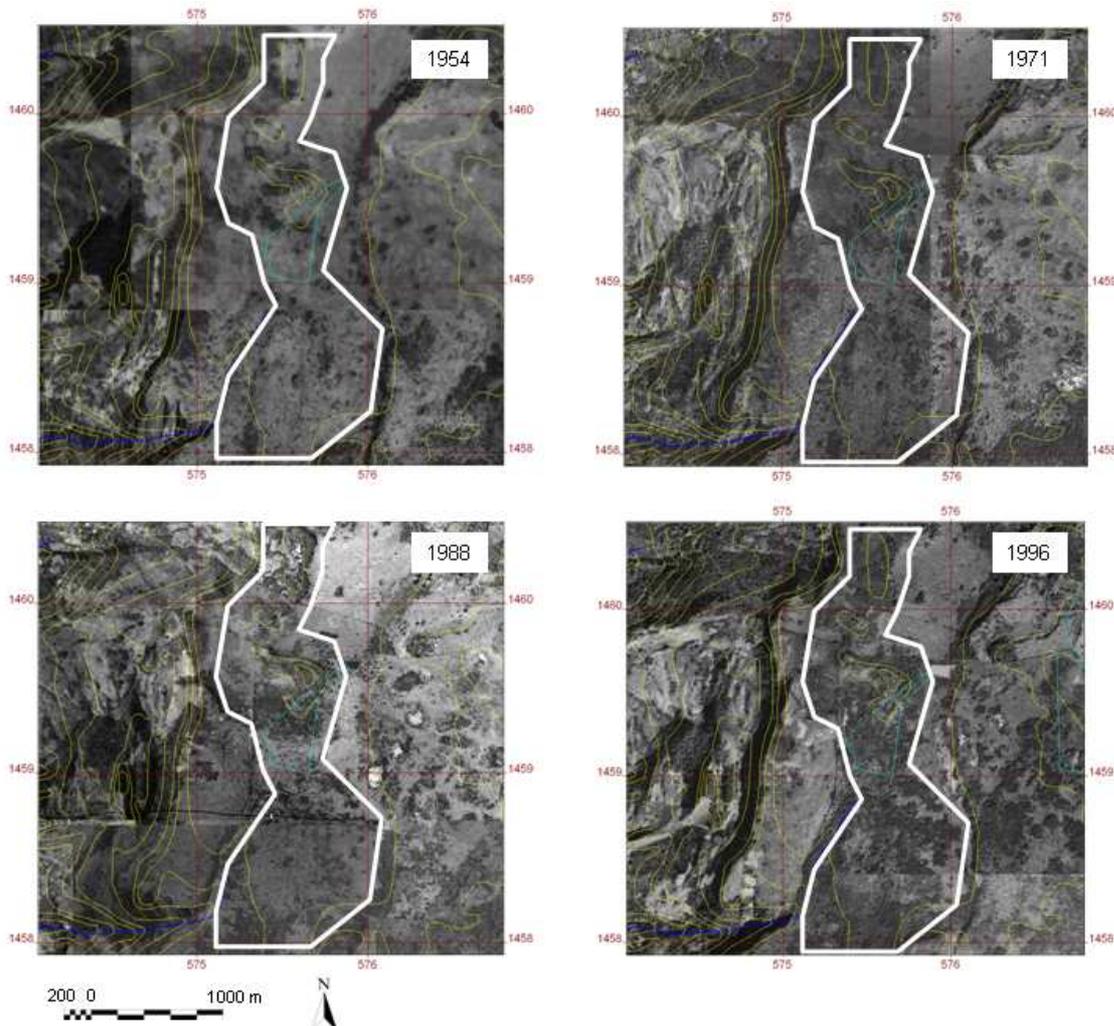
Three key changes stand out as affecting the resilience of the agro-pastoral system (green box in Figure 3).

First, **native pastures lands** have experienced a slow process of ecological transition from mature grasses (*Paspalum notatum* Fluggë) to either a degraded state or a bush and woody (e.g. *Acacia pennatula*) encroached ecosystem. This change has been observed by local land users and confirmed with aerial photographs and fieldwork (Tarrasón *et al.* unpublished data) (Fig. 4) and has been driven by both land intensification and land abandonment. Land intensification is problematic because although native grasses tolerate trampling and frequent grazing (Primavesi 2004), recurrent droughts combined with overgrazing and the introduction of exotic grasses species have spread non palatable species and inhibited the capacity of *P. notatum* from recovering from climatic shocks and stresses. The historical causes of land intensification are summarized in the Table 1. By contrast, some land has also been abandoned due to socio-economic and political conditions in the last three decades. In particular, neo-liberal macroeconomic policy changes and socio-economic uncertainty (Table 1) have meant that farming is currently no longer economically viable in some areas. Oral histories and the literature (Gibson 1996; Kaimowitz 1996) suggest that land concentration combined with credit shortage have increased land abandonment. In fact, according to the interviews, low income and highly indebted households have first intensified and then abandoned and sold lands to a few *latifundia*<sup>1</sup> and new commercial landowners. At the same time, economic stagnation and unclear land tenure have both reduced investments in technology, land management and labor. As a result, rural workers have passively exercised an opposition to exploitation and inequalities by working less efficiently and indirectly contributed to pasturelands encroachment. Other factors also affect the state of the native pastures, such as changes in environmental awareness that have driven the implementation of new environmental priorities and policies. For example, all interviews reveal that since the area has been declared “protected”, to defend small farmers from being shut out of land access and management by large scale landowners (Ravnborg 2008), local alliances and rules have been reestablished. Though the implementation of new management practices such as a fire and a logging ban and silvo-pastoral practices has provided *in situ* benefits, mainly during the dry season, this has resulted in bushes and trees spreading drought resistant such as *A. pennatula* and consequent inhibition of native grasses (Peguero and Espelta, unpublished data). These changes have affected the resilience of the ecosystem by reducing soil protection, threatening functional diversity, such as species control of native grasses (*sensu* Folke *et al.* 1996), decreasing productivity of pastures over a range of climatic perturbations (Walker *et al.* 1999) and favoring landscape fragmentation. Consequently, pasturelands’ degradation

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<sup>1</sup> The *latifundio-minifundio* land tenure system referred, in Latin America countries, to large estates of lands administered by few families with a patronage system (Latin: *lātus*, "spacious" + *fundus*, "farm, estate") scattered by tiny land plots (Latin: *minus*, "minor" + *fundus*, "farm, estate").

have decreased dairy and meat production, increased debt/income ratio for small farmers, reinforced food insecurity of households and reduced profits for commercial landowners.



**Figure 4.** Bush encroachment trends (1954, 1971, 1988, 1996) in the studied area. The area within the white line highlights the changes of the shrub cover.

Second, **agriculture lands** have experienced a decrease in yields and profitability just as the impact of climatic events (e.g. harvest losses) and economic crises (e.g. price volatility) have increased. For a long time, subsistence farmers had maintained a traditional grain system that minimizes external inputs in order to reduce costs and preserve long-term productivity. Nevertheless, traditional grain crops have progressively been replaced with a more intense mixed-farming system (e.g. cash and fodder crops) (Table 1). Despite providing a short-term boost of high productivity, this intensification has accelerated a long-term process of erosion of agro-biodiversity and soil quality. In fact, intensified agriculture reduces spatial diversity with effects on soil nutrient cycling (Ravera and Tarrasón, unpublished data), altered soil food-web composition through herbicide and pesticide use (Wardle *et al.* 1998), and enhances soil erosion under extremely strong rainfall and recurrent drought (Stocking and Murnaghan 2001). This affects stability of production and, as consequence, the ability of local household economies to adapt to change. Moreover, the agriculture intensification has increased farmers' dependency on inputs while reducing their capacity to handle debt in times of economic crisis.

Third, **dry-forest lands** are currently degraded and fragmented. This has been due to a range of historical forces including population pressure and changes in agrarian systems. Interview results suggest that, in spite of new protective rules, the inefficacy of local governance system has increased over time the disturbance of dry forests. In fact, grazing pressure, firewood extraction, accidental fires and tree harvesting have increased and this has reduced natural regeneration rate and trees growth (Tarrasón *et al.* 2010). Local perceptions confirm the literature (IPCC 2007) in that dry forest are currently more exposed to drier conditions and extreme events (e.g. intense drought) at individual (e.g. phenology), communitarian (e.g. distribution, interactions) and ecosystem level (e.g. water storage) than in the past. However, in the area a renewed sense of belonging has led to an increase in environmental-friendly practices and this may help decrease future forest degradation (Tarrasón *et al.* 2010).

#### *Socio-economic ability of individuals to adapt to change*

In the region studied, the extent to which individuals have access to assets that allow them to adapt to change was sharply divided between the commercial *versus* the household (small farmers agro-pastoral and landless peoples) economies. Key interactions in this system are highlighted in the blue box of Fig. 3. The two types of economies correspond to different objectives and strategies of resource allocation, and land management, i.e. maximization of profit and investments *versus* minimization of risk and food security maintenance. The individual and household decisions impact on the intensity of disturbance that accelerates or slows down ecological processes of land degradation. Over the past five decades, governmental policies have favored intensification and this has reduced the diversity of agricultural commodities being produced in the region (Table 1). Concurrently, local socio-economic structures have favored land concentration and this has displaced the poorest people onto less productive lands. Paradoxically, although small farmers had obtained access to land through the 1980s Agrarian Reform, they have quickly lost the financial assets to keep these lands productive and many farmers have fallen under growing debt burdens (Dufumier 2004; Baumeister, 2001). Although the cattle stocks have increased both nationally and locally for the last two decades (FAO, 2009a), the cattle raisers investment capacity stagnated and weak organizations have undermined the ability of both commercial and household economies to respond to market dynamics. This prevents technological innovations from being adopted and resulted in unequal access to wealth that has weakened individual's ability to cope with crises (Ravnborg 2003). Interviews show that the most vulnerable households are those composed of elderly parents, single parent women, or young landless people who work in commercial economy. These groups have limited access to land and natural resources, such as water and firewood, and lack human, physical and financial assets, such as wages, animals, technology and credit.

Historically, social capital has also played a key role in supporting individual's ability to cope with crises, especially food shortages. The perception analysis demonstrates that drawing on social networks is a well established risk-coping strategy (Box 1). Nevertheless, these mechanisms have been eroded over time. First, several drivers have affected the extent to which people trust their social contacts and maintain coping mechanisms. Second, the crisis of household economies has affected initiatives to sustain local management and livelihoods. This has increased out-migration. Demographic changes have meant there is a dwindling population of local younger more productive people, and this itself is driven by poor job opportunities, the local conditions and households' indebtedness and the attraction of urban lifestyles. Consequently, leadership renovation and long-term abilities of buffering have been affected.

### **Box 1. Coping mechanisms in the studied area**

**Productive mechanisms (medium and long-term responses):** i) transhumance migration systems of animals and people between semi-arid and lowlands or humid areas, ii) renting of farmland in the humid area to extend the growing season to minimize risk of losses (the *apante* is the growing season during the dry period).

**Land use changes and resources management mechanisms (medium and long-term responses):** i) agro-pastoral diversification and management to reduced impact of market volatility, ii) maintenance of traditional seed varieties to maintain a range of resistance characteristics, iii) retaining easily disposable assets, such as small livestock to be sold during time stress.

**Labour allocation and intensification mechanisms (long-term responses):** i) Temporary migration, both seasonal migration to obtain cash and to urban or foreign areas for remittance, ii) Allocation of work within the extended family;

**Collective mechanisms (medium and long-term responses):** i) a sharing system (*a media* means to share) in which landowners either rent grazing land in the dry season in exchange for half the milk production or dung, or purchase inputs for sharecroppers who provide labor; ii) in-kind transfers of goods and services between farmers, iii) family and social networks as a source of food or cash in crisis period (e.g.. seeds gathering by landless people during the dry season when landowners' cattle has migrated), and iv) Informal markets of dairy products through familiar bonds in the town;

**Destitution mechanisms (short-term responses):** i) permanent out-migration, ii) borrowing food and money from merchant and financial organisms at high rate of interest; iii) transference of capital stock to financial capital (i.e. sell animals or lands)

### *Institutional capacity to buffer and respond to crisis*

At national level, a lack of coordination across administrative levels has resulted over time in there being little in the way of disaster planning or early warning systems. This problem has been widely studied in literature for different periods (Table 1) (Pyner and Strachan, 1976; Biondi-Morra, 1993; Sahley *et al.* 2005). As a result, extreme weather events, such as Hurricane Mitch (1998), extreme droughts (such as happened in 2001 and 2005), and socio-economic shocks, such as the global economic crisis (2007-08; see: FAO 2009b), have all resulted in famines in this region. In particular, decentralization programs have failed to build human capacity and enhance investments and this has disempowered local governments (Martí i Puig 2004). Moreover, the World Bank's welfare programs, which were implemented by the neoliberal government to act as buffer for food security, have been ineffective (Sahley *et al.* 2005). Similarly, cooperative unions, small farmers' syndicates and historically powerful ranchers unions have all shown, since the collapse of the cooperative system, internal divisions at national and local levels, and have been unable to respond to crises. The State's incapacity to coordinate and handle crisis relief has been partly offset by NGOs who have played a key role in reinforcing social safety nets and providing assistance in hazard-stricken areas. On the other hand, NGOs' activities have reinforced a dependency amongst locals on these programs (Sahley *et al.* 2005). Recently, the new socialist central State has implemented a command-and-control regime of natural resources management systems and food production, distribution and storage. This has been criticized as it overlaps with local community authorities and risks undermining social relations (Muñoz 2007). A local level, new protectionist schemes, implemented in protected areas, have triggered locally new nature-

based conflicts (Nygren 1999, Ravnborg 2008). According to interviewees, the co-management scheme, still, lacks on transparency and legitimacy. As consequence, local tensions have arisen causing a loss of trust and a fragmentation of social ties. This has created a vicious cycle: the erosion of social networks has destroyed informal exchanges of goods and services, and this exacerbates social conflicts.

In figure 3 the red box shows the current linkages in this dimension of vulnerability.

### *Summary of trends in current vulnerability*

Taken together, the degradation of the landscape (which is driven by both land abandonment and intensification), the loss of assets available to poorer households (driven by economic changes and agricultural specialization), and a loss in the capacity of formal institutions to provide an effective social buffer or safety net system suggest that the vulnerability of livelihoods in this region has increased. From this, we may infer that future shocks (such as extreme climatic events as well as financial crisis) may have a commensurately larger impact than past ones.

### **Scenarios of Future Vulnerability**

Researchers and local stakeholders jointly developed scenarios for 2030 to reflect how livelihood vulnerability may change due to future multiple drivers in this agro-pastoral system. The main socio-economic components of the four scenarios suggested by the stakeholders are summarized in Table 2 and their short storylines appear in Appendix 3.

**Table 2.** Overview of main differences between drivers/components of the four participatory socio-economic scenarios for the area for 2030

<i>Components</i>	<i>I. “Business as usual”</i>	<i>II. “Community-based protectionism”</i>	<i>III. “Development and conservation”</i>	<i>IV. “Progress and technology”</i>
<i>National conjuncture</i>	Global and national instability	Political and socio-economic stability	Social and political stability	Political stability and socio-economic instability
<i>Market dynamics and international treaties</i>	Volatile markets without State control	Protectionism Economic treaties within alternative commercial alliances in Latin-America	New international partnerships and trade agreements with EU, USA, Latin-American countries	Free trade agreement with EU and USA
<i>Macroeconomic and sectoral policies</i>	Structural Adjustment Programs Absent sectoral policies for rural areas	Subsidized social programs and restrictive environmental plans, organic agriculture programs	Service-sector development (e.g. tourism), sustainable organic agriculture programs, environmental policies	Free competition and economic deregulation
<i>External agents</i>	Role of State limited to poverty alleviation programs and food relief	International funding supports conservationist programs and active research institutes	International funds promote rural initiatives, e.g. microcredit, and active research institutes	Foreign entrepreneurial investment
<i>Development initiatives /income sources</i>	Agriculture retract due to global prices markets on rural commodities Wealth	Community /cooperative agro-pastoral initiatives Few entrepreneurs	Job diversification Productive diversification Ecotourism	Agro-industrial development. Economic growth for commercial ranchers

	stratification	investment	promoted by entrepreneurs Payment for Ecosystem Services	and wealth stratification
<i>Local governance</i>	Local corruption, lack of transparency, weak trade unions	Reinforced local organizations, Effective environmental protection control and monitoring	Reinforced trade unions and partnerships, Upgraded systems for monitoring and controlling environmental protection	Strong trade unions of commercial ranchers, Weak local monitoring and control of environment
<i>Distribution of/access to land, natural resources and capital</i>	Progressive land abandonment Proletarianization, marginalization Limited access to land and natural resources	Land redistribution /regulation (prevalence of small farming system and household economies) National top-down control for guaranteeing access/use to natural resources.	Land regulation. Presence of different typologies of commercial and household economies, New local arrangements and rules for guaranteeing equal access and use of natural resources	Land concentration (deregulated and liberalized land markets) Unequal access to natural resources
<i>Land use and management</i>	Mono-functional land use (pastoral use) and intensification, Agropastoral and dry forest degradation	Mono-functional land use (agropastoral use) Expansion of subsistence cultivation systems (traditional and agro-ecological Low External Inputs Agriculture) and reforestation/ regeneration practices	Multifunctional land use Innovations in agropastoral systems management with agro-ecological semi intensification (Low External Inputs Agriculture and Forest regeneration/ conservation practices).	Mono-functional land use (pastoral use) High External Inputs Agriculture (intensification) Dismantled subsistence systems
<i>Labor market</i>	Economic stratification and labor exploitation persist. High out-migration	Few or moderate opportunities in rural areas	New job opportunities in a wide range of agricultural and service sectors	Only agrarian workers Few alternative opportunities in mechanized rural economies
<i>Social cohesion</i>	Low community spirit /workers' moral. Social and political conflicts over lands and natural resources.	Community based strong ties between landless people.	Collaboration and partnerships between local users and trade unions	Competitiveness and individualism deconstruct social ties.
<i>Culture, values, lifestyle</i>	Persistent corruption Resistance to change among local traditional big landowners Youth preference for	Historical coping strategies Strong sense of belonging	New rural lifestyle New sense of belonging (e.g. brand and green culture)	Weak sense of belonging Urban lifestyle attracts people in rural world

	urban lifestyle			
<i>Infra-structure and technology</i>	Absent investments	Investments in agricultural extension programs	Investment on green management practices (low input technology)	High technology and infrastructure private investments

In particular, local stakeholders were asked to debate a range of possible adaptation to an added stress of increasing in annual mean temperature of 3.5°C by 2050 (as compared with the 1980-99 average), and a shift of seasonality and high variability in intensity of rainfall events (Table A1.1 and Figure A.1.2, Appendix 1). The likely indirect impacts of this projection are summarized based on an extensive literature review (Table A.1.2 in Appendix 1).

The first scenario, called “managing the desert”, is the business as usual scenario. For this scenario, stakeholders agreed that the socio-economic forces observed in the last decade would continue. Adding the stress of climate change would, in their opinion, increase pressure on natural resources (e.g. more variable rainfall and extreme weather events add pressure on abandoned lands and intensified agriculture lands and this may lead to more mismanaged landscapes) while the global economic crisis would reduce households’ self-reliance and result in commercial and economic stagnation. Taken together participants were worried this would lead to sudden and irreversible shifts in ecosystem states (e.g. changes in grasses/bushes boundaries). Furthermore, economic opportunities for the rural poor are likely to shrink while wealth inequalities may increase. This would result in a loss of assets and livelihood buffers thus increasing the downward spiral of out-migration, a destabilized local demography, and new conflicts over critical resources (e.g. fresh water). Failed local governance leads to frail safety nets and high dependence on external aid.

A second likely scenario is one of “community-based protectionism” and results in contradictory tendencies between the dimensions of vulnerability. This scenario postulates what might happen if the government subsidized food self-sufficiency and community development. The stakeholders suggested that this could lead to conservative ecological practices being implemented to cope with climate change. While such policies should favor enhanced agro-ecosystem resilience, these policies would also likely result in subsidized forestry activities and this, plus the increase in crop land, would result in declining herd stocks and abandoned or fragmented rangelands. Therefore, the contradictory impact of these factors in combination with climate change on agro-ecosystem resilience is uncertain. Community development projects would increase opportunities to cope using social networks and this would enhance community resilience to climate change. However, as the State and local community take more control over land from large scale land owners and powerful families, new social conflicts would be expected to arise. Furthermore, rules and organization levels are uncoordinated for the purpose of achieving community control over resources and this means that institutions would be unlikely to provide effective crisis relief.

The third possible scenario, called “development with conservation”, hypothesizes that people might start to promote low-input technologies and that agro-pastoral system management would shift to protect native vegetation. Stakeholders agreed on suggesting processes through which these strategies could enhance functional diversity, productivity, and incomes. In addition, investments for environmental awareness in rural areas could be directed to support entrepreneurial initiatives that include local communities in private and communal projects. Smallholder farmers would receive incentives to develop small scale production outside

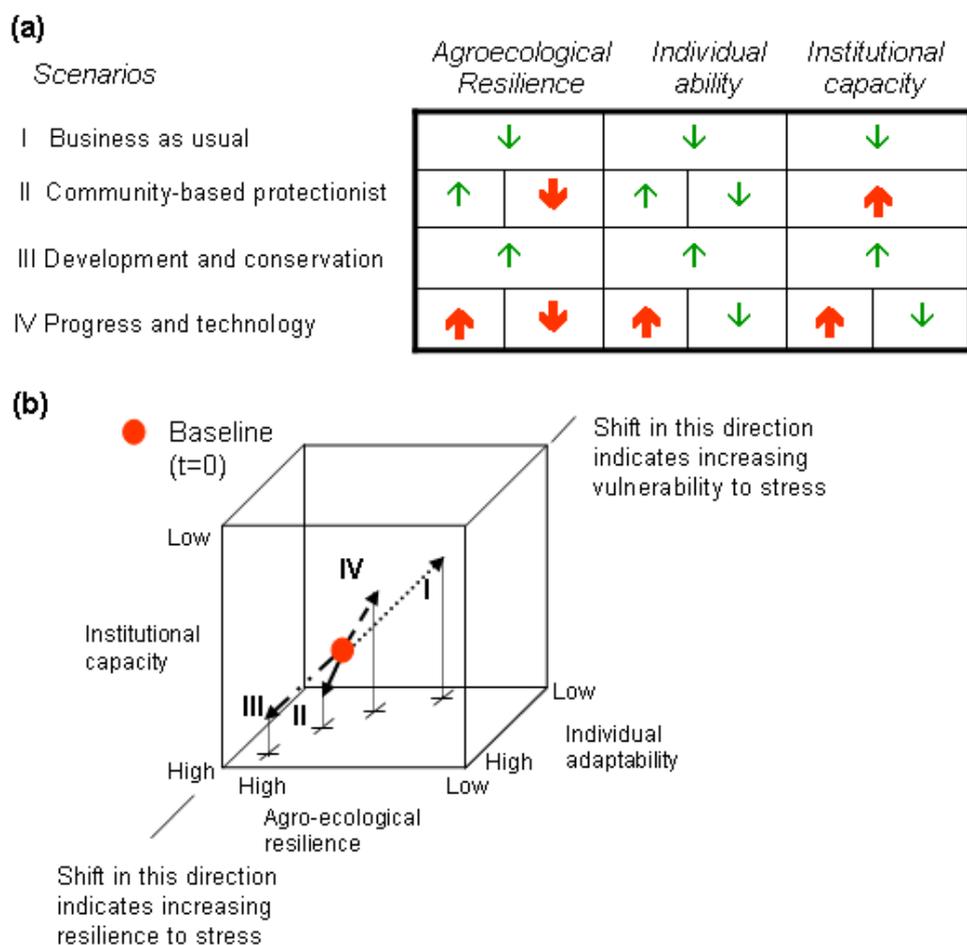
mainstream business contracts. New alliances between local stakeholders, trade unions and institutions would create long-term opportunities and facilitate capacity building of farmers for innovation and learning through experimentation. Finally, political and social stability, for example, more equitable land tenure access and transparent regularization, could improve local governance.

The fourth scenario is one of “progress and technology”. In this scenario, the stakeholders discussed the implications of how agro-industrial development could improve both biophysical and socio-economic conditions. Conflictive perceptions emerged and unclear and unpredictable cause-effects relationships were debated. They agreed that technological green innovations could enhance land productivity and would likely be ecological friendly and economic efficient. However, some other stakeholder argued that such innovations would have unexpected impact and would likely only be beneficial during climatically “normal” years because as agro-ecosystems are more intensively managed they would be more sensitive to droughts and other climatic stresses. This would likely benefit commercial ranchers who have huge land holdings (and are thus protected from small scale climatic problem) and they would be able to increase their assets, leading to greater inequalities and conflicts. This would create a further feedback as mechanized agriculture reduces the demand for labor, and this would increase migration and dismantles social mechanisms that buffer poor households against food insecurity. Safety nets are thus driven by private and external aid support, resulting in a high uncertainty about the accountability and transparency of the local governance.

#### *Summary of trends in future vulnerability and adaptation*

To summarize the implications for vulnerability to multiple stresses (Figure 5):

1. Scenario I suggests that in the future agro-ecological resilience, individual ability to adapt, and the capacity of institutions to provide buffers will all diminish. Uncertainty of the trends is low and mainly related to either ignorance or incomplete information and knowledge with regards to the extent of the change.
2. Scenario II suggests that it is unclear whether agro-ecological resilience will rise or fall, that the assets available to individuals will increase for household economies whereas commercial landowners will redistribute assets, and that the capacity of institutions will increase with high unpredictability due to possible contradictions with regards to the effects of a neo-socialist system.
3. In scenario III, all three dimensions of vulnerability are set to improve. Uncertainty of the trend is low, due to the confluence of visions with regards to the effects of drivers.
4. The final scenario (IV) has unclear and conflicting implications for all three dimensions.



**Figure 5.** a) Heuristic illustration of trends of vulnerability indicators within the four scenarios (↑ better=no reason for specific concern; ↓ worse=be alert or warning development). Colors and boldness of the line indicate the degree of uncertainty of the trend (red and bold line for high uncertainty, green and fine line for low uncertainty). (b) The resulted hypothetical pathways from actual baseline (t=0) to 2030 are represented in a 3D space (Adapted from Fraser, this volume). If the trends towards opposite direction have different degree of uncertainty the arrow shows the trend with low uncertainty. If trends towards opposite direction have the same degree of uncertainties this results in a no change of direction from the baseline.

As a final point, the consequences of different development pathways visualized in a systematic way helped local stakeholders in designing multi-scale bundle of strategies across the scenarios (Table 3).

**Table 3.** Individual and institutional adaptive strategies and policies proposed by stakeholders, their scale and dimension of intervention.

<i>Adaptive strategy</i>	<i>Scale</i>	<i>Dimension</i>
Institutional harmonization of planning responses, integrated participatory decision-making processes - Decentralization without deregulation that create, strength and delegate power and economic responsibility to local organizations/institutions - Private-public partnerships	National-regional-local	Institutional
Revised international trade policies to improve market access - Take advantage of existing mechanisms for “local products” and special “safe guard mechanisms” to protect national agricultural sectors - Establish appropriate food stock to prevent price volatility	National-International	Political

- Secure access to information and microcredit		
Mechanisms and funding to support rural investments: - appropriate policies to reduce impacts of food price inflation - invest in agriculture in low-potential areas as a social investment - diversified rural on-farm and off- farm economies - financial compensations for ecosystem services protection - infrastructure investments	National- International	Political
Law enforcement for land ownership and rights to natural resources access: - secure land rights - ensure land access for disadvantaged groups - restrict land sales to foreign investors	National	Political
Reinforced organizations and networks (Governance and Adaptive Comanagement): - capacity building for communities to achieve self-sustaining projects - strength alliances and coordination between co-managers (FORO Mirafior), communities, landowners, ranchers' trade unions, councils and academic institutions - enhance market competitiveness, e.g. construct warehouses for crop and dairy products.	Local-regional	Social- Institutional
Farmer to farmer knowledge exchange and extension: - share good farming practices through the establishment of model farms and strength capacity to monitor and assess - exchange native crop varieties through local seed fairs - join national networks, e.g. Farmer-to-Farmer Program; Initiative like "Seeds for Identity" - farm planning design towards 10 years	Local-regional- national	Social- Institutional
Innovative agricultural practices. - switch from monoculture to diversified agriculture: use traditional maize-bean intercropping system, cultivar rotation with green manure or farm cattle manure - Technological innovation (low energy input) to produce quality dairy products - equilibrate nutrient flows through integrated management with mixed-farming systems, crop-pasture nutrient management - improve livestock systems with rotational grazing systems, fodder bank for livestock, fodder tree in paddocks Support on-farm experiments with rotational livestock, and protein banks	Local	Environmental -productive
Dry forest conservation programs - Reforestation with local species for vulnerable and exposed areas - planned natural regeneration - development of management guidelines	Local	Environmental
Water system technologies - small scale water management solutions, i.e. rainwater harvesting techniques, tanks - water retention in soil with innovative agricultural practices	Local-regional	Social- Institutional Environmental
Alternative energy sources - creation of communal "energy forest" to supply fuel wood without threatening remaining dry forest - development of wind power	Local-regional- national	Social- Institutional - Environmental
Communication plans -transfer of technical and scientific knowledge to local stakeholders -coordination of early warning systems and disaster risk programs - coordination between co-managers and councils to enhance their prevalence in the area (strengthen the efficacy of local rules)	Local	Social- Institutional
Investigate feasibility of eco-tourism - creation and training of a tourism commission	Local-national	Social- economic

## FINAL REMARKS

### Empirical remarks about the drivers of vulnerability

This study focuses on understanding the key driving forces in change of semi-arid agro-pastoral systems in Nicaragua, providing some evidence of a larger picture of future vulnerability and suggestions with regards to adaptive strategies across space and time.

#### *Economic forces and the uncertain environment*

The literature shows that both global environmental and economic changes have an effect of livelihood vulnerability (O'Brien and Leichenko 2000; Stringer 2009). Therefore, anticipating future vulnerability in semi-arid environments must take into account varying degrees of ecological and socio-economic uncertainty. Our analysis shows that historical inequalities in land and wealth distribution were driven by macroeconomic policies and this affected local management of natural resources. In terms of how this may play out in the future, both scenarios I and IV suggest that inequalities can contribute to the continued destitution of small farmers and this may increase vulnerability (Ohlsson 2000) and environmental degradation (Rahman 2004). The study also suggests that the relationship between resilience, economic policies and instability is complex. Historically, incentives that stimulated both commercial farmers in the 1960s and cooperatives in the 1980s disrupted important local-level socio-ecological functions (Kaimowitz 1997). Top-down agricultural policies may erode ecological resilience even though political conditions are stable (Fraser and Stringer 2009). Conversely, in unstable situations, such as in neoliberal regimes, land abandonment, short-term investments and opportunistic behaviors in landowners, are common (Albers and Goldbach 2000). Finally, the research presented here shows that when local economies depend on few resources/activities they are vulnerable to the boom and bust nature of markets (Adger, 2000) and this accentuates the likely impact of future weather variability. In contrast, macroeconomic policies that favor equal access to land and diverse markets that include tourism and fair trade markets can cushion households during periods of food insecurity. These more optimistic futures are the subject of scenarios II and III.

#### *Leadership, social capital and governance system*

This study also confirms the literature (e.g. Folke *et al.* 2002) by showing how institutional failures disturb local mechanisms for environmental monitoring and that shifts in governance system can affect the ways communities deal with external shocks. For instance, changes that drove land resettlement undermined the way native pastures were managed and exacerbated vulnerability to drought. To rectify this, an institution-building process can help restore adaptive capacity and institutions need to empower local groups to experiment, learn and reflect (this is the subject of scenario III). Strengthened local leadership, flexible institutions, anti-corruption initiatives and new forms of social networks and collaboration would all enhance overall resilience and reduce the dependence on external help while increase safety nets. Therefore, this research suggests that neither centralization nor decentralization are appropriate but that but cross-level interactions may lead to a sharing of management power and responsibility. This calls for a transparent and interactive commitment across the decision-making scales and new forms of integrated policies (IPCC 2007).

#### *Cultural drivers*

Local institutional arrangements and land-user behavior are deeply influenced by cultural values. The historical evidence and future scenarios illustrate how international lifestyle and

values have changed (e.g. consumers' demand of green products) and have influenced land use and management. For example, technological innovations in conventional agro-industry (Scenario IV) are perceived to boost rural development and improve living standards for some while aggravating social inequalities. In contrast, the technological changes discussed in scenarios II and III are more socially inclusive. Providing funding that supports ecosystem services management (Goldman *et al.* 2008) is an illustration of this, and has been used to combat poverty and enhance nature conservation (Hecht 2004). However, these programs have failed to recognize the roles of agro-pastoral system as provider of ecosystem services (Pagiola *et al.* 2007) and to support subsistence farmers as conservationists. There is a need, therefore, to develop new context-specific strategies that value knowledge exchange between local stakeholders and researchers.

### **Methodological remarks about studying vulnerability**

Reflecting on the process undertaken to conduct this research, the paper highlights some theoretical and methodological challenges concerning vulnerability assessments. First, the study demonstrates that conceptual modeling and participatory scenario development can be powerful tools for bringing knowledge systems together, empowering local stakeholders to distinguish opportunities and threats, and enabling negotiation. Second, overlapping the baseline conceptual model with future scenarios and climatic stress, allowed us to imagine creatively an anticipatory rather than reactive adaptation window. Framing interrelated drivers and factors into the three dimensions of vulnerability is a manageable format for dealing analytically with multidimensional assessment of vulnerability to change, and helps identify critical components for making the systems more vulnerable or resilient. Finally, the paper finds that integrated methodological frameworks can deepen our understanding of semi-arid livelihoods system as a whole and our comprehension of hypothetical factors that may reinforce or weaken their vulnerability (Knutsson and Ostwald 2006). In conclusion, the framework of assessment proposed has been demonstrated a helpful instrument in planning processes, to explore possible future pathways and negotiate on the key components of scenarios that help prioritize adaptation decisions. However, the vulnerability assessment needs further refinement. Further research will be focused on defining irreversibility in maintaining resilience when indicator thresholds are passed and on building the interface between social research and mathematical modeling, both theoretically and practically.

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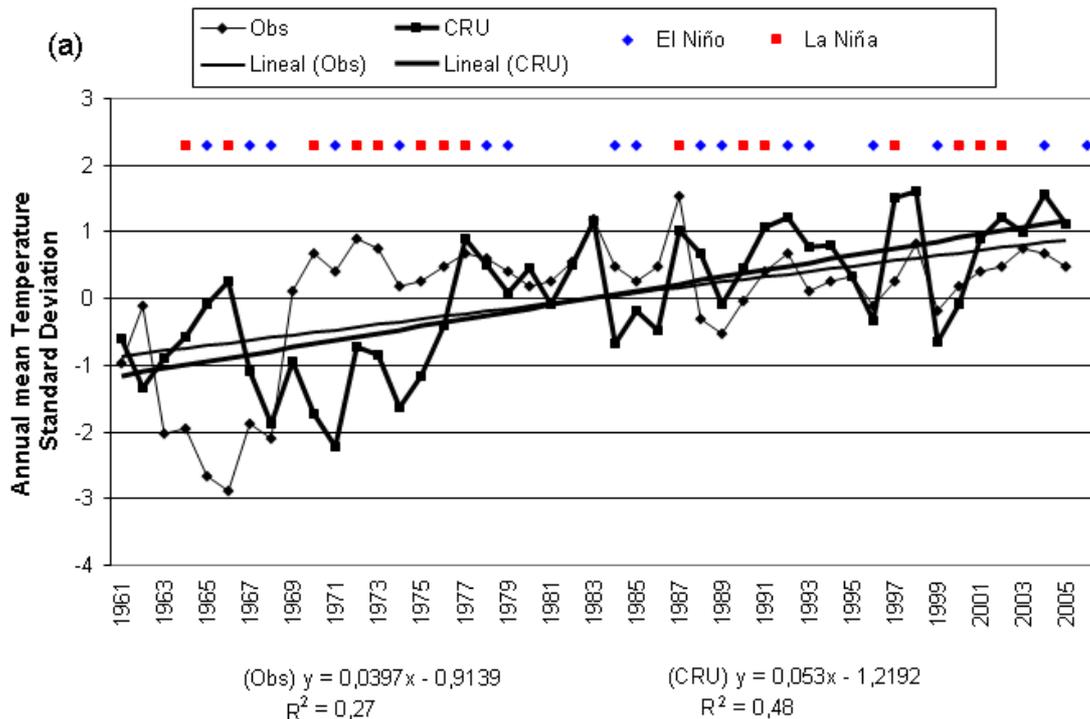
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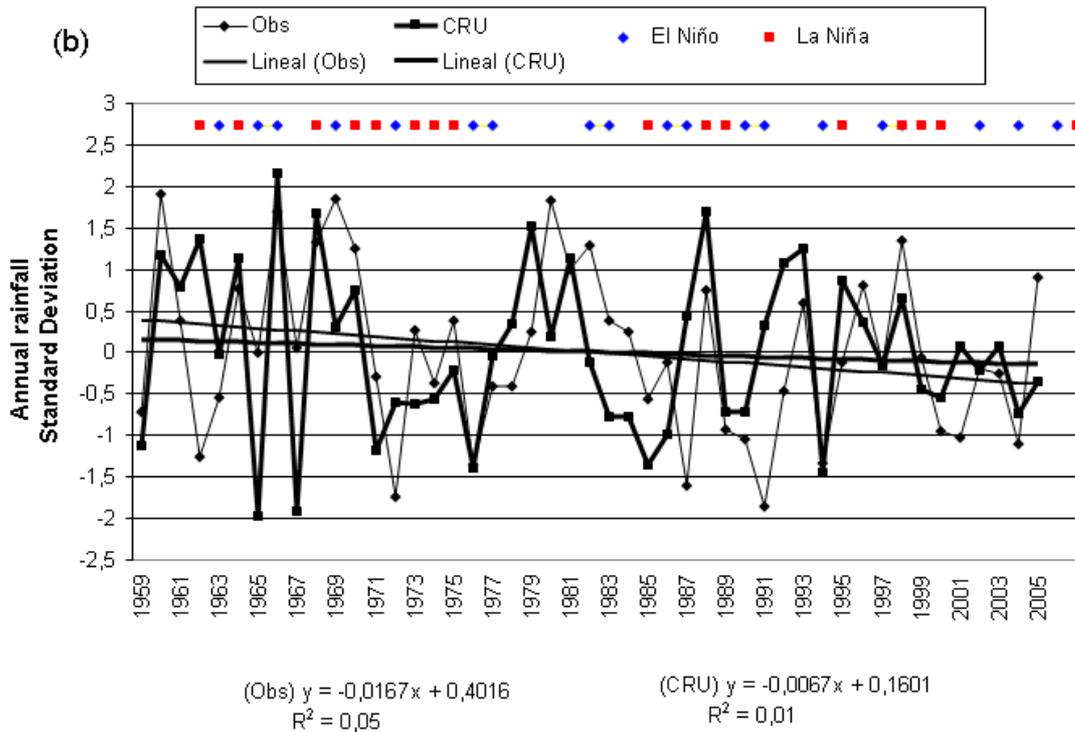
## Appendix 1

### *Historical trends and natural hazards*

The analysis of historical trends in annual temperature and precipitation were based on monthly data observed for the period 1961-2004 from four meteorological stations in the semiarid zone of Estelí department (Figure A.1.1 a and b). To provide a more robust analysis for the baseline, we also compared the observations with Climate Research Unit TS3 dataset (CRU TS3) for the corresponding grid and period (University of East Anglia Climate Research Unit, CRU, 2008). The long-term historical temperature and rainfall in general show few clear trends for many parts of Central America (Magrin *et al.* 2007). For the studied area the average annual rainfall shows an insignificant decline, while the annual mean temperatures significantly increases by about 0.4°C/decade between the 1960s and the 2000s.

Historically, extreme events and associated natural hazards (e.g. hurricanes, droughts) were particularly related to El Niño and La Niña cycles (NOAA, 2010). The El Niño phases were associated with warmer regional temperatures and strong rainfall anomalies (Figure A.1.a and b), i.e. low rainfall with severe droughts (1972, 1976, 1987, 1990-91, 1994, 2004) and peaks in rainfall (1966, 1969, 1998), causing floods and landslides. The La Niña phases were associated with floods, and occurred mostly in years with peak rainfall (e.g. 1968, 1970, 1998) while occasionally in years with low total annual rainfall (1962).





**Figure A1.1** Trends in annual **a)** mean temperature from 1961 to 2005 and **b)** total rainfall from 1959 to 2005. The data have been standardised to enable comparison. One of the rainfall stations had an abrupt decline in rainfall in the late 1990s that could have influenced the trend for the observations.

*Future projections and potential impacts*

The future climate scenario for the study area was built on two projections of temperature and rainfall changes. As a result, table A1.1 shows the change in annual mean temperature and precipitation of A1B (worst case) scenario for 2050 compared to the baseline period 1980-99. This was estimated from seven General Circulation Models and the four main scenarios from Special Report on Emissions Scenarios between 1980-99 and the projections for 2020-2030 and 2050 (projections were developed by Ruosteenoja et al. (2003). To develop the future scenarios for this study, the annual changes were first calculated as the mean changes for the dry and wet season, respectively. The future projection show that the minimum temperatures may increase by 1.4 - 2.0°C and for maximum temperatures between 4.6 - 5.5°C for 2050,, while the maximum rainfall may increase by up to 24% and minimum rainfall decrease by 45-57%. These scenarios also project that the frequency of extreme wet seasons may only increase by 2% while dry seasons are projected to increase between 15-25%.

**Table A.1.1** Observed long-term annual mean temperature (T°) and total rainfall (P) for the baseline 1980-99, and A1B scenarios for 2050 for four meteorological stations in semi-arid Estelí Department.

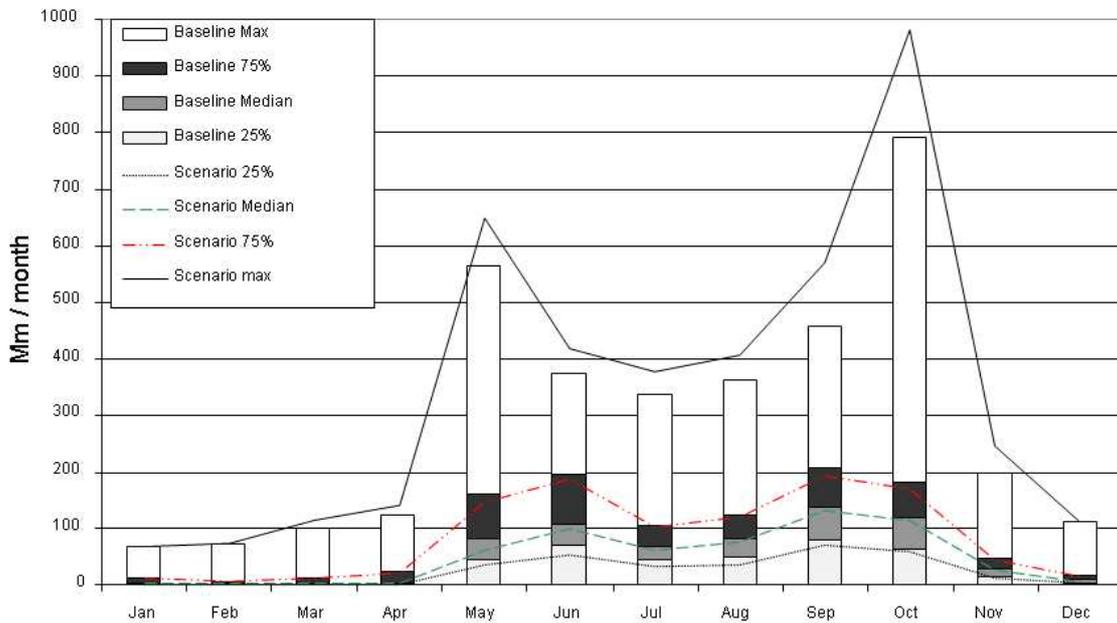
Meteorological stations	Latitude N Longitude W	Elevation (masl)	T° 1980-99 (°C)	T° 2050 +3.5% (°C)	P 1980-99 (mm yr <sup>-1</sup> )	P 2050 -13.5%/ +4% (mm yr <sup>-1</sup> )
St Leonor	13°28'00" 86°19'44"	490	n.d.	n.d.	533	461/554
Condega	13°20'02"	560	24.5	25.4	839	726/873

	86°23'07"					
Estelí	13°07'00" 86°21'36"	820	23.0	23.8	822	711/855
La Concordia	13°12'00" 86°10'00"	900	n.d	n.d	936	810/973
Average obs	<i>n.a</i>		24.0 (n=2)	24.8	791 (n=5)	684/823

Figure A1.2 shows the ranges of change in projections of average total annual rainfall for 2090. These projections were based on the seasonal changes from a set of 21 global models for A1B scenario for Central America between 1980-99 and 2080-99 (Christensen et al. 2007 table A1.1). The projected differences in minimum, maximum, median, 25% and 75% quartiles between the baseline and 2080-99 periods were used to modify the distribution of the observed baseline.

In resume, assuming this gives a rough estimate of the annual changes and the seasonal rainfall variation, the future exposure is related to more uncertain winters:

- Summer - Temperature increases moderately compared to other seasons, while maximum temperatures increase by up to 2.5 °C.
- Winter - More frequent heat waves and extreme dry spells. The highest increase in minimum temperatures 1°C, of all seasons and maximum temperatures increase by up to 2.7 °C. Higher intensity rainfalls and stronger and/or more frequent tropical storms



**Figure A1.2** Range of past (1980-99) and projected monthly rainfall by 2090s. To illustrate the likely increase in extreme events (both floods and droughts), the maximum May rainfall between 1980-99 was 565 mm, while by 2090s it may reach 650 mm. However, the median rainfall was only 80 mm and may decline further to 67 mm. The figure shows minimum, maximum, median, 25% and 75% quartiles between the baseline and 2080-99-periods.

The most likely immediate impacts are more intense and recurrent drought risk in both seasons. Moreover, flood and wind risk damages are expected in winters. Table A.1.2. shows a literature review of the key expected impacts on tropical dry-land systems with

some specific examples for Latin and Central America, particularly focusing on those with potential effects for the studied area.

**Table A.1.2** Effects of climate change expected for semi-arid tropical environments.

<i>Component of the system affected</i>	<i>Effects or impact</i>	<i>Confirmed by literature</i>
Socio-economic	- Human migration from drought-affected areas	IPCC (2007); Dixon, J. <i>et al.</i> , (2001)
	- A warmer and wetter climate contributes to several diseases, e.g. dengue/dengue hemorrhagic fever	Patz <i>et al</i> (2005)
	- New and fluctuating weather patterns could have a strong negative impact on economic activities in agriculture, e.g. reducing yields, increasing production costs.	IPCC (1998)
	- Increasing competition over critical resources such as freshwater as driver of tensions and conflicts	Homer-Dixon and Blitt (1998)
	- Change in rainfall distribution and frequency of extreme weather events contribute to the accentuated vulnerability of human systems to natural disasters (floods, droughts, landslides, etc.).	IPCC (2007); Seo and Mendhelsohn (2007)
Institutions	- More expenses expected for emergency relief. - Food security at risk and possible tense social relations due to scarcity	Barnett and Adger 2007
Grassland	- Changes in grassland/shrubland boundaries - Change in specie composition	IPCC (1998); Sala <i>et al.</i> (2000)
Cash-crop	- Increasing risks of heat stress for crops. With prolonged sequences of daily temperatures above 30°C, plant physiological functions may be damaged and production reduced.	Battisti and Naylor (2008)
	- Mechanical damage on crops and yield losses from heavy rains /hurricanes.	IPCC (1998)
	- Species characterized by high reproduction rates generally are favored by temperature increase, increasing the distribution and occurrences of pest infestation and pathogens	Magrin <i>et al</i> (2007), Rosenzweig <i>et al.</i> (2001)
Grain-crop	- Yield losses in the range of 2.5 to 16% for every 1°C increase in seasonal temperature.	Lobell <i>et al.</i> (2008)
	- Higher minimum temperatures in autumn may shorten the growing season, particularly if water is limited.	Giménez (2006), Magrin <i>et al</i> (2007)
Livestock	- Declining survival rates of livestock due to drought	Richardson <i>et al.</i> (2007)
Soil	- Increasing runoff and potential evapotranspiration rates due to higher surface and near-surface temperatures, dries topsoils and accelerates soil erosion by wind and water.	Magrin <i>et al.</i> (2007)
Dry forest	- Seasonally dry forests are considered severely threatened by global warming - Tropical forests are likely to be more affected by changes in soil water availability from seasonal droughts or soil erosion and nutrient leaching resulting from heavy rainfall events.	Halpin <i>et al.</i> (1995); IPCC (2007)
	- Deforestation for agricultural land likely consequence declining agricultural productivity and increasing food demand.	.IPCC (1998)

Biodiversity	- Wild life extinction rate increase.	MEA (2005); IPCC (2007)
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## Appendix 2

In this study, scenarios are interpreted as alternative futures that are neither predictions nor forecasts, but stylised and contrasting desirable or alarming images of how the future might unfold. Drawing on participatory research (Reed *et al. in press*), the scenario development in this study has some innovative merits, such as combining explorative and anticipatory methods. At the core of the framework was an iterative, two-way learning cycle between researchers and stakeholders for formulating a portfolio of environmental management options and policy proposals for adaptation to change. The scenario analysis specifically addressed uncertainties and surprises, by incorporating alternative and potentially conflicting perspectives, values and interests and by encouraging participation through negotiated deliberation processes. The conceptual modeling exercise and scenario analysis were developed in three key phases: 1. exploring narratives of the agro-pastoral system's historical and current structure and functions, 2. Envisioning desirable and adverse visions for the future, 3. Back-casting to discuss how these futures could emerge and what policy options could be implemented to achieve them.

### *Conceptual modeling exercise*

Once the key stakeholders' interests and relevance had been characterized (Ravera *et al.*, 2009), their early participation was vital to ensure representative, dynamic and durable decision-making throughout the process. The historical analysis of trends and drivers of vulnerability of livelihoods in the studied area was obtained by a triangulation of participatory methods that include key informant interviews (N=5), a focus group with village elders (N=12) and more classical research methods such as aerial photographs and satellite images interpretation (1954, 1971, 1988, 1996 and 2008), literature review and archive material study. Secondly, a perception analysis was carried out to explore conflictive concerns with regards to environmental and development issues and perceptions and representation of vulnerability changes. Two series of in-depth and semi-structured interviews were conducted (respectively N=23 and N=41) within categories of local stakeholders (landless people, small agro-pastoral farmers, medium semirural cattle raisers, traditional large scale landowners and commercial entrepreneurs, women single parents, youth people). They were selected through snow-ball sampling. Four focus groups were, then, involved small agro-pastoral male farmers (N=15), women (N=20), youth (N=12) and landless people (N=13) in a collective discussion. We also interviewed representatives of institutions interested or involved in natural resource management in the area (N=13) (e.g. local authorities, Government's agencies, local administration, trade unions, NGOs, private enterprises) and we organized a focus group of local experts from NGOs and research institutes (N=12). A mix of methods was then used to code and represent local narratives, such as visual representations and grounded theory analysis applied to transcripts and combined with literature and field observations. The final decisions on how to visualize the narratives as conceptual model were taken in two series of meetings with experts. These meetings included Nicaraguan and Spanish researchers, on agro-economy, agronomy, ecological economics and ecology, and Nicaraguan teachers and environmental technicians. The experts also decided how to present uncertain and conflicting visions. A simplified version of the conceptual model was discussed in in-depth interviews with key

informants (N=12) and presented back to local stakeholders during a series of extended meetings: four meetings with small farmers and landless people, two meetings with large scale commercial traditional landowners and entrepreneurs and a meeting with representatives of local institutions. The conceptual model was cross-validated with researchers from system analysis, ecological economy and ecology (N=5) and then developed in VENSIM program.

#### *Envisioning exercise*

In a complementary exercise stakeholders were asked to envision the connections between components and drivers to changes and future vulnerability. To account for different future visions and discuss potential uncertainties and surprises, the focus groups participants (see above) were divided into mixed subgroups and were guided to construct a set of desirable and undesirable scenarios. To engage participants without formal education, illustrations, such as collages from magazines, photographs, sketched maps of the region etc., were used to create an image of the future and discuss associated storylines on drivers and changes in the multiple dimensions of vulnerability based on Fraser's work (2007). A complementary series of in-depth interviews (N=23) was used to explore metaphors that capture stakeholders' expectations about the future. Quite independently of the details, the metaphors dramatized the inner significances of the situation and alluded to the kind of world within which stakeholders belong. Titles and the final storylines of future scenarios were then re-elaborated by the research staff in-desk.

#### *Back-casting exercise*

A second series of focus groups was conducted with male small farmers and landless people (N=13), women (N=15), commercial landowners and medium semi-rural ranchers (N=6) and local authorities' and institutions' representatives (N=10). Here, the conceptual model inputs and scenarios narratives were the base for a back-casting exercise. Starting from the future scenarios the participants were asked to go back to the present time, identifying obstacles and opportunities that might emerge on the way. For each scenario, likeliness of factors that should influence the vulnerability was inferred. To converge conflicting interests the likelihood and desire of different scenarios were discussed, and resulted in a "compromised sustainable scenario". The participants started by identifying what changes in land use allocation, land management practices and socio-economic and institutional arrangements were to be implemented in the present time in order to lead to the respective future scenarios. The support of a 3D landscape model helped to ground the discussion in the current context and landscape and to heuristically anticipate measures to avoid undesirable futures. Participants were asked to respond to a list of key policy questions, derived from the analysis of assumptions and components for the four scenarios. Then, a set of plausible pathways to achieve desirable states was created and adaptive management strategies were discussed. Throughout the process, the feedback and dissemination with stakeholders allowed for a dynamic participatory learning process experience and a set of different tools were useful for overcoming language barriers and prevent misunderstanding. In the future, further steps of the research will use indicators of vulnerability to empirically monitor and simulate within a dynamic computer-based modeling future changes in vulnerability of livelihood under each scenario and options.

### Appendix 3

I. “Managing in a desert” (suggested by all the stakeholders). The national and uncertain stagnant economic situation persists with falling production values and salaries. Failure of the State’s commitment, transparency and fragmentation of administrative interventions continue. Institutional failures lead to natural resource mismanagement, e.g. illegal felling and unstable local governance. Landowners are reluctant to change and innovate. Land distribution and access to natural resources, such as water and firewood, are inequitable. Small and medium-scale farmers intensify production and over-exploit natural resources or sell off and move. Rural depopulation, social stratification and local conflicts demoralize social networks. Absent on-farm job opportunities, worsening insolvency and environmental degradation make the region dependent on external aid and food relief programs, hence more sensitive to economical and environmental shocks.

II. “Community-based protectionism” (suggested by landless people, small famers and women, local authorities and other institutions with social and environmental concerns). This is a community-based natural resource conservation scenario with improved small scale farming systems within a protectionist Sandinista policy framework. Investments and state subsidized programs with credit schemes and guaranteed prices provide incentives for small farmers to explore new market opportunities. Policies on consumption, including food aid, are implemented in response to rising commodity prices. Communities, trade unions of small farmers and cooperatives are organized, with NGO support, to export within Central and Latin American alliances. These schemes promote fair-trade contracts and alternative production, e.g. dairy, organic or livestock production. Community co-management strengthens local governance. Local communities are guaranteed access to land and natural resources by law. Large scale commercial production doesn’t receive incentives. Improved education, off-farm job opportunities, and effective international funds that support conservation programs and environmental policies contribute to reduced land pressure. Main land use changes are a mosaic of small farmland and dry forest expansion. Diverse small-scale farming systems may provide local food.

III. “Development and conservation” (suggested by women, small farmers, medium scale semirural cattle raisers, large scale commercial traditional landowners). This negotiated scenario emphasizes agro-environmental programs that encourage Payment for Ecosystem Services mechanisms, low-cost green technologies, agro-ecological practices and are enforced through international funds. State interventions promote equitable land distribution, rural investments with long-term credits, micro-enterprise development and public-private partnerships between landowners and communities, food and agricultural input and commodity price protection and other policies on production and trade. Local institutions are reinforced through decentralization and determined initiatives to reduce corruption. Agro-ecotourism based on traditional production and handicraft provides local capital influx and diversifies household incomes. Off-farm economic opportunities, income redistribution and improved labour conditions are encouraged by changes in local development pathways. As the population increases and exchanges with urban areas become more frequent and traditional values, solidarity and local culture thereby coincide with new lifestyles.

IV. “Progress and technology” (suggested by medium scale semirural cattle raisers, large scale commercial traditional landowners, commercial entrepreneurs and local institutions with development concerns). National economic growth and neoliberal policies dominate this scenario. Governmental actions and functions are constrained. Agro-industries are oriented towards dairy and meat production. Opportunistic investors and landowners take advantage of liberalized land tenure and international trade agreements. Local agro-pastoral systems are progressively intensified and mechanized. Small-scale and traditional farming systems vanish. Rising demand for green energy upholds land conversions towards bio-fuel plantations. Land concentration reinforces socio-economic inequalities. Social programs and creation of skilled-jobs in the agro-industries have trickle-down effects on the community welfare by providing new livelihood opportunities. Young people adopt modern lifestyles.