Ain Shams University
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Climate Change-Resilient Productive Landscapes

An Assessment of Climate Adaptation for the Community of Cerro Negro, Nicoya, Costa Rica

A Thesis submitted in the Partial Fulfillment for the Requirement of the Degree of Master of Science in Integrated Urbanism and Sustainable Design

by

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07/29/2018

Disclaimer

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Abstract

In tropical dry-wet climates, the agricultural production of smallholder farmers is heavily threatened by climate change. In the specific case of the North Pacific region of Costa Rica irregular rainfall patterns and water scarcity related to the El Niño climate phenomenon, are affecting seasonal crop yields and jeopardizing the livelihoods and economic stability of remote rural communities. In order to broaden the understanding of the vulnerabilities and adaptation needs of these communities a study was conducted in the mountainous farming community of Cerro Negro in the canton of Nicoya. A vulnerability assessment was conducted with the farmers in order to characterize the vulnerability of the socio-ecological productive landscape, and to identify their existing adaptation strategies as well as their needs. The farmers are particularly vulnerable to water scarcity, temperature rise, and intense rainfall and wind, which affect the seasonal patterns of cultivation and diminish the agricultural production to a minimum. Several adaptation practices based on local and external knowledge are available to the farmers to reduce vulnerability and risk however, accelerated processes of youth migration, lack of financial resources, and lack of access to infrastructure and services seriously affect the overall adaptation capacity of the community. Increased external support, in the form of knowledge and resources, is needed to improve the resilient capacities of the community and secure their livelihoods for future generations.

Key words: dry-wet climates, socio-ecological productive landscapes, climate change, climate adaptation, climate vulnerability, agriculture, rural communities, Cerro Negro, Nicoya

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Figure 1: Farmers association advertisement before reaching Cerro Negro. Source: Author

Chapter 1: Introduction

According to data from the World Bank, in the year of 2014 rural areas still accounted for almost half of the world population including approximately 70% of the poor people in the developing world (IPCC 2014, p.616). The communities living in these areas are, not only known for their difficult socioeconomic situation, but as well for being the most vulnerable to the negative effects of climate change: According to IPCC'S Fifth Assessment Report (AR5) the "major impacts of climate change in rural areas will be felt through impacts on water supply, food security, and agricultural incomes" (IPCC 2014, p.616) which will put serious pressure on the resilience capacity of rural communities considering their high dependence on agriculture and natural resources for their livelihoods and income. Additionally, under-investment in agriculture, lack of incentive to the small producers, regional and international trade policies, processes of environmental degradation, as well as increasing rural-urban migration (IPCC 2014, p.616), are causing major negative economic transformations in these communities, and raising the discussion of the need to increase efforts and investments in the development of climate change-adaptation strategies for rural areas.

In tropical dry-wet climates, the agricultural production of smallholder farmers is heavily threatened by climate change. Irregular rainfall patterns and water scarcity due to increasing episodes of drought are increasingly affecting seasonal crop yields and jeopardizing the livelihoods and economic stability of rural communities in the global south. Falling into this category is the North Pacific of Costa Rica, a highly vulnerable region to climate variability and a cyclical drought phenomenon related to El Niño which is responsible for most of the socio-economic hardships currently faced by the agrarian sector. According to the United Nations University 70% of global food production is still taking place in small farms (UNU-IAS, 2013 p.5) and agricultural adaptation to climate change is identified as one of the major challenges for rural development that need to be considered in future development strategies of poor countries (UNIQUE 2013, p.6). This claim is supported by the 2030 Agenda for Sustainable Development which recognizes that “a healthy and dynamic agricultural sector” is the foundation of rural development, and an essential component for poverty eradication in a global scale (UN 2015).

The understanding of the vulnerabilities and adaptation needs of rural communities is a fundamental step required to develop successful climate adaptation strategies aimed at the empowerment of local communities through awareness raising and capacity building. Using the mountain rural community of Cerro Negro in the canton of Nicoya, Costa Rica, as a case study, this research aims at understanding the internal processes of change ongoing in remote rural communities of the North Pacific region of Costa Rica in the face of climate change. To achieve this, an assessment of the adaptive capacity of the productive landscape to the hazards of drought and seasonal weather phenomena was conducted following a semi-participative approach which involved the inhabitants of the community. The study is focused on documenting and assessing the performance of the agricultural practices used by the farmers, with a special emphasis on the practices based on traditional knowledge, in order to identify their relation with the overall adaptive capacity of the community. The final result is a set of recommendations which can be used as a reference to develop contextualized adaptation strategies in the future.

The first chapter of this thesis will be focused on giving an introduction to the research, starting with an overview of the topic and its relevance of study followed by a description of the main problem to be the tackled and the primary focus of the thesis. Finally, the methodology used to structure this research will be presented at the end of the chapter. Chapter 2 gives an insight regarding the current state of knowledge of the topics of climate change, rural resilience, climate adaptation and traditional knowledge. The main purpose of this chapter is to establish the theoretical base from which the research will be supported. Chapter 3 will be used to make a climatic and socio-economic characterization of the North Pacific region of Costa Rica departing from an understanding of its global, regional, and local context. The main purpose of this chapter is the development of a reference database for following chapters. Chapter 4 will be focused on making a characterization of the biophysical and socioeconomic systems of the community of Cerro Negro -focusing on the micro-watershed area- with the aim of developing a base of knowledge to be used in the assessment chapter.In chapter 5 a vulnerability assessment is conducted in order to identify the main climate-related hazards affecting the community, as well as the social groups and livelihoods which are more affected. In the second part of the chapter an adaptive capacity assessment is done based on the performance of the agricultural practices used by the farmers and the influence of the socioeconomic variables. Finally, in chapter 6, recommendations are given for the enhancement of the current and future adaptive capacity based on the findings of chapter 5.

1.1 Problem definition

Entire regions around the world are now being reshaped, seasonally and permanently, by the impact of unprecedented extreme climate events such as heat waves, wildfires, droughts, cyclones and floods, revealing how significantly vulnerable and exposed are many ecosystems and human systems to current climate variability (IPCC, 2014 p.6). Loss of biodiversity, scarcity and degradation of natural resources, food insecurity due to diminished productivity levels and general loss of livelihoods are some examples of environmental and socio-economic related issues that pose huge pressures on the capacity of resilience and development of many rural communities and its inhabitants. According to The World Bank climate variability and climate change threatens to interfere with, and even reverse, hard-earned poverty reduction and development gains (World Bank 2008, p.2) which is why “poor communities should be actively supported in efforts to strengthen resilience” (UN-HABITAT, 2014 p.6).

The increased attention in many scientific fields for the studies of interactions between humans and their environments along with the adoption of the Sustainable Development Goals (SDG), have stressed the importance of addressing the challenges to rural development in an integrated manner, and at a landscape level, considering its importance for socio-ecological production and resilience building (UNU-IAS, 2013). Moreover, there is a growing concern about the level of consideration that is given to the complex interactions between the complexity of landscapes and the role of local communities regarding specific rural issues (UNISCAPE, 2015 p.118), whereby the UNDP call for “approaches that combine a holistic view of rural landscapes, the communities and the ecosystems that comprise them, with an ability to address the combination of income, food security, environmental, and social issues that confront rural families” (UNDP, 2016 p.3).

According to the Intergovernmental Panel on Climate Change (IPCC): greater dependence on agriculture and natural resources is what makes rural areas "highly sensitive to climate variability, extreme climate events, and climate change" (IPCC 2014, p.618). This dependence however, has allowed rural people, over centuries, to develop a closer relationship with their landscape, giving them the capacity to adapt to changing environmental conditions, either through the development of farming practices, or through the use of wild natural resources. Today's shifting world puts at risk the stability of this rural people-landscape relationship as the speed and intensity of climate change outpaces the speed of autonomous adaptations and threatens to overwhelm the ability of poor rural people to cope (IFAD 2008, p.3).

Small farmers and rural communities of developing countries are the most vulnerable to this change. According to the International Fund for Agricultural Development (IFAD): "even a small increase in local temperatures could lead to reduced crop yields for those living at lower latitudes, especially in seasonally dry and tropical regions" while "more frequent and extreme weather events, such as drought and floods, are expected to make local crop production even more difficult" (IFAD 2008, p.3). Within these regions the Central American Dry Corridor is, according to the Food and Agriculture Organization, one of the world's most vulnerable to climate variability (FAO 2017), being affected periodically by the El Niño-Southern Oscillation phenomena (ENSO) in the form of seasonal droughts and tropical storms. The drought of 2014 and 2015 in particular, destroyed around 70% to 80% of the yields, affecting around 3.5 million people and intensifying the food security crisis of the region (OXFAM 2016).

External collaboration and the development of new strategies of climate adaptation is much needed for rural communities facing rapidly changing climate conditions. In the case of remote rural communities with limited access to external support and resources, this strategies should aim specially at building self-sufficiency and reducing external dependency. Within this framework, the reinforcement and revitalization of traditional knowledge based practices should be an integral part of the development process of rural communities and a valuable asset from which to capitalize on the identification of effective climate change adaptation strategies (World Bank, 1998 p.3). However, the search for new strategies of climate adaptation also opens a window to explore other approaches. For example the study of global climate zones and the exploration of climatic and cultural affinities between different regions of the world provides a good source of knowledge to turn to that has not been explored enough

In any case, the choice and design of any adaptation strategy or practice should be contextualized and sensible to the specific reality of each community. To achieve this, a prior understanding of the hazards and key vulnerabilities that affect each community, is fundamental before any attempt of taking action. In this sense, the use of climate vulnerability assessment methodologies constitute a highly efficient tool to get a better understanding of factors driving vulnerability within a community as well as their in-built adaptive capacity, based on local experiences of climate change, needs, resources, knowledge, and livelihood systems (IFAD 2016 p.50). Despite the growing body of knowledge related to the development and implementation of climate vulnerability assessment methodologies in rural communities all over the world, in Costa Rica there are very little documented cases of the application of this tool and even fewer cases addressing remote rural communities. As a result, there is limited information regarding their overall vulnerability to climate change and the adaptation mechanisms that have been developed internally by its inhabitants, based on their own traditional knowledge, to respond to the adverse effect of climate change and climate variability, that is worth studying and documenting.

1.2 Research questions

Following the aforementioned premises and using the community of Cerro Negro in Nicoya, Costa Rica, as my case study I will attempt to answer the following question:

‘Which are the linkages between the currently used agricultural practices based on traditional knowledge and the climate-adaptation capacity of Cerro Negro’s socio-ecological productive landscape?’

1.3 Research Aim and Objectives

Aim

The assessment of the adaptive capacity of Cerro Negro’s socio-ecological productive landscape, which will provide a set of recommendations aiming at the improvement of current and future adaptation capacities.

The results are oriented for the use of the inhabitants of Cerro Negro, the inhabitants of other mountain rural communities facing similar challenges, and as a reference for any entity interested in the development of future climate adaptation strategies.

Objectives

-To identify the main climate hazards affecting the livelihoods of the inhabitants of Cerro Negro
-To assess the performance of the climate-adaptation practices currently used by the community: locally and externally based.
-To identify climate adaptation practices currently used in the community which were transferred from traditional knowledge of other regions of the world, in order to prove the possibility of developing transferability mechanisms between Cerro Negro and other regions sharing commonalities in the future.

1.4 Research Methodology

The methodology of this research is divided into four main steps, each one with a corresponding outcome or milestone which helped to verify the correct progression of the research process:
-*Research base:* This is the backbone of the research, the accomplishment -or not- of the aim and objectives established in this step determines the success of the research. The main outcomes of this step are the definition of a research structure that will serve as a guide for the following stages, the selection of a case study, as well as the development of the theoretical framework from where the main concepts and theories used in the research will be extracted. The content of this stage will be divided between chapters 1 and 2 of this thesis.
-*Data collection*: The aim of this step is the collection of all the data and information that will be needed to answer the research question and accomplish the aim of the research. The data collection process is divided in two parts: A desk research part and a field research, which include institutional visits and the visit to the site of the selected case study. The field research is one of the most delicate parts of the research as the quality of primary data obtained is determined by the clarity of the researcher regarding the informationrequired and the methods of data collection selected. The content of this step will be divided between chapters 3 and 4.
-*Data processing*: This is the assessment step. The database obtained in the data collection step is tested using different participatory and non-participatory methods of evaluation. The final outcome of this step will be the assessment of the adaptive capacity of the community of Cerro Negro to the hazards identified in the vulnerability assessment step. Until this stage the majority of the aims and objectives of the research shoul have been completed. The content of this step will be unfolded in chapter 5.
-*Proposal:* Include a set of recommendations aimed at improving the

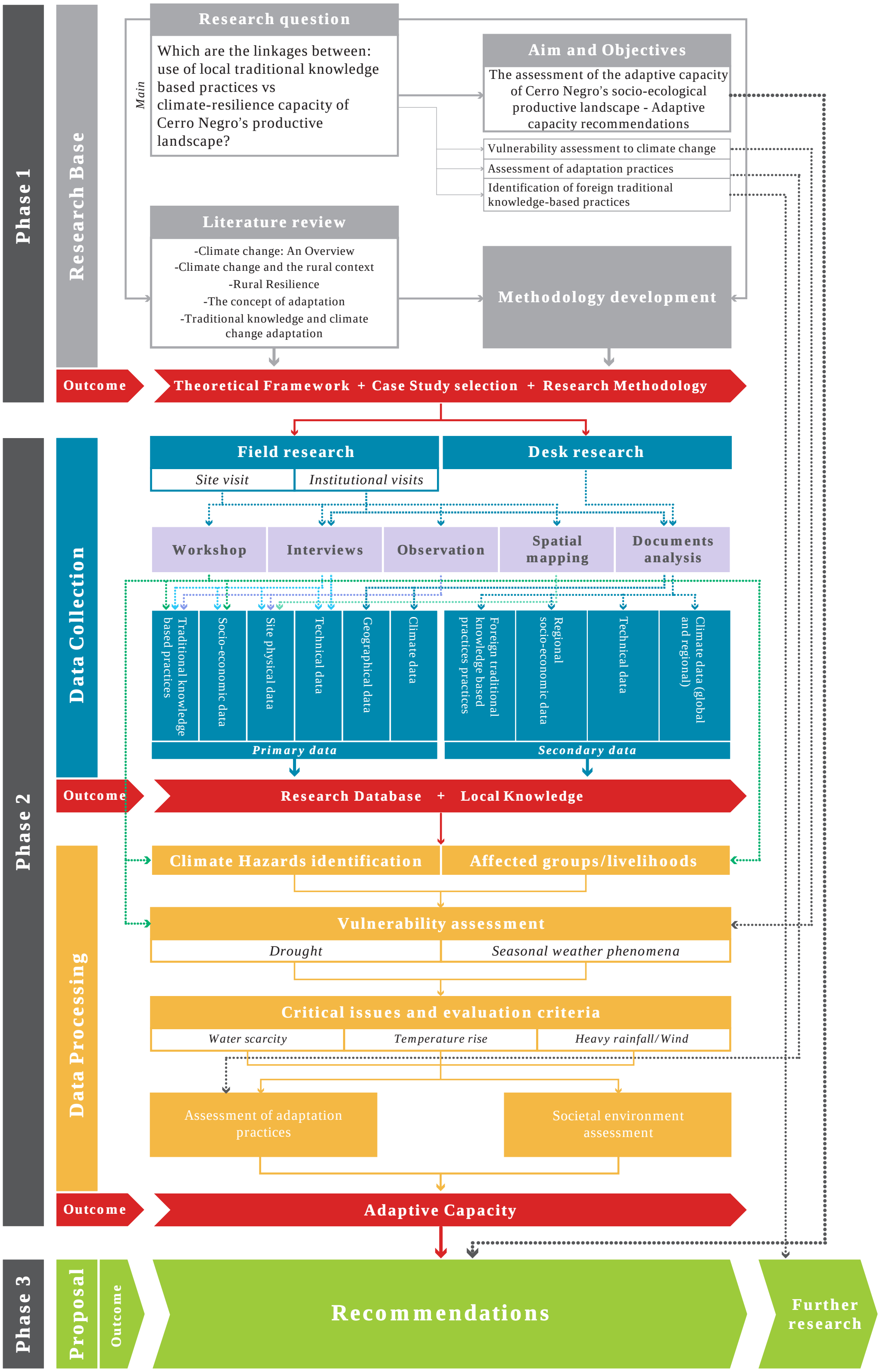


Figure 2: Research methodology diagram. Source: Author

assessed adaptive capacity as well as further recommendations related to the accomplishment of the third objective of the research. The content of this step will be unfolded in the last chapter of the thesis.

Figure 3: Mountains of Nicoya. Source: Author

Chapter 2: Theoretical Framework

2.1 Climate Change: An Overview

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods of time" (United Nations 1992, p.3). Usually described as anthropogenic climate change, this type of change is characterized by a rapid and abrupt climate transformation that contrasts heavily with the natural climate variability not only for the pace at which it occurs, but also for the impact it has on human and natural systems all across the globe. The human influence on the planet's climate is not new and that it dates from millennia ago however, it is in recent decades that the evidence of human related climate-change impacts has become strongest and more palpable in the form of increasingly frequent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires (IPCC 2014, p.6).

Increased average global temperature due to greenhouse gas emissions is almost universally pointed out as the main cause behind the anthropological climate change that characterizes this era and will continue to do so way past the end of this century. According to the Intergovernmental Panel on Climate Change (IPCC) "cumulative emissions of CO2 largely determine global mean surface warming by the late 21st century and beyond" and it will require not only substantial but also sustained reductions of greenhouse gas emissions in order to limit the speed and impacts of global climate change (IPCC 2013, p.1029). As the magnitude of warming increases so it will do the likelihood of "severe, pervasive and irreversible impacts" (IPCC 2014, p.14), even the most optimistic low-emission mitigation scenario (RCP2.6), which projects a temperature increase between 1 or 2°C above preindustrial levels, poses considerable risks to a high number of unique and threatened systems (ecosystems and cultures), especially to those with limited adaptive capacity (IPCC 2014, p.14) (See figure 4).

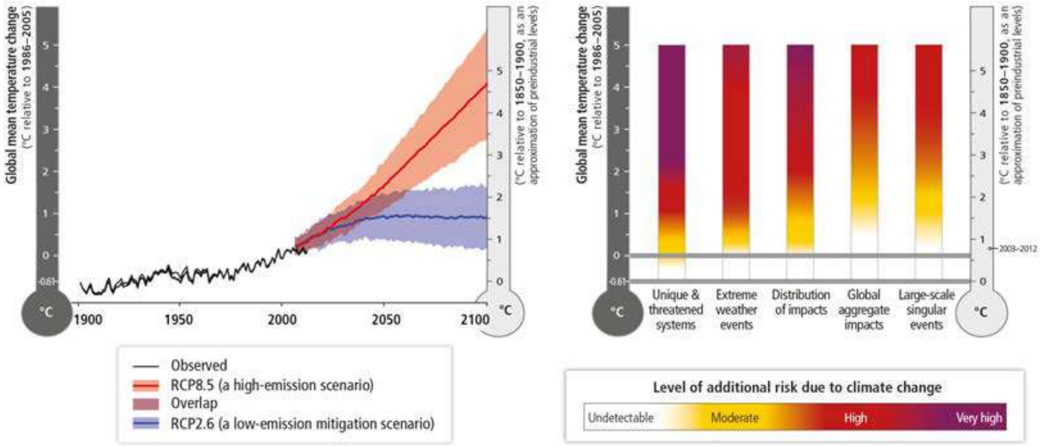


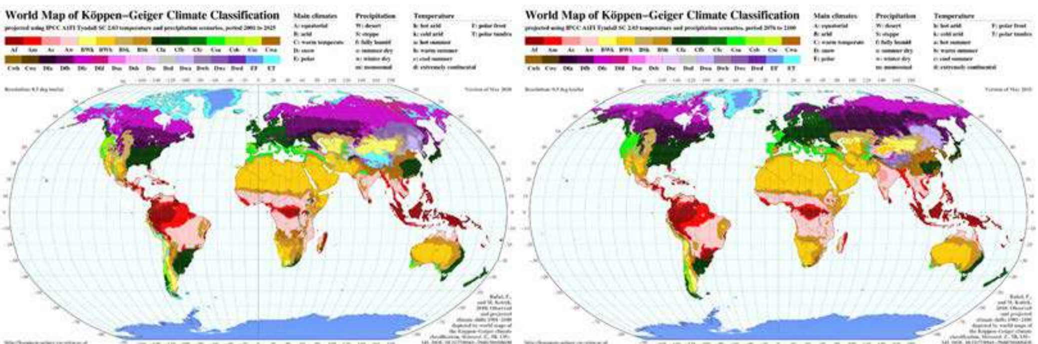
Figure 4: Relation between global warming and increased risk due to climate change. Source: IPCC 2014

According to the German Corporation for International Cooperation (GIZ): "Climate change is one of the key future challenges for both developed and developing countries. With a growing world population, rising demand for food, water and energy and a dwindling natural resource base, climate change will act as a threat multiplier, aggravating resource scarcity and putting further stress on socio-ecological systems" (GIZ 2015, p.12). The level of threat however, is not equal for all: despite the fact that industrialized countries are the main producers of greenhouse gas emissions, poor and marginalized people from developing countries are the most threatened by current climate variability and future climate change. According to IPCC, these differences of exposure and vulnerability originate from non-climatic factors and multidimensional inequalities that are often the product of 'intersecting social processes' (IPCC 2014, p.6) and uneven development processes which end up shaping dissimilar risks (IPCC 2014, p.40). Several treaties and international conventions address the urgency for climate action and more and more governments around the world are making strong commitments to reduce their carbon footprint through ambitious short and long term environmental strategies. Certainly mitigation through the reduction of greenhouse gas emissions is an effective way to lessen the adverse effects of climate variability and climate change however, as aforementioned, even in the best projected emission scenarios it is impossible to "completely prevent significant changes in the world's climate" (BMZ 2015, p.12). Therefore, it is fundamental that, at the same time, societies and economies worldwide –with an emphasis on the case of developing countries- prepare themselves and double their efforts to adapt to the potential impact of climate change.

Through the analysis of historical data and the modelling of future climate scenarios, several studies published in 2013, confirmed the existing links between climate change and the shift of climate types around the globe (Chen et.al 2013, p.71). By using the Köppen-Geiger climate classification system[1] as a base, these studies projected "large shifts in the world distribution of climate zones by the end of this century" and suggested a direct correlation between the pace of shifting climate zones and the rise of global temperature (Mahlstein et.al 2013, p.739). According to this study under the RCP8.5 high-emissions scenario "the pace nearly doubles by the end of this century and about 20% of all land area undergoes a change in its original climate" (Mahlstein et.al 2013, p.739). Which implies exponentially less time for adaptation of human and natural systems to Köppen zone changes in the future and with it an increased risk of extinction (Mahlstein et.al 2013, p.739) (See figure 5).

Over the recent years it has emerged a growing interest in the scientific community in using climate classification systems to identify changes in climate and potential changes in vegetation over time (Chen et.al 2013, p.69), since they add a new dimension to the description of climate change by considering more climate variables, when compared to the most traditional approaches which often describe climate change using a single variable (e.g temperature). In the case of the already mentioned Köppen-Geiger classification system, the reviewed literature show the potential of using the system as a diagnostic tool to monitor changes in the climatic condition at a global scale (Chen et.al 2013, p.69), but reveal its limitation to be used equally useful in a smaller scale, as the main variables measured by the system –temperature and precipitation- exclude other climate variables needed to understand the characteristics and behavior of particular climates on a more regional or local scale.

Analyzing the case of tropical and sub-tropical regions, the Holdridge Life Zones



2001-2025 2076-2100

Figure 5: Projected climate zone distribution of the years 2001-2025 vs 2076-2100 under a high-emission scenario . Source: http://koeppen-geiger.vu-wien.ac.at/pics/kottek_et_al_2006.gif

system proved to be a more comprehensive system to describe specific local climate types and its variations. By using life zones[1] as the main unit of classification, this system allows a deeper understanding of how different ecosystems react to certain climatic conditions by considering several variables, such as average biotemperature, average annual precipitation, potential evapotranspiration ratio, humidity as well as altitude (Sapta et.al. 2015, p.167). The measurement of this variables allows to predict potential vegetation types that can grow better in certain regions and under specific climatic conditions (Sapta et.al. 2015, p.167), making it highly applicable in assessing changes of natural vegetation patterns due to global warming (Leemans 1990). In rural contexts, this feature can be greatly beneficial for agriculture as it allows the selection of the most suitable areas for specific crops, as well as the development of prevention measures to reduce environment degradation and ecological impact caused by farming activities (CCAD 2011, p.44).

The reviewed literature stresses on the importance of climate classification systems as a monitoring tool to depict climate variation and climate change on a global, regional and local scale and its impact on human and natural systems. These analysis can provide useful information which can be the base for the development of environmental measures and climate change related policies. According to Chen et.al "while the spatially stable climate regions identified are useful for conservation and other purposes, the unstable regions mark the transition zones which deserve special attention since they may have implications for ecosystems and dynamics of the climate system" (Chen et.al 2013, p.78). In most of the consulted literature however, a bigger emphasis is given to trying to understand the underlying processes behind the shift of climate zones that to trying to understand its consequences. Moreover, there is a lack of literature addressing the existing link between the unstable/transition regions that result as a product of the shift of climate zones and the processes of climate adaptation of vulnerable human groups living in such regions.

2.2 Climate Change and the rural context

By 2014 rural areas still accounted for almost half of the world population, and approximately 70% of the poor people in the developing world (IPCC 2014, p.616). People living in rural areas in developing countries are generally the more vulnerable to the negative consequences of climate change due to a number of factors that include, high dependence on agriculture and natural resources for their income, food security and livelihoods, risky geographical locations and low adaptive capacity (IPCC 2014, p.617). According to IPCC's AR5 the "major impacts of climate change in rural areas will be felt through impacts on water supply, food security, and agricultural incomes" (IPCC 2014, p.616). In addition, rural people in developing countries are subject to many stressors not related to climate such as under-investment in agriculture, lack of incentive to the small producers, problems with policies related to land and natural resource management, as well as processes of environmental degradation, that compromise their adaptation capacity (IPCC 2014, p.616).

Rural areas are, arguably, the spatial unit in which transformations associated with climate change will be more palpable. A speeding globalization, product of migration, urban-rural labor linkages, regional and international trade policies, and new information and communication technologies, is causing major economic transformations (IPCC 2014, p.616) which are raising the discussion of the need to increase investments in climate change-adaptation for rural areas. Agricultural adaptation in particular, is identified as one of the major challenges for rural development that need to be considered in future development strategies of poor countries (UNIQUE 2013, p.6), after all, according to the United Nations University (UNU), in 2013, 70% of global food production was still taking place in small farms (UNU-IAS, 2013 p.5), and the current demand of food from a growing urban population is increasing exponentially. The dynamic nature of rural areas is viewed by the scientific community as an opportunity to assess climate change and the possibilities for adaptation. This, is supported by a growing body of literature on adaptation practices that document practical experiences in agriculture –as well as water, forestry and biodiversity- in both developed and developing countries, at the same time that calls for a major involvement of practitioners in the climate change-adaptation processes of rural areas (IPCC 2014, p.616).

2.3 Rural resilience

Drawing an analogy with urban resilience, Heijman et.al define rural resilience as "the degree to which a specific rural area is able to tolerate alteration before reorganizing around a new set of structures and processes" (Heijman et.al. 2007, p.383). Despite some variations in terminology, all the consulted literature agree on the fact that resilience is not based on a single factor and instead is dependent on the system's ability to cope with its inherent economic, social and environmental vulnerability simultaneously (Mc Manus et.al. 2012, p.22) (see Figure 6). This inter-relationship means that changes in one factor can affect

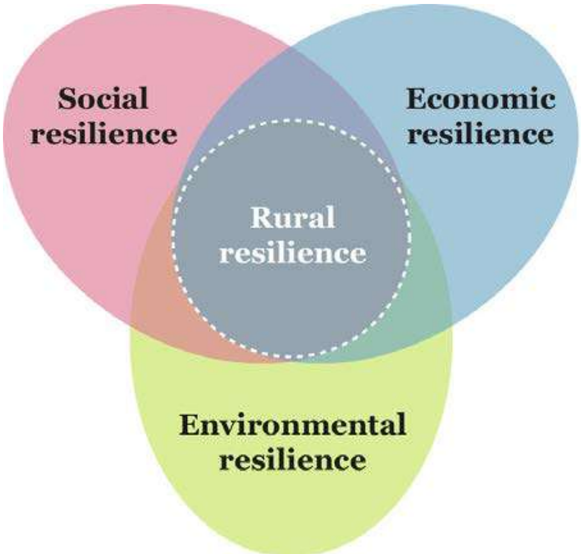


Figure 6. Rural resilience components. Source: Author based on Heijman et.al. 2007

resilience in other factors (Heijman et.al. 2007, p.385) which in turn indicates that for rural communities to be "resilient in economic, social and environmental terms, they need to develop strong multifunctional characteristics" (Wilson 2010, p.368).

According to Sánchez et.al community resilience is focused on the collective capacity of the members of a community to adapt to change caused by internal and external shocks, this could be slow and progressive (e.g. withdrawal of public services from governmental institutions), or sudden, such as the ones related to climate events (e.g. hurricanes or floods) (Sánchez et.al 2016, p.103). In the case of rural communities the term socio-ecological productive landscape (SEPL's) is a term used to describe production landscapes characterized by high levels of resilience, that are the product of generations of harmonious interactions between rural communities and nature in which "a strongly interlinked set of traditional practices and production activities have been adapted and transformed to maintain and improve the community's well-being while absorbing shocks to the system" (UNU-IAS, 2013 p.10).

SEPL's today are a testament of how rural community resilience to past threats and crisis however, current pressures associated to climate change, accelerated globalization and unprecedented rates of rural to urban migration are compromising the capacity of absorption and adaptation of these systems to shocks and stresses (UNU-IAS, 2013 p.10). According to UNU, "fundamental changes to SEPLs have the potential to unbalance customary sustainable use processes, leading to decreased resilience and increased vulnerability" (UNU-IAS, 2013 p.10). Therefore, a better understanding of the components of resilience is needed as well as immediate action "to manage the existing and future risks within the framework of broader understanding on the most likely impacts of climate change" (Baas et.al. 2008, p.iii). Such process should aim to the empowerment of local communities through awareness raising and capacity building, giving them the tools to understand their own resilience by recognizing "negative trends and potential opportunities for further strengthening resilience" (UNU-IAS, 2013 p.10). Nonetheless, without first comprehending the vulnerabilities and adaptation processes that unfold within the rural context, the aforementioned is certainly an impossible task.

2.4 The concept of adaptation

According to GIZ, adaptation to climate change refers to "a process of adjusting to actual and expected climatic changes, or to the effects of climate change on social and ecological systems" which "aims to moderate harm to human well-being associated with those changes, and to exploit potentially beneficial opportunities" (GIZ/WRI 2011, p.11). Adaptation is becoming embedded in the planning and development process of many governments around the world as they become aware of the threats related to climate change (IPCC 2014, p.8) however, there is no recipe for adaptation as needs vary considerably between regions, people and sectors. Which means that priority should be placed on the development of strategic adaptation plans that address the most affected systems in an effective way. For this, the concept of 'vulnerability' can help practitioners understand "what lays behind adverse climate change impacts and also to identify hotspots that are most susceptible towards climate change" (GIZ 2015, p.18). Furthermore, the conducting of a vulnerability assessment is a highly recommended to identify and prioritize adaptation interventions in any given context.

2.4.1 Climate change vulnerability

The concept of climate change vulnerability allows a better comprehension of the relationship of cause and effect between climate change and its impact on people, economic sectors and socio-ecological systems (GIZ 2015, p.20). Even though there are a multitude of vulnerability definitions with their own terminology, for this research, I will refer to the definition provided by the Fourth Assessment Report of the IPCC (AR4), which defines vulnerability as "(...) the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC 2007, P.6). Based on this definition, exposure, sensitivity, potential impact and adaptive capacity are identified as the key components that determine whether, and to what extent, a system is susceptible to climate change (GIZ 2015, p.19) (See figure 7).

'The Vulnerability Sourcebook' (GIZ 2015, p.21-22) describe each component as follows:

Exposure: The stressor, directly linked to climate attributes, such as its character, magnitude, and rate of change and variation. Precipitation, temperature and evapotranspiration are typical exposure factors as well as extreme events such as drought or tropical storms.

Sensitivity: The extent to which a system is affected (adversely or beneficially) by a given climate change exposure. It is shaped by natural/physical attributes of the system as well as by the social environment.

Potential Impact: It results from the combination of exposure and sensitivity. For example, heavy rains (exposure) in combination with flat areas close to water bodies (sensitivity) might result in flooding (potential impact).

Adaptive Capacity: The ability of a system to adjust to climate change, lessen potential damage and cope with the consequences. It is also related to the "set of factors which determine the ability of a system to generate and implement adaptation measures" such as the availability of resources and the socio-economic, structural, institutional

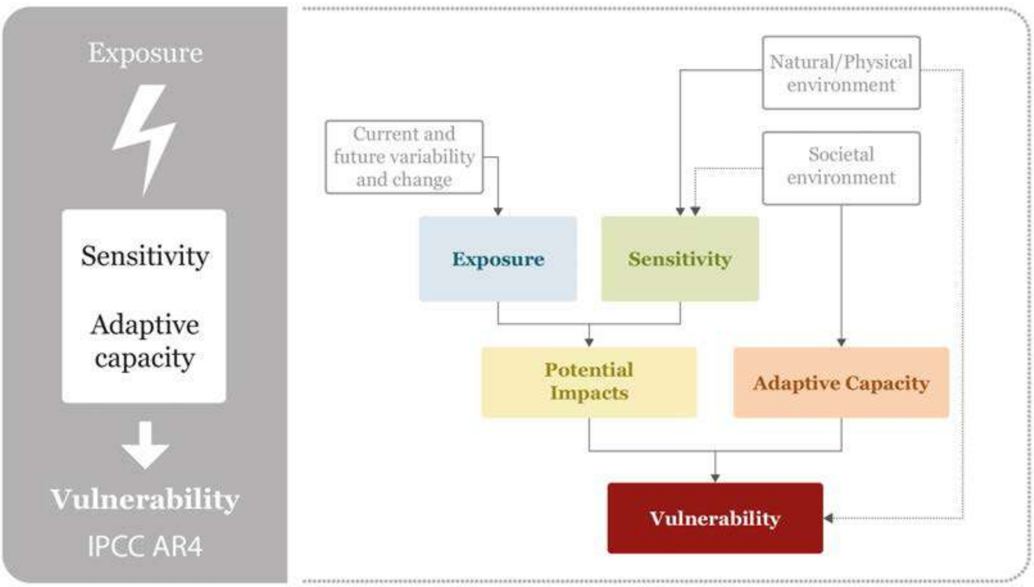


Figure 7: Key components of Vulnerability. Source: Author adapted from Adelphi/Eurac 2014

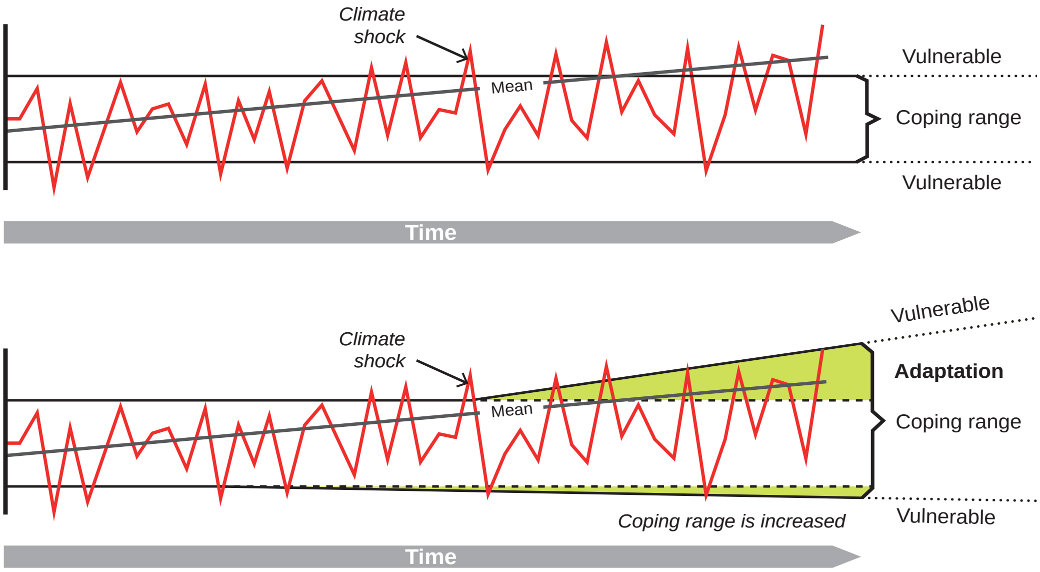


Figure 8: Adaptation measures can increase the coping range of different systems. Source: Author adapted from FAO 2012

and technological characteristics and capacities of human systems (GIZ 2015, p.22). Improved adaptation is believed to be the best way to reduce vulnerability and increase system resilience. Experiences of climate adaptation interventions in all continents have shown a good degree of success reducing climate change vulnerability at national, regional and at community levels. These interventions, which can go from the introduction of irrigation techniques to overcome water scarcity to the improvement of tillage systems to fight soil erosion (GIZ 2015, p.24), aim at lowering sensitivity to climate exposure. More importantly however, is the fact that they can also target the increase of adaptive capacity from within communities by building new knowledge and capacities which, is a building block needed to address the "urgent and immediate needs" of developing countries (United Nations 2016, p.7) (See figure 8).

2.5 Traditional knowledge and climate change adaptation

Traditional, or indigenous knowledge, understood as the "knowledge and know-how accumulated across generations, which guide human societies in their innumerable interactions with their surrounding environment" (Nakashima et.al, 2012 p.29), has for millennia demonstrated an 'inherent dynamism' originated from the ability of indigenous people to adjust and modify in response to environmental change (IFAD, 2016 p.5). Through extended processes of recollecting information, testing and application, indigenous people have been able to overcome risks and impacts associated to climate variability and extremes through millennia in a sustainable way.

The value of traditional knowledge in relation to climate change has been increasingly acknowledge in the past decades by international institutions and the scientific community. The International Fund for Agricultural Development (IFAD), recognize the importance of traditional knowledge as a source of climate history and baseline data that can complement “conventional science and environmental observations” (IFAD, 2016 p.7), as well as the role of traditional innovations and practices on supporting the social well-being and sustainable livelihoods of rural poor communities (IFAD, 2016 p.50). In the same line, the United Nations, recognizes “the need to strengthen knowledge,technologies, practices and efforts of local communities and indigenous peoples related to addressing and responding to climate change” (UN 2015, p.19), and urges to establish a platform for the documentation and exchange of effective climate change adaptation and mitigation measures based on traditional knowledge.

Along with rapid modernization and changes in lifestyle, accelerated climate change is one of the aspects that poses the biggest challenges for the preservation of traditional knowledge as its exposing communities to unknown climatic conditions for which their traditional knowledge becomes worthless. Addressing this aspect Shaw et.al stresses on the importance of transferability as a viable option to reduce disaster risk and enhance adaptation capacity. According to his premise, “communities that have developed local practices to cope with certain conditions over time, such as drought or flood, can provide lessons and strategies for other communities newly facing these conditions“ (Shaw et. al., 2009 p.5). This process, he concludes, needs to be done considering the commonalities between communities, “if the two groups face similar risks and have similar contexts, then knowledge is more likely to be transferred” (Shaw et. al., 2009 p.10).

Regarding the current relevance of knowledge transfer, the World Bank stresses on the need to learn, preserve and exchange indigenous knowledge due to its importance as a key element of the ‘social capital’ of the poor, and urges its integration into the development process of developing countries. Finally, it states that the process of knowledge exchange should take place, not only between developing countries, but also from developing countries to industrialized countries in order to break the unidirectional nature of current knowledge transference (World Bank, 1998 p.3).

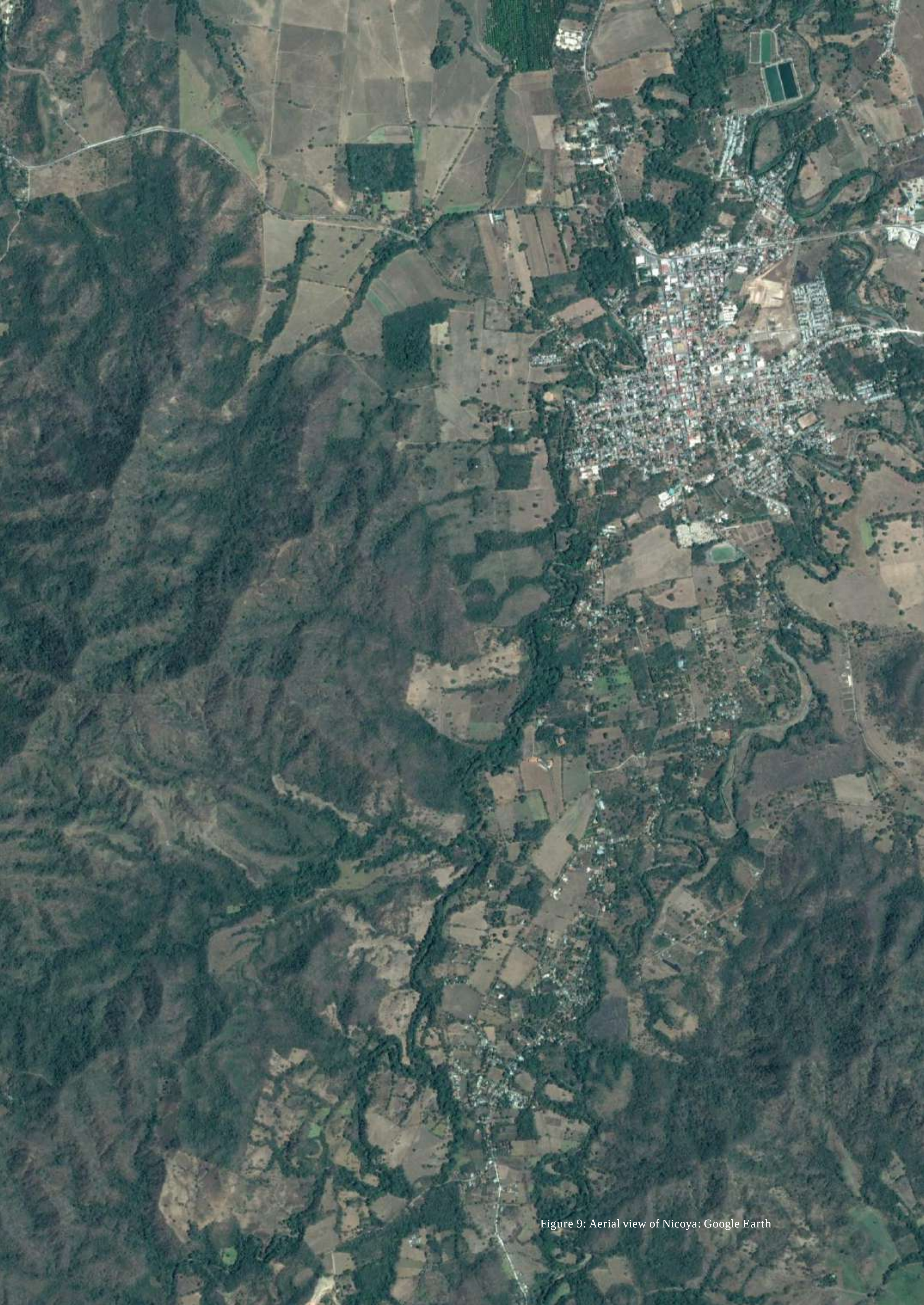


Figure 9: Aerial view of Nicoya: Google Earth

Chapter 3: The Context

3.1 Introduction

Costa Rica's geographical location, its abundance of natural resources and the presence of a tropical climate without thermal seasons, has allowed the flourishment of a rich agricultural tradition that represented the base of the country's economy even before the colonial period in the 16th century (Molina et.al 2011). It is until the decade of 1980, due to internal and external economic factors, that the agro-exporting model, which lasted for 100 years, transitioned into the current service-based economy and paved the way to a progressive disappearance of the farmer class and an accelerated sprawl of urban areas that remains until today. Despite its decline, the agricultural sector still plays an important role in the country's economy, making approximately 6.5% of the total GDP (Trading Economics 2018) and employing around 12.9% of the country's labour force (Statista, 2018). Today, small farmers and rural communities of Costa Rica face challenges associated with climate change and variability that compromise the preservation of their livelihoods and their resilience capacity. Among these, the communities located in the North Pacific region are, arguably, the most vulnerable ones due to their geographical location and socioeconomic reality. The purpose of this chapter is to develop a climatic and socio-economic characterization of the North Pacific region of Costa Rica departing from an understanding of its global, regional, and local context.

3.2 The climate in Costa Rica

According to the Köppen-Geiger's climate classification Costa Rica's climate belongs to the type A (equatorial) which are described as Tropical Moist Climates. They extend in a nearly unbroken belt around the Earth northward and southward from the equator to about 15° to 25° of latitude (Pidwirny, 2006). Due to their global location in a region of the globe in which available net solar radiation is relatively constant from month to month these climates present average temperatures above 18 °C [64 °F], a virtual absence of thermal seasons (Britannica, 2009) and annual precipitations greater than 1500 mm (Pidwirny, 2006). The A group in turn is subdivided into four minor climate types based on seasonal distribution of rainfall (Kottek et.al 2006, p.260) (see Figure 9).

Costa Rica's tropical climate is modified by the interaction of different geographic, atmospheric, and oceanic local factors which in turn, are the main criteria used by the National Institute of Meteorology of Costa Rica (IMN) to define the country's climatic regionalization (IMN 2008, p.8). A first division is made based on the northwest-southeast orientation of the mountainous system which divides the country into two slopes: Pacific and Caribbean, each one with its own precipitation regime and temperatures with particular characteristics of spatial and temporal distribution (IMN 2008, p.8):

-The Pacific regime: characterized for having two very well defined seasons: a dry season that goes from December to March –with April as a transition month-. And a wet season that goes from May to October –with November as a transition month-(IMN 2008, p.10).

-The Caribbean regime: does not present a well-defined dry season due to the fact that even during the driest months there is still a considerable amount of rain which ranges from 100-200 mm (IMN 2008, p.9).

Departing from this separation of precipitation regimes, seven main climatic regions are established based on the altitude and orientation of the mountains,

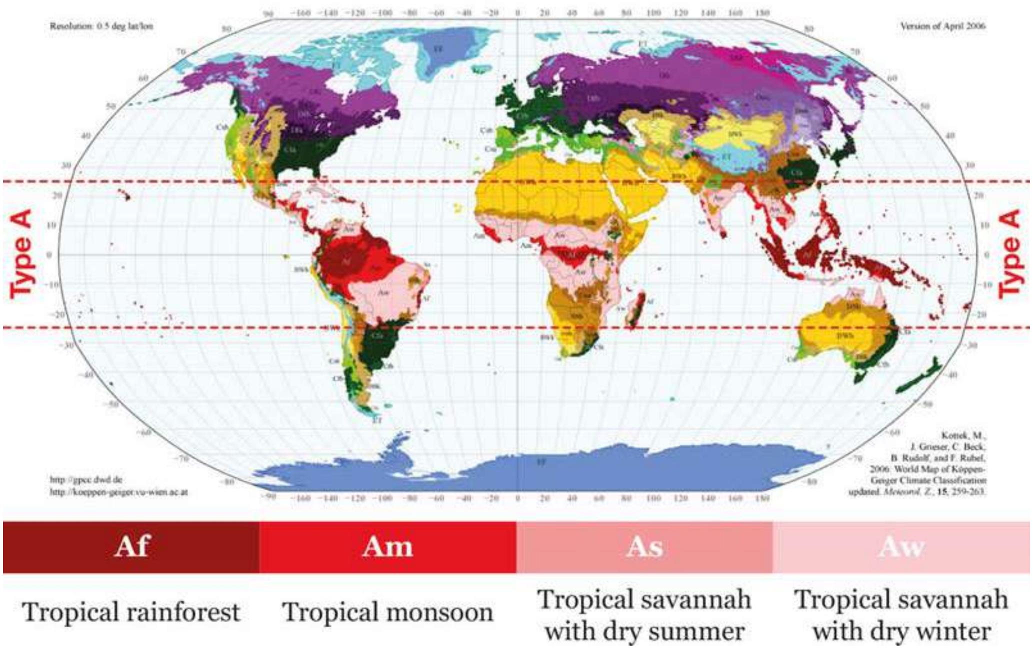


Figure 10: Köppen-Geiger Climate Classification: Type A . Source: http://koeppen-geiger.vu-wien.ac.at/pics/kottek_et_al_2006.gif modified by the author

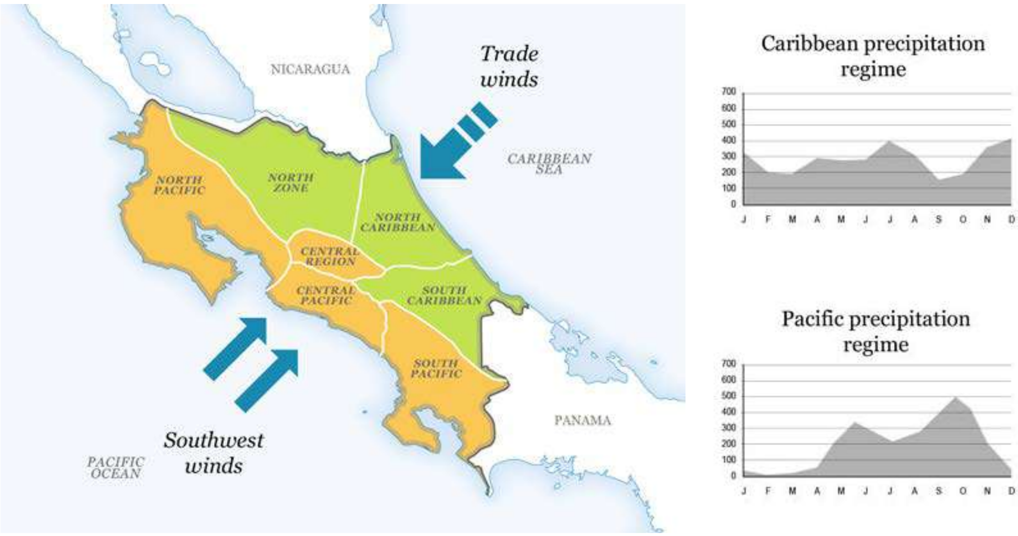


Figure 11: Climate regions of Costa Rica. Source: Author adapted from the National Meteorological Institute of Costa Rica 2008

the predominant wind and the ocean influence: North Pacific, Central Pacific, South Pacific, Central Region, North Zone, Northern Caribbean Region and Southern Caribbean Region (IMN 2008, p.10) (See figure 10). Moreover, each one of the regimes determine the susceptibility of each region to different climate extremes: while the regions in the Caribbean regime are more susceptible to tropical cyclones between the months of May and November, the regions in the Pacific regime are more susceptible to extended dry periods specially in the North Pacific region (IMN 2008, p.11)

3.2.1 Climate change in Costa Rica

There is clear evidence of the current effects of climate change on different natural systems all around the country (coastal, forestry, biodiversity, etc) which is supported by scientific data. In a local report on climate change published by The National Meteorological Institute of Costa Rica (IMN) in 2011, based on historical data from the years 1961 to 2006, significative changes in temperature and -especially- in precipitation that exceed the standard deviation, were identified in different parts of the country (IMN 2008, p.53): while an increase of rainfall was detected in the South Caribbean region, an important disminution of rainfall has been happening in the North Pacific region (IMN 2008, p.54). Additionally, an increase in frequency of extreme climatic events (dry and rainy) events was identified with an increased number of hurricane episodes related to the ENSO phenomenon (IMN 2008, p.54).

Regarding future climate change, two local studies conducted by the IMN have made projections of how changes in temperature and precipitation will affect each one of the climate regions by the end of the century under different emission scenarios. One of these studies concludes that, while there will be a reduction of rainfall in the northern part of the country, the opposite will occur in the southern part leading to a climate exposed to dry and rainy extreme events (IMN 2008, p.68). Both studies however, agree on pointing out the North Pacific as the region that will be most affected by rainfall scarcity with predictions of up to 56% of decrease in annual rainfall (IMN/MINAET 2012, p.29) (See figure 12). Finally, this is confirmed by another study which, as well, categorizes the North Pacific as a region highly vulnerable to future water scarcity, identifying the cantons of Santa Cruz, Nicoya and Carillo as highly critical due to their low human development index, low water availability, and high percentage of disabled population (IMN/MINAET 2011, p.72).

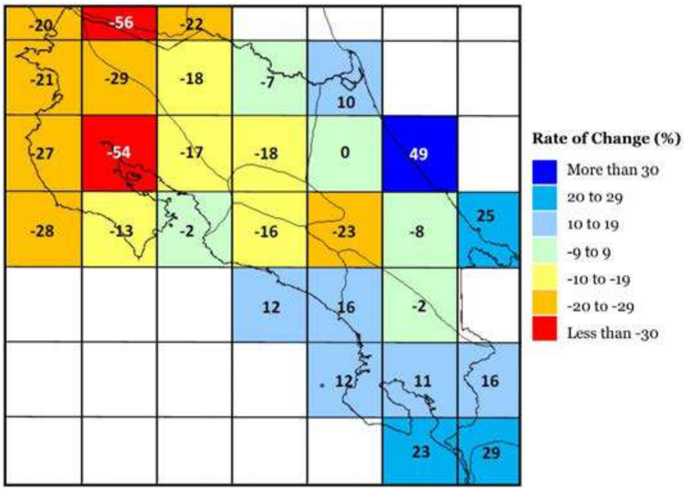


Figure 12: Climate change scenario for rainfall in Costa Rica. Source: IMN 2008

Finally, Jimenez et.al, using the Holdridge life zone map as a base, projected future scenarios with the purpose of determining possible changes in the geographical distribution of Costa Rica's life zones due the global rise of temperature (Jiménez et.al 2009, p.1). According to the projections, for the year of 2020, there will be a considerable shift of the position of the life zones, with the major change being observed in the North Pacific region, where the tropical dry forest will expand its area by displacing the wet tropical forest for both A2 and B2 emissions scenario (Jiménez et.al 2009, p.5) (See figure 13).

The current and projected climate situation of the North Pacific shows a vulnerable region which will be greatly affected by temperature change and water scarcity in future years which demands immediate attention. According to the IMN: "regions that already show a clear tendency to change and which future projection indicates a reinforcement of such tendency, should be constantly monitored and prioritized for the design of adaptation strategies" (IMN 2008, p.8). Based on this affirmation and the findings of the aforementioned studies,

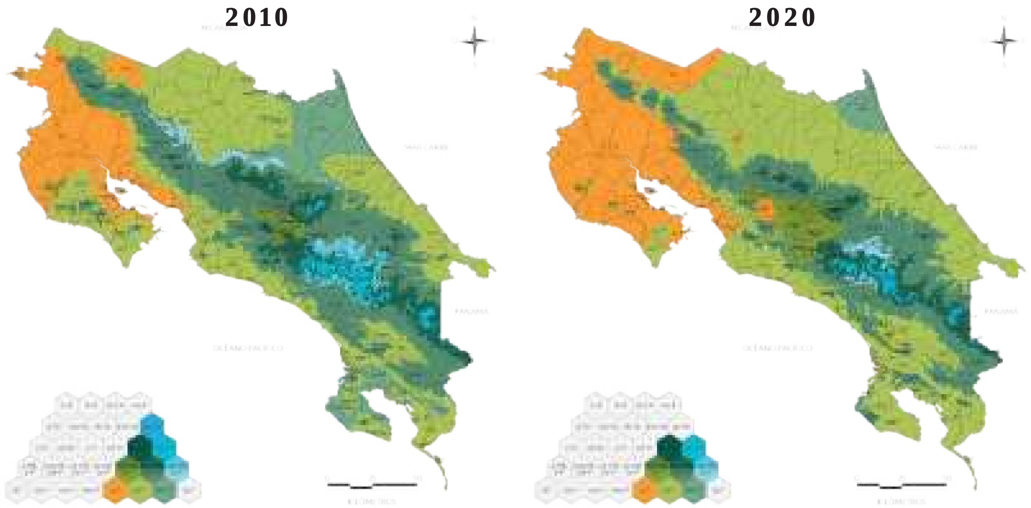


Figure 13: Projected scenarios of the Holdridge life zone distribution for the year of 2020 . Source: University of Costa Rica 2018

this research will be focused on the study of the North Pacific region, with special emphasis on the characterization of the productive communities that live within its boundaries.

3.3 The North Pacific region

Before starting to characterize the North Pacific region it is important to conceptualize it as a part of a bigger regional unit called the Central American Dry Corridor (CADC) (See figure 14) which is composed by several other regions that not only share climate, socioeconomic and cultural characteristics but also face common climate change-related challenges. This corridor, which stretches

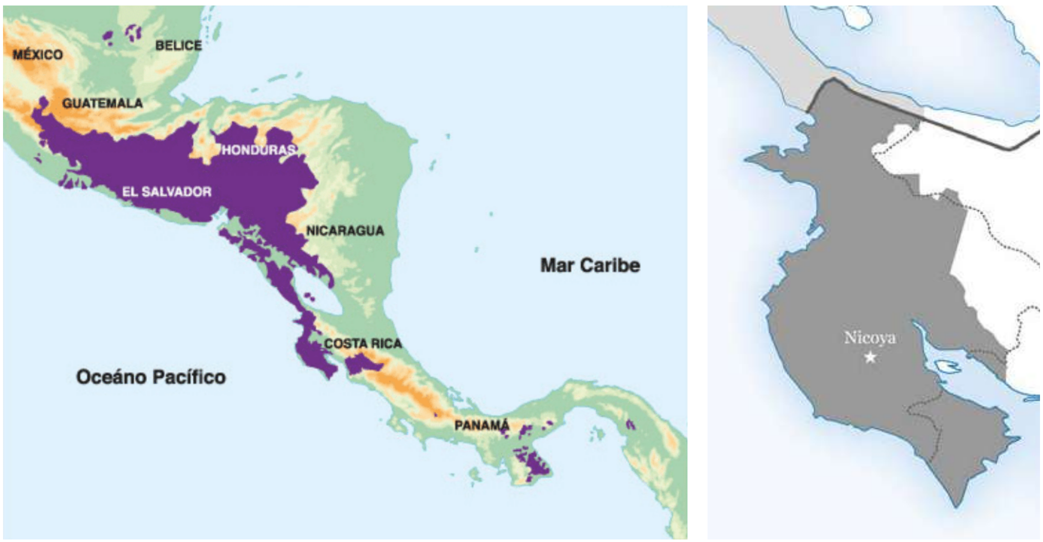


Figure 14: The Central American Dry Corridor and the North Pacific region. Source: http://ojoalclima.com/america-central-busca-400-millones-blindar-zonas-mas-aridas-del-cambio-climatico/corredor-seco/

along the Pacific coast of Central America, from Chiapas, in Mexico, to some of the western provinces of Panama (FAO 2017), is mostly delineated by the Tropical Savannah climate (Aw) which determines the climatic pattern of the entire region in two distinct wet and dry seasons. The region is characterized by its agricultural activity -one tenth of its population are small producers of basic grain crops- but also for its high levels of poverty (FAO 2017). The main characteristic of the CADC however, and the reason of its name, is that it has a cyclical drought phenomenon -closely related to the El Niño-Southern Oscillation climate phenomenon (ENSO), that periodically hits the region and which is responsible for most of the environmental and socio-economic issues that affect its inhabitants (FAO 2012, p.8). In the year 2017 the Food and Agriculture Organization of the United Nations (FAO) categorized the CADC as "one of the most susceptible regions in the world to climate change and variability" (FAO, 2017).

3.3.1 Climate characteristics

From all the regions under the Pacific regime, the North Pacific region is the one which presents the most extreme variations of precipitation between the dry and the wet season being consistent with the Tropical Savannah climate (Aw) that predominates in the region. During the dry season (from December to March) just 4% of the total annual rainfall is registered, being common the cases of months in which 0 millimetre of rain are measured. The remaining 96% of rain falls through the rest of the year including not only the wet season (May to October) but also the transition months (April and November). This period of rain -which reaches its peak in September and October- is divided in two periods which are separated by an intermediate dry period known as the Mid Summer Drought (MSD) in the month of July (IMN 2008, p.11) (See figure 15).

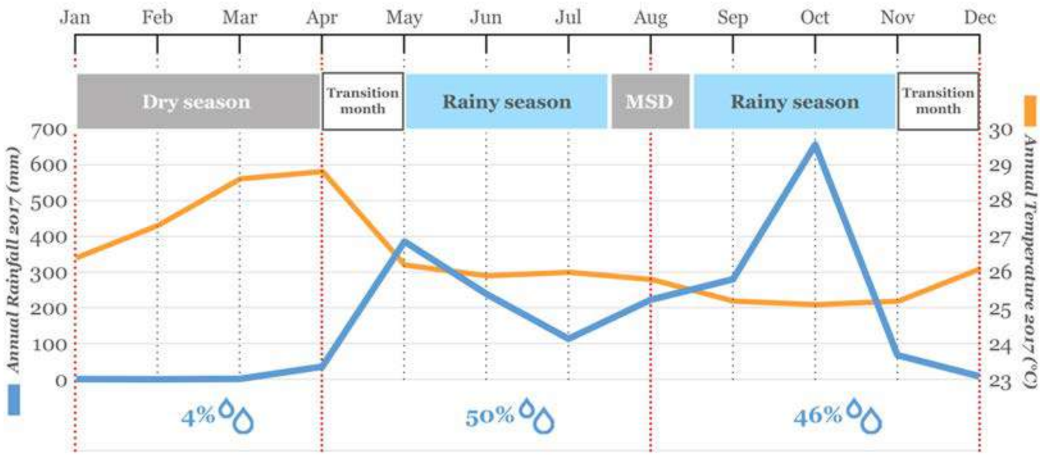


Figure 15: Distribution of seasons in the North Pacific region . Source: Author with data of the Liberia Canton provided by the IMN 2018

This characteristic rain pattern supplies abundant amounts of water to the whole region during the rainy season but produces an important water deficit in the dry season which, combined with an increase in temperature, causes rivers, streams and water springs to decrease or totally lose their flow heavily affecting the agricultural activity of the region (SEPSA 2015, p.4). The region has an average rainfall of 1750 mm that varies from 1500 to 2000 mm -depending on the location-, and an average temperature of 27 °C which fluctuates between 16 °C and 33 °C also, according to the location and time of the year (SEPSA 2015, p.4).

3.3.2 Socio-economic characteristics

Despite its abundant natural resources and rich cultural heritage the North Pacific region is one of the less developed and economically disadvantaged regions in the country. According to the National Household Survey of 2012 the region ranked as the second poorest in the country with an incidence of poverty in households of 34.5% (INEC 2012). As it is often common in areas with a high amount of rural population -62% of its 348304 inhabitants live in rural areas (Mata 2010, p.5)- some of its main social issues are related to high unemployment rates (11.4%, almost double than the national average) high emigration rates (seasonal and permanent), low levels of human development and poor access to service infrastructure, specially the supply of drinking water during the dry season (INEC 2012).

The North Pacific region is characterized for being one of the most important agricultural regions in Costa Rica both because of the diversity of its production as well as for the high production volume that it contributes, both for local, national and export consumption (SEPSA 2015, p.13). According to the National Agricultural Census of 2014, this region holds the highest amount of agricultural land in the country with 24.6% of the total extension (INEC 2014) and the agricultural activity gives jobs to 22.9% of the population (SEPSA 2015, p.13). These numbers however, are reducing gradually as the traditional agricultural economy gives way to a service economy oriented towards the tourism sector.

Even though the current agricultural production of the region is giving priority to crops with a higher export value such as melon or citrus fruits, basic grains (corn, beans and rice) remain as the base of the agricultural production of most local producers and an important part of their tradition. Its cultivation and harvesting schedule, tightly synchronized with the variations of rainfall, reflects a deep knowledge of the climate developed by the farmers through centuries of

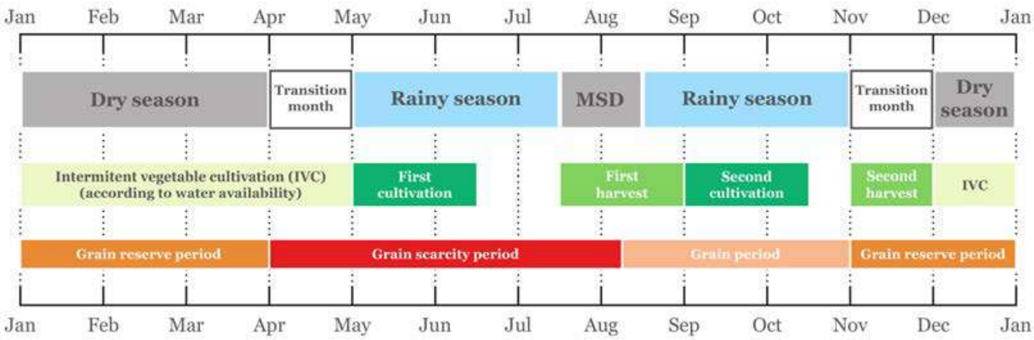


Figure 16: Basic grains cultivation schedule . Source: Author adapted from Bonilla 2014

interaction with the environment that has been preserved until today (See figure 16).

3.4 Climate variability and the ENSO phenomenon

The United States National Oceanic and Atmospheric Administration (NOAA) defines the ENSO cycle as “the coherent and sometimes very strong year-to-year variations in sea- surface temperatures, convective rainfall, surface air pressure, and atmospheric circulation that occur across the equatorial Pacific Ocean” (NOAA 2012). Though a single climate phenomenon, it has three phases in which it can be in: a warm phase called “El Niño”, a cold phase called “La Niña,” and a “Neutral” phase in the middle of the continuum (NOAA 2014) (See table 1). As part of the CADC, the North Pacific region is affected by the ENSO phenomenon which affects the region periodically and, with which small farmers have somehow, learned to cope and adapt through the years, despite its irregular frequency and difficult predictability.

On average ENSO related events occur every 2 to 7 years with many registered cases of warm and cold phases occurring in a consecutive manner (IMN 2016). In the last 70 years El Niño has been more frequent than La Niña with 25 warm episodes registered, 8 of which were categorized as strong or very strong and with ranges of duration between 8 to 19 months (NOAA 2018). On the other hand 22 cold episodes has been registered, 7 of which were categorized as strong and with durations between 10 to 24 months (NOAA 2018). In recent years however, the frequency and intensity of ENOS related phenomena has been increasing in the North Pacific region, as well as in the CADC, in a pace and intensity that is uncommon for the dwellers of the region and is leaving them in accute vulnerability.

Small scale producers and rural communities are the most vulnerable groups to extreme climate variability. In the CADC in the last 10 years a constant and accumulative succession of climatic extremes that started with a severe drought

Neutral phase

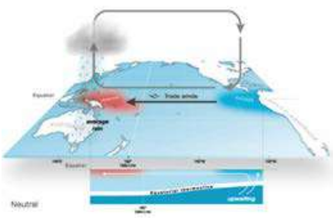


Figure 17: Neutral phase. Source: http://www.bom.gov.au/climate/enso/history/ln-2010-12/three-phases-of-ENSO.shtml

Tropical Pacific sea surface temperatures (SST) are generally close to average. Trade winds blow from east to west across the surface of the tropical Pacific Ocean which brings warm moist air and warmer surface waters towards the western part keeping the central part with relatively cool temperatures (Australian Government Bureau of Meteorology 2012)

Related events:

-None

El Niño phase

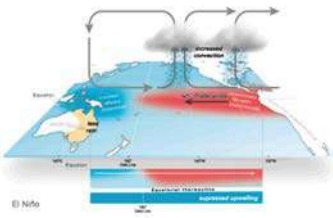


Figure 18: El Niño phase. Source: http://www.bom.gov.au/climate/enso/history/ln-2010-12/three-phases-of-ENSO.shtml

Consists of a warming of the ocean surface, or an above-average raise of sea surface temperatures (SST) in the central and eastern tropical Pacific Ocean as an effect of the weakening or reversing of trade winds (NOAA 2014).

Related events:

-Strongly related to the occurrence of drought events.

La Niña phase

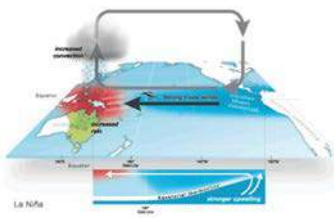


Figure 19: La Niña phase. Source: http://www.bom.gov.au/climate/enso/history/ln-2010-12/three-phases-of-ENSO.shtml

Consists of a cooling of the ocean surface, or a below-average drop of sea surface temperatures (SST) in the central and eastern tropical Pacific Ocean due to the intensification of the Walker Circulation, which produces an increased convection and stronger trade winds (NOAA 2014).

Related events:

-Tropical waves

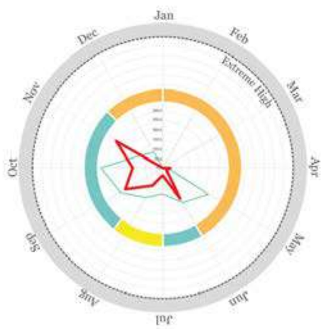
-Tropical storms

-Hurricanes

Table EC: ENSO phases. Source: Author

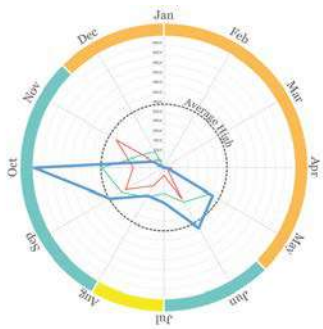
2013: Neutral year

1500 mm



2015: Extreme drought year

1100 mm



2017: Hurricane Nate

2150 mm

Table 1: Annual Rainfall in the Nicoya Canton for the years of 2013, 2015 and 2017. Source: Author with information provided by the IMN 2018

of 2009 has worsened the vulnerability of the families that live in the region into a complex situation that encompasses the loss of livelihoods, decapitalization of household economies, impoverishment and migration to urban areas and food and nutrition insecurity (FAO 2016, p.1). In the specific case of the North Pacific region of Costa Rica, the El Niñ0 drought episode of 2015 -the strongest in the last 78 years (La Nación 2015)- and the 'Nate' tropical storm of 2017 -associated with La Niña and categorized as one of the worst natural disaster of the country in decades (EFE 2017)-, had devastating effects on the agricultural sector and the economy of the region.

3.4.1 Future scenarios for the ENSO phenomenon

According to several studies the frequency and intensity of the ENSO phenomenon experimented today is closely related to climate change and will continue to rise many years into the future. In the case of El Niño, a study published in the Nature Climate Change magazine in 2014 presents climate modelling evidence for a doubling in the occurrence of extreme El Niño episodes due to greenhouse warming (Cai et.al 2013, p.111) (see Figure 20). Wang et.al reaches the same conclusion in 2017 under a most likely emission scenario (RCP2.6) in which global warming reaches 1.5°C above pre-industrial levels -aspirational limit of the Paris Agreement- (Wang et.al. 2017, p.568), and adds that this linear increment will not stop until the second half of the 22nd century even if temperature rise levels off (Wang et.al. 2017, p.570). The same study indicates that in the case of La Niña there will be little to no changes in frequency if global temperature rise is limited to 1.5°C or 2°C (Wang et.al. 2017, p.568).

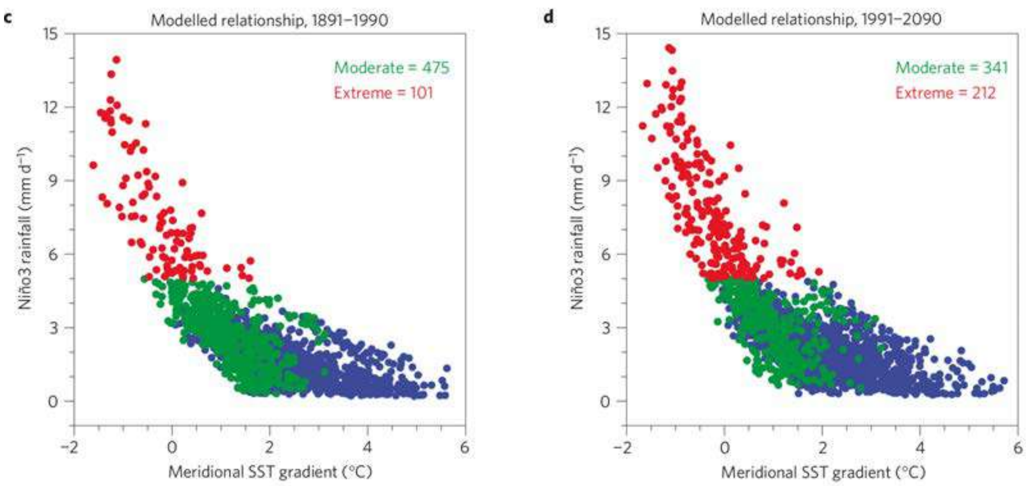


Figure 20: Comparative diagram of the changes in occurrence of extreme El Niño events under greenhouse warming :Red indicates extreme el Niño, green indicates moderate El Niño, and blue indicates La Niña and neutral events. Source: Cai et.al. 2013

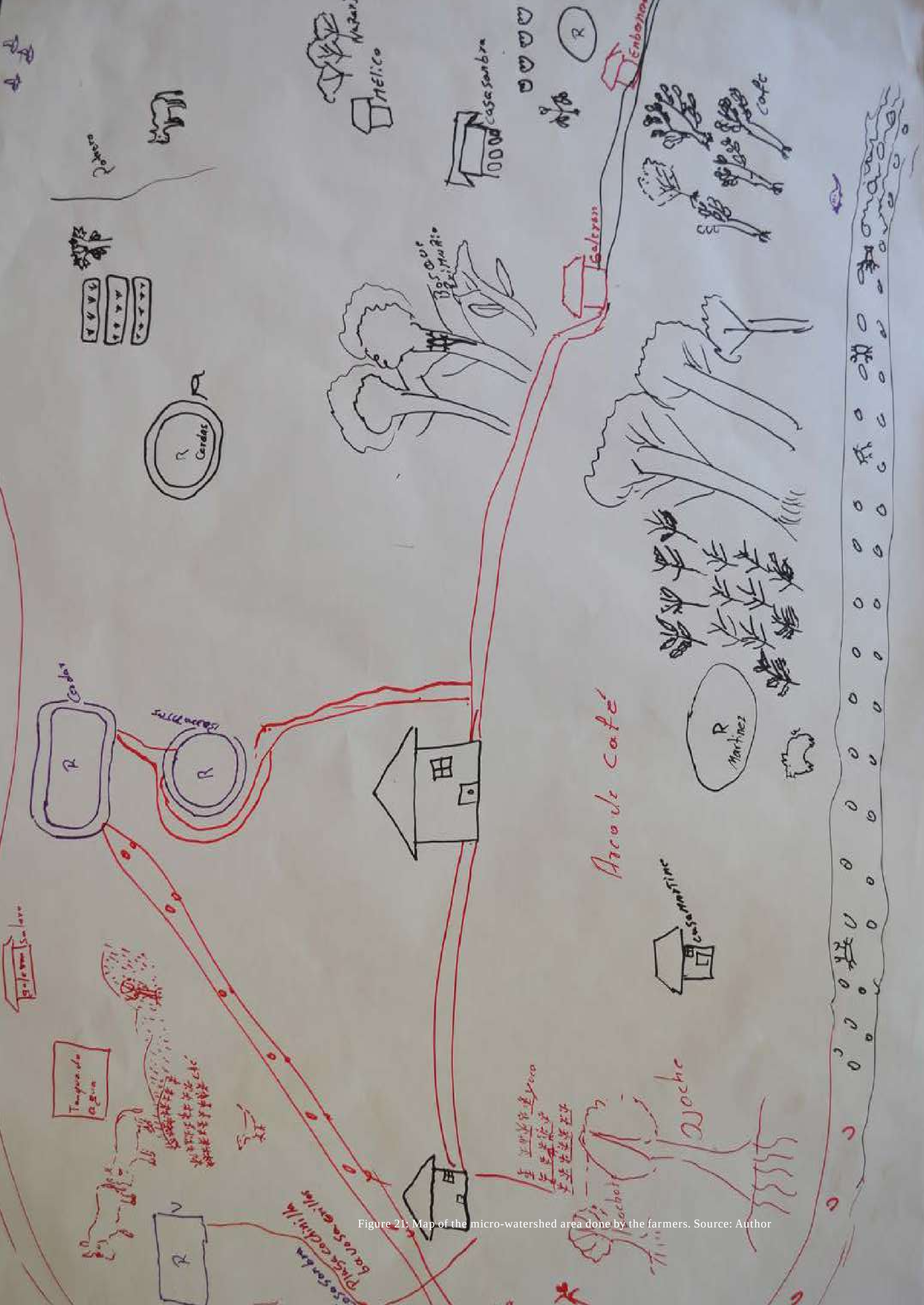


Figure 21: Map of the micro-watershed area done by the farmers. Source: Author

Chapter 4: Case study

4.1 Intr0duction

Once the selection of the North Pacific region as the area of analysis was made, as shown in the previous chapter, the next logical step was the selection of a community within its boundaries that could be used as a case study. For this, the first step was to narrow down the geographical scope into the canton of Nicoya, based on the future climate change projections for 2030 done by Echeverría, who identified Nicoya -along with Santa Cruz and Carrillo- as one of the most vulnerable cantons in the region to future water scarcity (IMN/MINAET 2011, p.72), the selection of this canton over the other two was supported by the amount of information available about the area. After a thorough examination process of various potential communities in Nicoya -which could not have been possible without the collaboration of other researchers along the way- the mountainous rural community of Cerro Negro (Black Hill) was selected due to their particular situation of vulnerability to climate change and to their history of collaboration with other research institutions which, eventually, facilitated considerably the process of data collection and evaluation. The content of this chapter will be focused on establishing a detailed characterization of the section of the community living in the micro-watershed area with the purpose of identifying local climate change exposure and which areas of the biophysical and socio-economic system are more sensitive to this exposure.

4.2 Methods of data collection

The majority of the information that will be presented in this chapter is the product of a data collection process of one week in which the researcher had the opportunity to live inside the community hosted by one of its head families. During this time different data collection methods were used according to the type of qualitative or quantitative data required (See figure 22). The majority of the data had to be generated or obtained directly from primary sources since

the only previous research done in the area (Houdijk 2017), present limited information regarding social and environmental aspects, giving more emphasis to economical aspects related to the agricultural activities.
The process of data collection was carried out mostly in the farm land belonging to the the farmers association, in which members of all age groups from the main four families were interviewed, and the participatory workshop was conducted. The limitation of the physical scope of analysis respond to the fact that, the difficult topographical conditions of the area, the long distances between inhabited areas, and the absence of a transportation vehicle, affected the mobility within the settlement which, in the end proved to be detrimental for the process of data collection and the complete fulfilment of the research visit schedule.

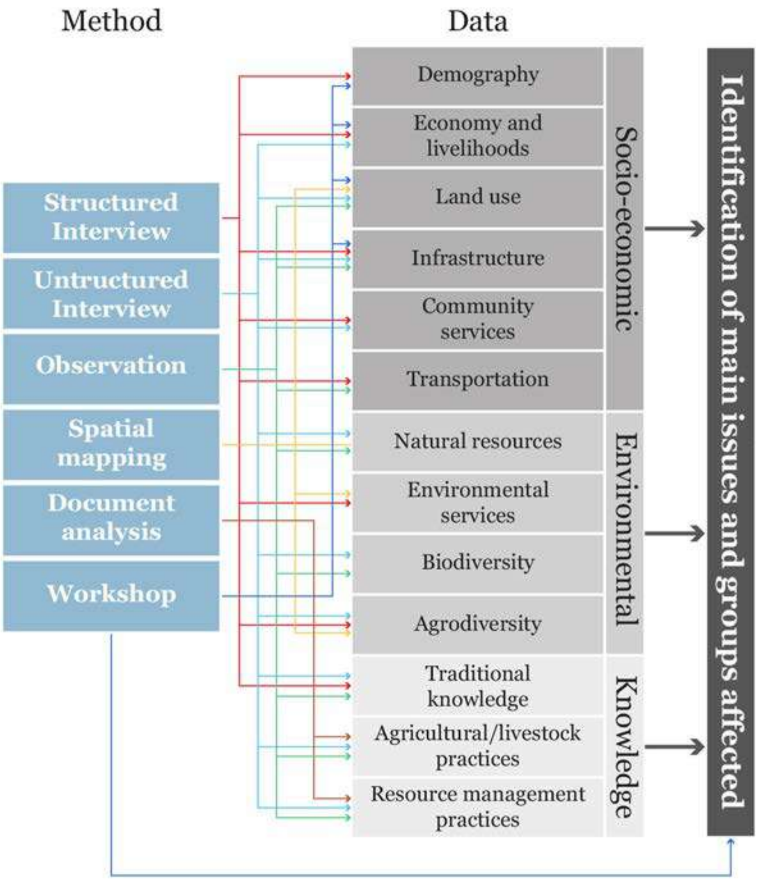


Figure 22: Methods of data collection. Source: Author

4.3 The Cerro Negro community

Cerro Negro is a rural mountainous community located 680 m.a.s.l in the western part of the Nicoya canton in the province of Guanacaste. As most of the mountainous communities inhabiting the Nicoya Peninsula region, it has an economy based on small scale agricultural and livestock activities that have shaped the landscape through centuries (See figure 23) and which has been heavily affected in the last decades by a combination of increased climate variability and free market policies. However, unlike other communities of the region, the community of Cerro Negro has managed to consolidate an organizational structure in the form of a farming association which started in 2002 (Houdijk 2017), and which remains until today, thanks in part to the family kinship shared by a big majority of its members, but mostly due to the consolidation of strategic networks with external actors throughout the years.

The work of the 'Association of Organic Farmers from Cerro Negro' (in short 'Organics El Cerro') has allowed the community to attract the attention and support of many national and international organizations and the establishment

Figure 23 : Typical mountain landscape of the Region. Source: Author

of important collaborations with several academic and research institutions which -along with the access to new markets-, has been detrimental for the enhancement of the community's adaptation capacity to climate change. Despite these advances, the community has still a long way to go in terms of climate change adaptation: the decrease in productivity due to rising temperatures or the total loss of crops experimented by the farmers in November of 2017 due to the hurricane Nate is one proof of this. Nevertheless, this community presents an interesting case, on how community organization and networking can lead to an enhancement of the climate change resilience of rural communities, which will be studied and characterized in the following sections.

4.3.1 Location and general characteristics of the settlement

The community of Cerro Negro is located in the mountainous region of the Nicoya Peninsula in the southern part of the North Pacific region, in an area that, administratively, belongs to the Central district of the Nicoya canton in the Guanacaste province. Even though the exact boundaries of the entire settlement were not possible to determine due to lack of cadastral information, an approximate boundary was delineated based on previous research, satellite images and information obtained from local residents (See figure 24).

The availability of water and the topography have determined a settlement configuration atypical for most found in the region in which, the 'downtown' is detached from the area in which the majority of the community live: while higher

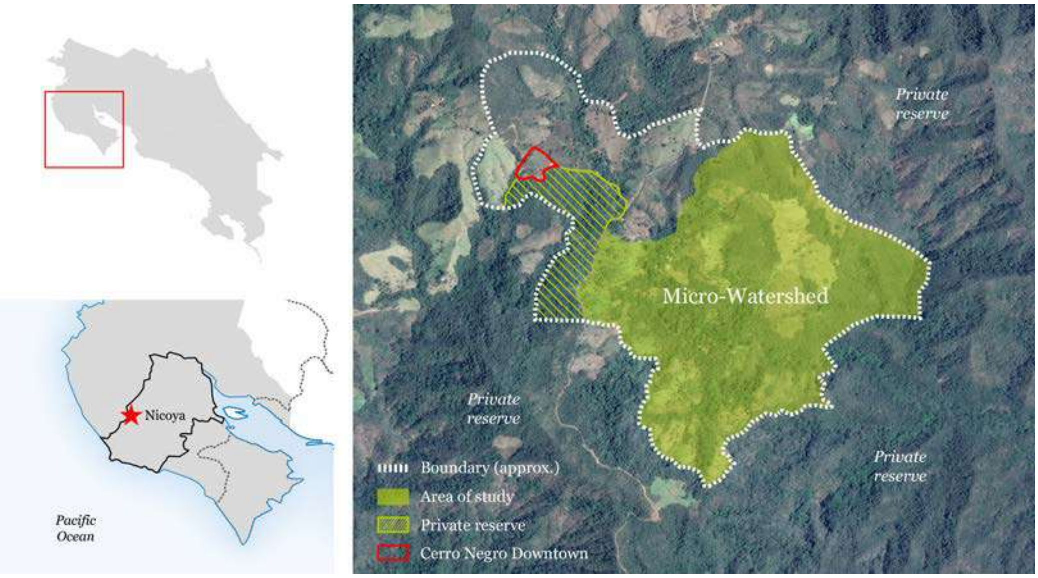


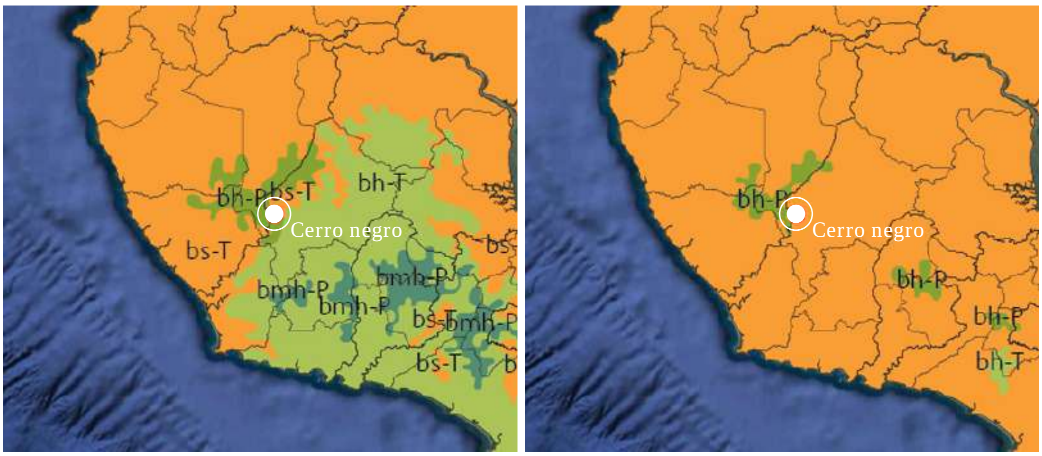
Figure 24 : Location of Cerro Negro in the Nicoya Peninsula. Source: Author, adapted from Houdijk 2017, base map Google Earth

and flatter areas proved more suitable for the location of community facilities such as the church, or the football plaza, the micro-watershed presented more accessibility to water and therefore better farming and living conditions. This, will be the selected area of study for this research, not only because its conditions as the most populated area in the settlement, but the global importance of this particular contexts as productive rain fed areas. According to Wani et.al: “a watershed is not simply a hydrological unit but also a socio-political-ecological entity which plays a crucial role in determining food, social, and economical security and provides life support services to rural people” (Wani et.al 2009, p.1).The micro-watershed of Cerro Negro constitutes a socio-ecological unit with dynamic environmental conditions that over the years have determined the changing relationship of the community with the landscape.

4.3.2 Climate change exposure

As part of the North Pacific region, the community of Cerro Negro is exposed to the same hazards related to the type of climate and geographical location. The impacts of these hazards however, are felt differently across the region depending on several byophisical and socio-economic factors that influence the way the people experience shock and stress. In the last two decades the community has been affected by the same episodes of drought and tropical storms associated with the ENSO phenomenon that have affected the entire North Pacific region however, the locals describe the year of 2012 as a turning point in the climate of the area that brought changes in the form of dryer and longer periods without

2010 2020



Premontane wet forest (bh-P)
Rainfall: 1200-2200mm

Tropical dry forest
Rainfall: 800-2100mm

Figure 25: Holdridge life zone comparison between the years of 2010 and 2020. Source: Author, adapted from UCR 2018

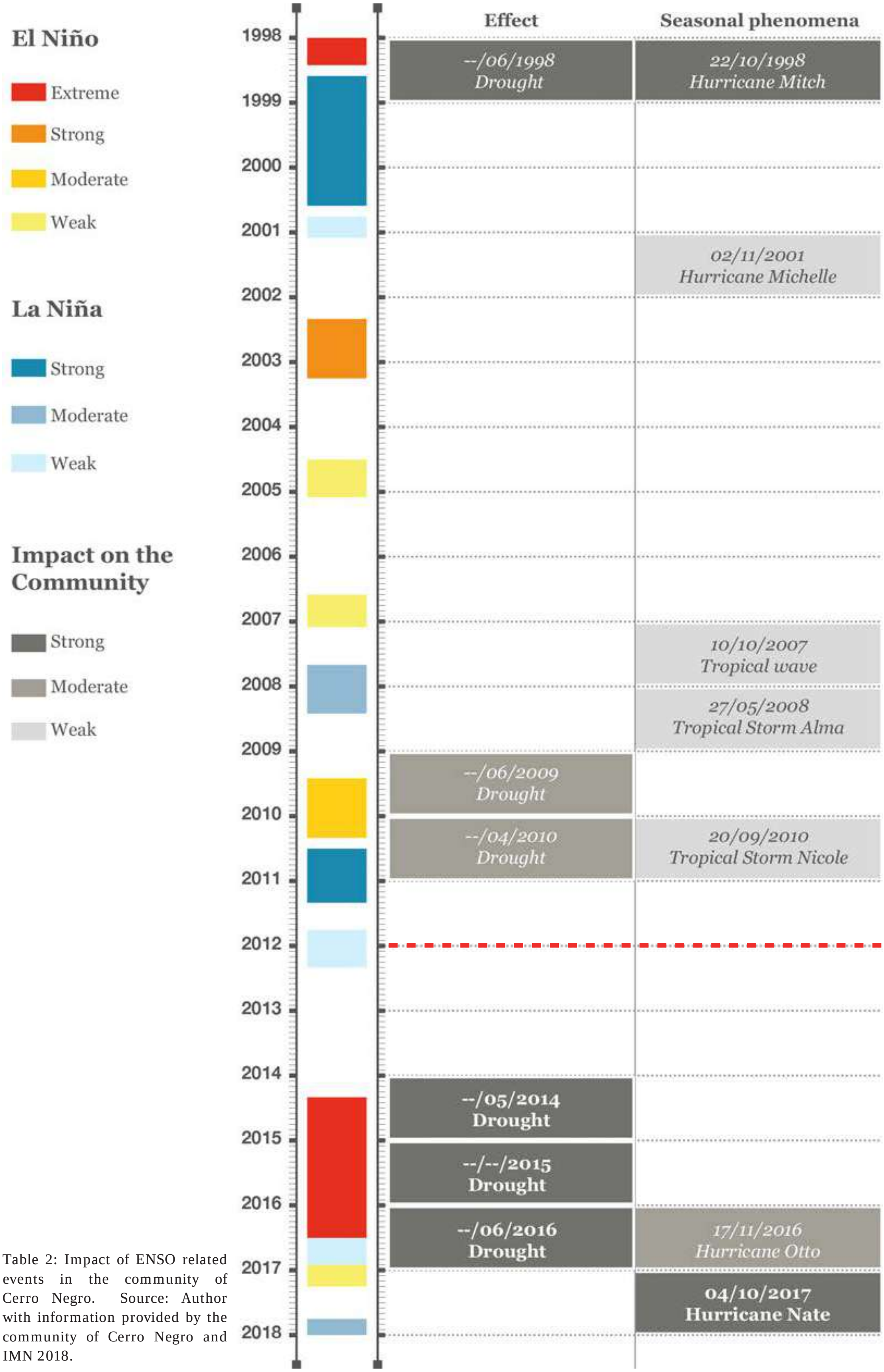


Table 2: Impact of ENSO related events in the community of Cerro Negro. Source: Author with information provided by the community of Cerro Negro and IMN 2018.

rain, higher temperatures that affected the productivity levels of certain crops like coffee, and the complete disappearance of some springs (See table 2).

This dry period reached its highest intensity with the extreme drought of 2015 which, has been described by the locals as the worst drought episode they can recall in their history and which consequences can still be felt until today. However, the climate episode that is more vivid in the local minds, ocurred in the month of October of 2017 when the community was struck heavily by the tropical storm Nate, which caused several damages in the infrastructure and landscape, wiping out the entire crop yield of that season, causing high economic losses for the farmers, and compromising their basic grain reserve for the dry months.

As exposed in Chapter 3 of this research, the frequency and intensity of these episodes will increase in future years as global temperature rise and with it, the issues of water scarcity and extreme rainfall characteristic of the wet and dry season type of climate. Additionally, if we overlap the geographical location of Cerro Negro with projected future Holdridge life zones maps, it shows that the settlement is located in an area that will experiment a shift of climate zones in coming years that will affect its climate patterns in the form of reduced rainfall levels, increased mean temperature and a modification of the type of vegetation that can grow in the area (See figure 25). The next sections of this chapter will be focused on characterizing the biophysical and socio-economical systems of the selected study area with the aim of identifying the sensitivities of these systems to the existing climate conditions.

4.4 The Micro-watershed

4.4.1 The Bio-physical system

A watershed is a hydrological unit covering a specific area in which all runoff water from rainfall is collected and drained in a common point (Wani et.al 2009, p.3). Its size can vary from hundred of square kilometers to a few hectares and depending on its size is termed in different ways. The micro-watershed is the smallest of this classifications with sizes ranging from 1 to 10 sq. Km (SLUSI 2018) (See figure 26).

4.4.1.1 Water sources

It is the more valued resource of the micro-watershed, all their productive activities are heavily dependant of the availability of this resource. The area is irrigated by several springs and streams that flow into a bigger stream in the lower part of the valley which is the one that gives shapes to it. The volume of

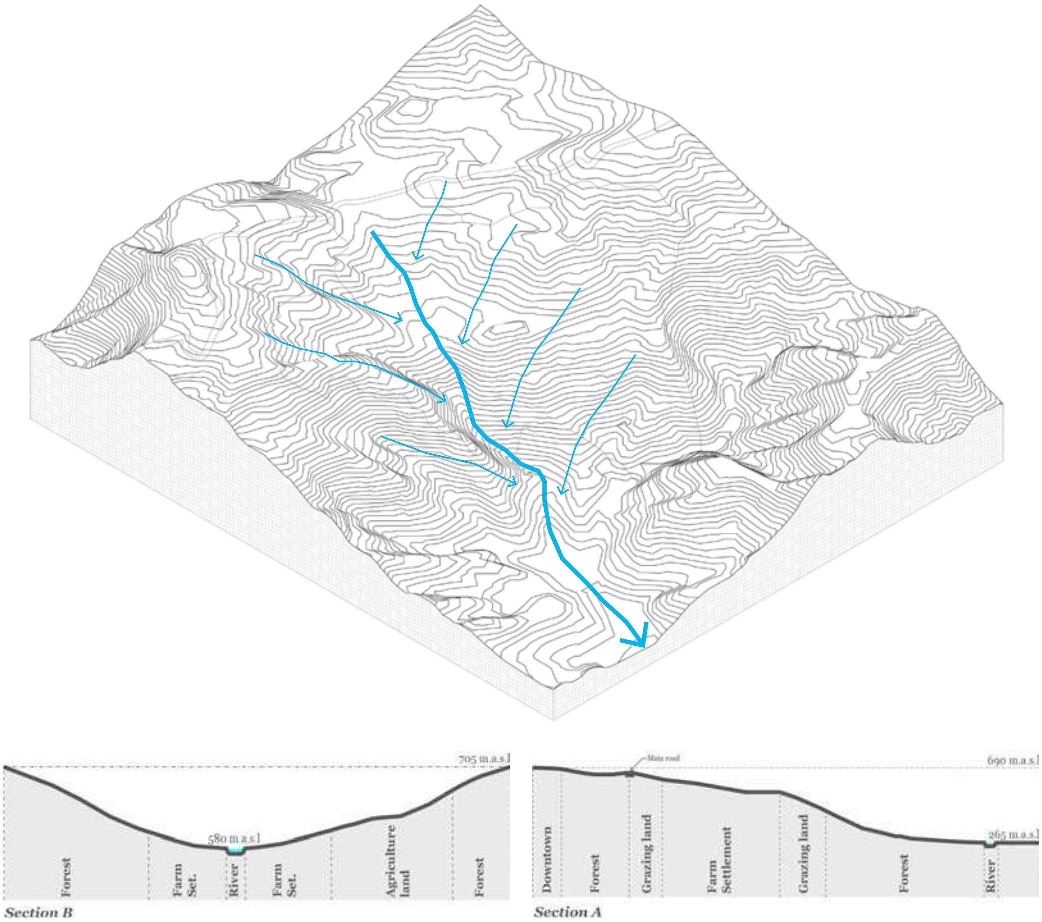


Figure 26: Topography of Cerro Negro. Source: Author based on data of the National Geographical Institute of Costa Rica.

water of each one of these streams however, varies according to the flow of spring water that feeds them. This flow is inconsistent along the year with most of the water springs drying completely or partially in the months of February to April which are the warmest and driest months of the year (See figure 27).

Mountain contexts, in specific, are more affected by a speeding reduction of the water table during dry periods without surface recharge, due to the effect of gravity which keeps the water moving to lower areas, where, in comparison, water is retained by the soil for longer time since water remains more static. Other factors such as, strong winds or, more importantly, the deforestation of high areas and river beds, also affect the amount of flow of springs and streams as they accelerate the evaporation rate of surface water and affect negatively the recharge of underground water. In this last matter there is a clear conscience among the community members about the importance that the preservation of river bed vegetation has for the conservation of water bodies which is reflected in the landscape (See figure 28).

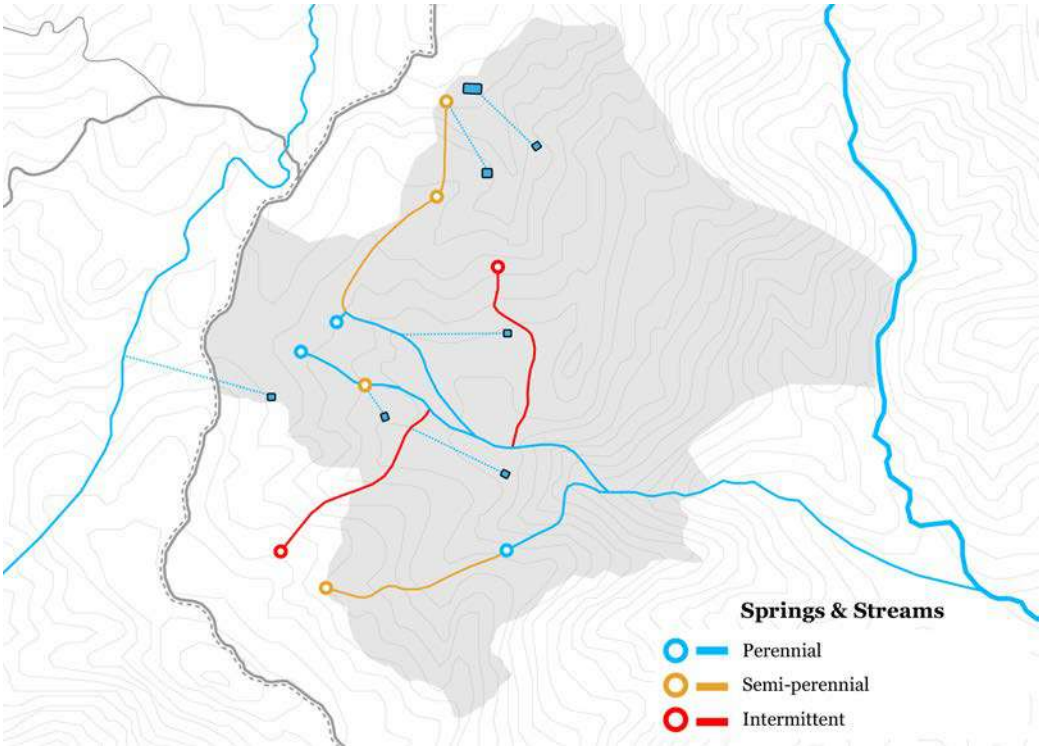


Figure 27: Water sources map. Source: Author based on information provided by Minor Barrantes

Figure 28: Water flow reduction during the dry months. Source: Left image: https://www.tripadvisor.co.za/LocationPhotoDirectLink-g309241-d1011909-i50165419-Cabo_Blanco_Absolute_Natural_Reserve-Nicoya_Province_of_Guanacaste.html. Right image:Author

4.4.1.2 Forest

Forest areas and its resources are abundant in the context, Cerro Negro is surrounded by big extensions of private and governmental reserves, including the Diriá National Park located just 5 Km North of the community. Within the farm boundaries 30% of the land is preserved as primary forest and around 13% as secondary forest. Some of this area is under the model of Payment for Ecosystem Services (PES) which, consist on a payment that the government give to land owners for the protection of forests (Costa Rica 2011). Regarding the type of forest found in this area, according to the Holdridge Life Zone classification, it is

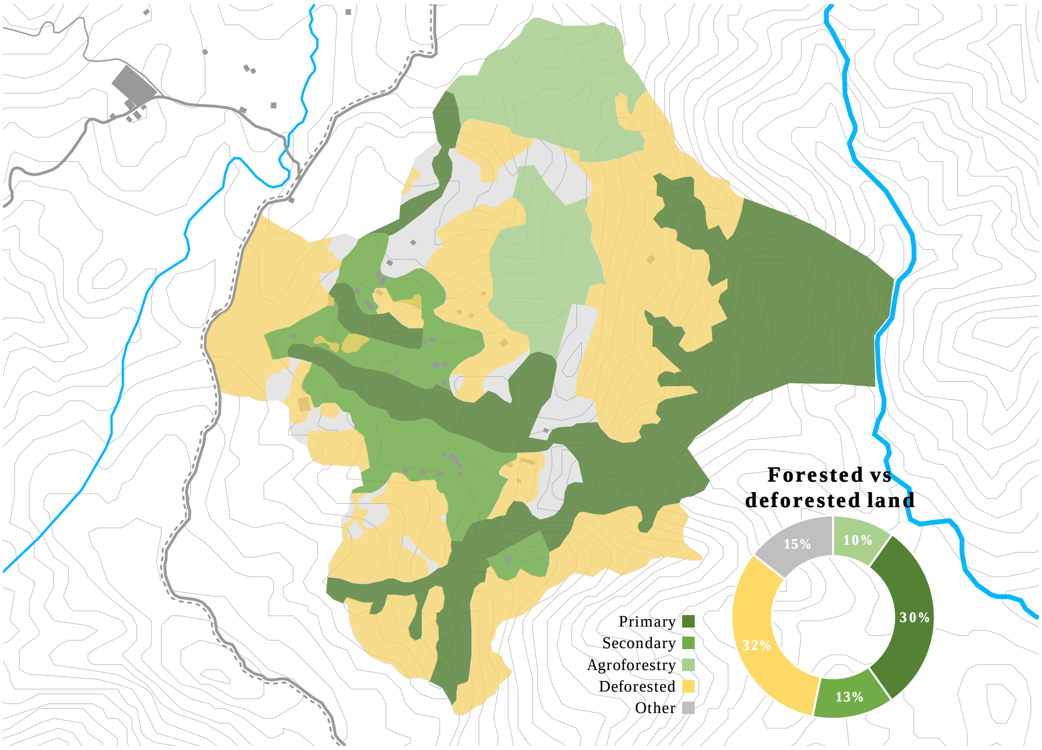


Figure 29: Forest land map. Source: Author based on Houdijk 2017 and Google earth


Figure 30: Palm heart extraction . Source: Author


Figure 31: Firewood used for cooking. Source: Author

described as semi-decidious with trees heights ranging from 10 to 30 mts, which are completely adapted to the seasonal variations of the Tropical Dry Forest and are capable of enduring long periods without any water (UCR 2012, p.67).

The community depends on forest resources for most of their daily life activities. From the forest they extract many raw materials such as fibres, fodders, resins, medicines and of course wood, which is used to build all types of infrastructure going from the construction of a fence to the construction of a house. Food resources are also obtained from the forest in the form of plants or animals, this last resource however, has been reduced greatly due to the implementation of stronger hunting laws in the country. In recent years one product in particular, the

Ojoche fruit, has been processed and commercialized to local markets becoming an extra source of income for some families (See figures 30, 31).
Deforestation is not considered a major issue in the area as it was in past decades, thanks in great part to the implementation of the PES model since 1996 however, it is still common to find cases of illegal logging and an irregular shift between deforested and reforested areas through the years mostly due to the creation of new grazing for livestock purposes. This activity, even though secondary in the watershed is the one that generates the a big impact in the landscape taking of the watershed area (See figure 29). Even though the area present stable soils with minor landslide cases, it is susceptible to soil loss by erosion due to intense rains and wind specially in the sectors with steep slopes and lack of vegetation.

4.4.2 Socio-economic system

4.4.2.1 Demographics

It was not possible to establish official numbers of the total population of Cerro Negro since there are no records specific to the community available, nevertheless, according to estimates from interviewed locals, the total amount of population of Cerro Negro is approximately 130 people divided in 30 families, from these 17 live in the micro-watershed and the rest are spread all over the settlement. These numbers however, are in descent as the community have been experimenting a considerable shrinking of its population in the last two decades owed to the fact that many farmers are abandoning agriculture to work in other sectors outside the community. The negative impact that recent climate related phenomena has had in the agricultural production in the last five years has intensified this trend exponentially.
The community also experiments traditional seasonal migration patterns when the agricultural activity is low, and most men (specially the young ones) travel to other parts of the country to work in different jobs such as banana plantations, or “other type of hard physical work to support their families the rest of the year” (Houdijk 2017, p.4). Lack of job sources is one of the main drivers of temporary and permanent migration in Cerro Negro which in turn is a characteristic of the whole region. Unemployment in the North Pacific region is almost double than the national average and along the drought is considered one of the main issues of the region (INEC 2017).

4.4.2.2 Social groups

In this section of the research a characterization of the main actors that comprise the community will be carried out in order to identify their position and roles within the community. The aim is to identify the most vulnerable groups and develop a preliminary understanding of the issues affecting them.

Farmers

Is the biggest group in the community, nearly 100% of the male population is engaged in some kind of local agricultural activity either seasonally or during the whole year. Even though some women participate sporadically in agriculture -specially in times with high demand of hand labour-, is mostly a male dominated sector. The average age of the farmers is around 50 years old, which is in the lower side of the national average of 54,1 (INEC 2014, p.24) however, the farmer population is aging rapidly and according to local farmers there is a generational shift problem as very few young people is interested in continuing with the activity of their fathers. Additionally to this, disabilities and lack of governmental support to the small producer are pointed out by the interviewed as the main problems affecting the group. Because of the nature of their activity this group is the most affected by seasonal water scarcity, climate variability and extreme climate events. This group also includes those involved in cattle raising as, in the few identified cases this activity was complementary to agriculture .

Elderly

They are the founders of the community, the main holders of the traditional knowledge of the community and the ones who brought the practices of agriculture and livestock to the area. Due to the lack of hand labour in the community most of them are still involved in agricultural practices despite the advanced age of some of its members. This situation, along with abrupt weather changes, heavily affects the health conditions of this group. As well is one of the most vulnerable groups to the lack of drinking water during the dry season.

Housewives

Most of the women of the community are responsible for the management of the household. These include housekeeping duties, cooking, the care of the children, as well as the raising of small farm animals like chickens and pigs which are an important source of income for the household economy. This group is also in charge of the care and management of the traditional family house gardens which constitute an important source of resources and food for the household, specially in periods of scarcity.

Farmers

Figure 32: Minor Barrantes, local farmer. Source: Author

Elderly

Figure 33: Porfirio Martinez, local elderly. Source: Author

Housewives

Figure 34: Jessica Brenes, local housewife. Source: Author

Youth

Figure 35: Jafet Barrantes, local youth. Source: Author

Youth (15 to 24)

The amount of youth in Cerro Negro has been in descent in the last years due to the aforementioned migration phenomenon. The majority of the young people of the community has a lack of interest towards local agricultural activities preferring to pursue other more lucrative activities outside the community. The plantations of melon, sugar cane, and pineapple are the most sought jobs in the region, however others travel to the capital or the Caribbean coast to work as security guards or in the banana plantations. Just until one year ago the younger ones (13 to 17) had the opportunity to attend high school for the first time in the history of the community. It is the most vulnerable group to the lack of education, job opportunities, knowledge and training.

4.4.2.3 Economic Activities

Since its foundation, almost a century ago, agriculture and livestock has been the two main productive activities in Cerro Negro. As most rural communities of the North Pacific region with the same economy base, Cerro Negro has faced the same problems of lack of infrastructure, water scarcity, difficult access to markets, and social related issues that have hindered its development. However, unlike other rural communities, it has managed to create a collective organizational structure that has allowed the diversification of their productive activities, a wider reach of the market and an overall improved economic resilience.

The Organization

Since 2002 the productive activities in the micro-watershed have been running in the form of an association of organic farmers under the name of 'Organics El Cerro', which was created in response to the growing demand of organic products in some of the most important eco-tourism destinations of the region

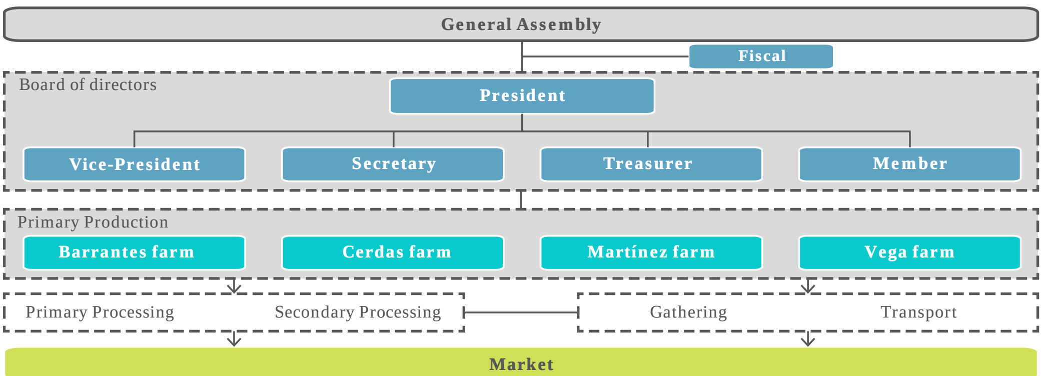


Figure 36: Structure of the association. Source: Author adapted from Houdjik 2017

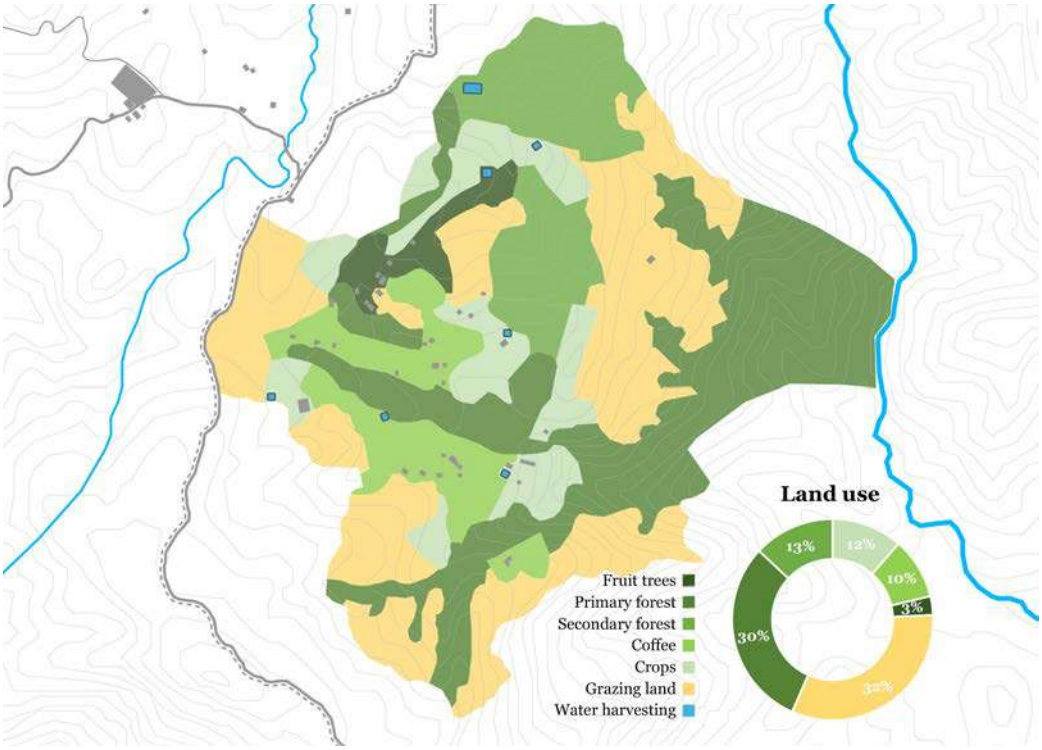


Figure 37: Land uses in the micro-watershed. Source: Author adapted from Minor Barrantes 2018, Houdjik 2017, and Google Earth

(Houdijk 2017, p.4). According to its founder, Reiner Barrantes, the aim of the association was to improve the employment conditions of the community and with this, achieve a reduction of the amount of people leaving the community (Barrantes 2018). Even though agricultural products are the priority of the association, through the years it has diversified its offer to animal based products and processed cereals made of the ojoche fruit.

The association is composed of sixty associates -including six members of the board of directors- belonging to four different families, each of which owns one of the four farms where the association produces their crops. The functioning of the association consists of assigning specialized products to each farm, which will then be sold on demand to a common buyer. Some of the advantages of this system is that it avoids internal competition, the earnings of each product go directly to its corresponding producer, there is no return of unsold products, and there is no duplication of efforts and resources, as there is only one responsible for tasks such as product processing or transportation (See figure 36). The resulting landscape is a complex farming system encompassing multiple land uses which reflect, not only an increasing variety of functions , but also a "poly-culture management system" high in biodiversity (Houdijk 2017, p.11) (See figure 37).

Agriculture

Agriculture is the main economic activity in Cerro Negro and the most developed one. The production of maize and beans, along with the production of coffee, has been the base of the agricultural activity of the small farmers in the community for decades which, beyond a few technological innovations introduced in recent years, it is still practiced in a rudimentary way without the involvement of beasts or special machinery. Over the years this aspect has reduced the amount of area destined to cultivation, as the determination of the size of the cropping field relies heavily on the amount of work force available which, as mentioned before, is one of the biggest shortcomings of the community.

In the last two decades, two events can be pointed out as the main drivers of change in Cerro Negro's agriculture: The shift from conventional agriculture to organic agriculture in 2002, and the introduction of rain water harvesting reservoirs in 2009: The adoption of organic agriculture not only meant the adoption of more sustainable agricultural practices, but also opened new markets and new demand of products which led to a diversification of the agricultural offer, meanwhile the introduction of rain water harvesting reservoirs allowed an extension of the cultivation period of certain crops to almost all-year long, breaking the traditional

Figure 38: Crop field in Cerro Negro. Source: Author

pattern of seasonal production used by the community for almost a century. Agriculture in Cerro Negro is vulnerable to several environmental factors which significantly affects the performance of the activity:

Water scarcity: Even though some farmers have the possibility to keep cultivating in the dry season thanks to the reservoirs, the quality and quantity of the yield reduces considerably due to the limited amount of water available for irrigation which, by the month of April usually reaches zero.

Pests: The use of pesticides is prohibited in organic agriculture which leave crops more exposed to the attack of pests and diseases. Even though the farmers recur to the use of natural pesticides, this issue affects them in a yearly basis.

Climate change: Small farmers in the micro-watershed point out the rise of temperature as the main cause of the reduced productivity of coffee. Once a staple product of the association, now its cultivation is transitioning to other type of trees better adapted to the current climate conditions, such as the orange.

Climate variability: The drought is a familiar phenomenon for the locals however, according to all the interviewed farmers, since 2012 it has reached unexpected levels of intensity for which they were not fully prepared. The extreme drought of 2015, for example, extended the dry season almost for 2 months, delaying the first cultivation period and reducing the yearly harvest almost to a half. On the other side of the spectrum, the Nate hurricane that struck the country in October of 2017, produced excessive amounts of rain and strong winds causing total loss of yields and compromising the food reserve for the dry season of 2018 (See figure 39).

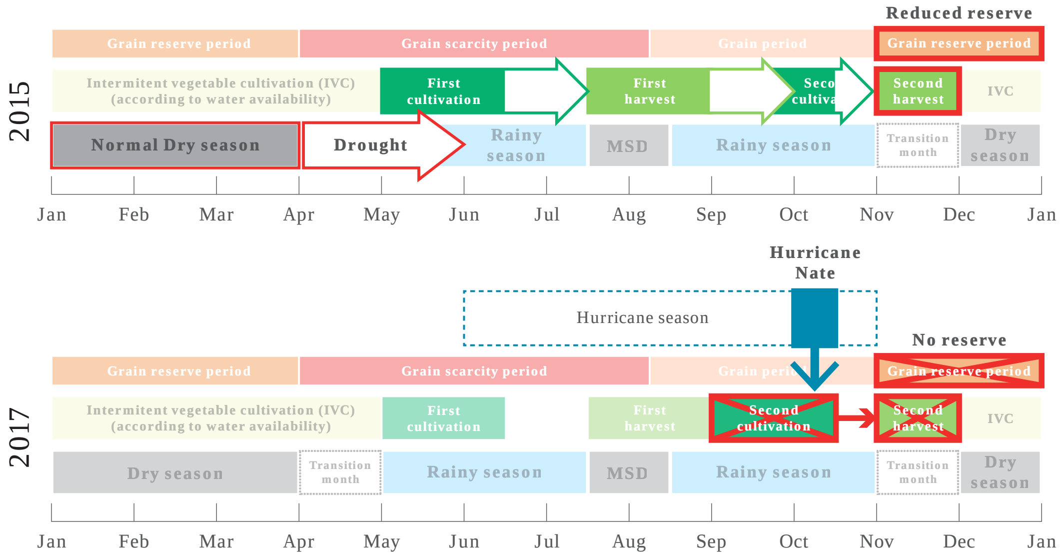


Figure 39: Impact of the extreme drought of 2015 and the hurricane Nate of 2017 on the basic grains reserve . Source: Author

Livestock

Only 21% of the farmers are engaged on cattle raising activities (Martínez 2018). According to Pedro Martínez, a local farmer and cattle raiser, this activity is complementary to the agriculture activity and the purpose is not profiting neither with meat nor with animal based products, but to have an economic support from the selling of the cattle in times of scarcity or crisis (Martínez 2018). Besides the raising of cattle, some few also raise pigs for the consumption of its meat, and chickens for their meat and eggs, which are sold as a product of the association.
Water scarcity is the main aspect that affects the livestock activity. The introduction of the rain water harvesting reservoirs has been the most efficient measure to tackle the lack of water in the dry season as it provides the animals with their needed intake of water to survive.

4.4.2.4 Infrastructure and Services

Infrastructure is an essential aspect of economic development, even though it does not directly produce goods or services it facilitates the adequate execution of economic activities. The next section will be used to analyse the existing physical and social infrastructure in the community as well as the available services, and its relationship with the development conditions of the community

Physical Infrastructure

Roads

The difficult access to Cerro Negro due to a lack of public transport service and the poor conditions of the road that leads to the community -dirt road with steep topography-, is the first evidence of the problem of infrastructure and one of the main reasons of the isolation of the settlement. Some sections of the road can only be passed with an off-road vehicle and the in periods of heavy rain the conditions worsen. This not only affects the productive activities, as it difficult the transportation of goods inside and outside the community, but as well the transportation of people and external aid, specially in cases of an emergency.

Transport

Internally, the condition of the road network limit the use of vehicles to only some parts of the community. Most of the people get around by foot with the exception of few locals that own motorcycles. There is only one car in the community which the only way the farmers have to transport products to the outside markets. The only transportation services are private and by request, including one that every day takes some youth to a high school outside of the community.

Figure 40: Road infrastructure. Source: Author

Figure 41: Water catchment tank. Source: Author

Figure 42: Community Center. Source: Author

Figure 43: Cerro Negro school. Source: Author

Figure 44: Community church. Source: Author

Figure 45: High school bus stop. Source: Author

Figure 46: Traditional house. Source: Author

Figure 47: Internet dish for the school. Source: Author

Water

Even though every activity in the community (productive and non-productive) depends to different degrees, on the use of water, the access to this resource is still one of the main challenges in Cerro Negro. The area does not have water supply service and the only attempt to install an aqueduct in 2006 failed after two years of operation, due to poor installation and maintenance. Until today, all the water consumption of the community (drinking and irrigation) depends of the springs and streams that run though the watershed however, the topography and the location of some of the houses and agricultural fields in relation to the sources difficult its access specially for the elderly and disabled.

Energy and telecommunications

The municipality and a regional cooperative installed the electricity service fifteen years ago The only mean of communication with the outside -either calls or the use of internet- is with the use of cellphones as there is no phone line service or public telephones in the community.

Social and community facilities

Most of the community facilities are located in downtown where is possible to find the catholic church, the school, the football field and the community center (See figure SF). With exception of the school, which is attended from Monday to Friday by five children of the community, and the church, which is used every Sunday, the other facilities have come gradually in disuse as the population decreased. Recently, eight adolescents started attending high school in the town of Portal de Belen, which is located 15 km away from Cerro Negro.

Services

There is no provision of services inside the community. Some of the services like health center and post office can be found in La Virginia, a community located 9.5 km away (30 min) from Cerro Negro while for the rest (police station, pharmacy, banking, grocery shopping, hospital, etc) it is necessary to travel to the center of Nicoya which is located 30 km (2 hours) away from the community.

4.5 Rural development cooperation

Over the years several institutions and organizations have been involved in the development of the community of Cerro Negro through different initiatives oriented towards the provision of financial aid, donation of equipment, development of infrastructure or training and knowledge building. External support has come mostly in the form of projects that have addressed specific issues of the community in areas such as agriculture, health, food security, infrastructure, biodiversity, etc. (See table 3). According to the neighbours, the installation of the electricity service in 2003 and the construction of the rain water harvesting reservoirs in 2009, were the projects that generated the biggest impact on the improvement of the lives and the economy of the inhabitants of the community. However, lack of continuity and integral vision are emphasized as the main weaknesses of most of the projects implemented. Finally, community organization has been instrumental to raise the voice, and generate pressure, especially to authorities and local government, about the specific needs of the community and the urgency to tackle them.

Institution or organization	Project or programme
Municipality of Nicoya	Road infrastructure (ballasting and curbs)
	Electricity service installation
MAG (Ministry of Agriculture and Livestock)	Trainings
	Seed and fertilizer donation
	Road infrastructure (ballasting and curbs)
	Shade mesh advising in installation
	Aquaduct equipment donation*
	Barns construction*
	Pens construction*
	Green house construction*
INA (National Institute of Learning)	Training on terrace and rill control making
IMAS (Mixed Social Assistance Institute)	Shade mesh donation
	Training on chicken raising*
	Food handling course*
BANHVI (Mortgage Bank of Housing)	Housing bonds
INDER (Rural Development Institute)	Green house construction
	Nursery construction
	Mesh for the reservoir donation
ICAFE (Coffee Institute of Costa Rica)	Loans and financing to coffee producers
Coopeguanacaste R.L	Electricity service installation
UNA (National University of Costa Rica)	Construction of the firsts rain water harvesting reservoirs
	Market advising
	Drip irrigation training
UCR (University of Costa Rica)	Conducted a research to develop climate change adaptation proposals
FAO (Food and Agriculture Organization	Polyethylene geomembrane donation for the reservoirs
	Shade mesh donation
	Tools and equipment donation
Private advisors	Training on making organic fermented fertilizers

Table 3: External cooperation in Cerro Negro. Source: Author with information provided by farmers of Cerro Negro

Figure 48: Initial Vulnerability Assessment workshop. Source: Author

Chapter 5: Assessment

5.1 Intr0duction

The following chapter will be focused on understanding how the interaction of the biophysical and socioeconomic factors present in the micro-watershed determine the susceptibility of the socio-productive landscape to the impacts of climate change and variability, and which are the measures taken by the farmers to respond to these impacts. To achieve this purpose a vulnerability assessment was developed divided in two separate phases: a participatory assessment phase -aiming at the identification of key vulnerabilities in the micro-watershed-, and an expert assessment phase which final aim is to determine the adaptation capacity of the socio-productive landscape to the scenarios of drought and seasonal weather phenomena.

5.1.1 Methodology

The vulnerability assessment follows a mixed methodological approach composed of OXFAM's Vulnerability and Risk Assessment Methodology (VRA) (OXFAM 2016), and the standardised vulnerability assessment approach developed by Adelphi and EURAC (GIZ 2015). Both methodologies share many similarities: both use the same framing of vulnerability provided by IPCC in the AR4 -which defines it as a function of exposure, sensitivity and adaptive capacity (OXFAM 2016, p.3), they allow to evaluate susceptibility to climate change in multiple systems, and both allow to develop a "better understanding of the factors driving the vulnerability of particular climate change hotspot" (e.g. agriculture) (GIZ 2015, p.26) .

The main difference between both methodologies is that the VRA puts a higher emphasis on analysing the community as part of a socio-ecological landscape and not as an isolated entity. As well, the VRA's approach is strictly participatory and meanwhile it aims at the collective identification and design of possible measures to promote resilience (OXFAM 2016, p.4), Adelphi/EURAC's approach is orientated towards evaluating vulnerability based on existing conditions.

Due to difficulties presented during the field research visit, which prevented the completion of the vulnerability assessment under the VRA approach, a combined process was conducted including an initial participatory assessment phase (extracted from the VRA assessment process) and subsequent expert assessment phases developed based on the researcher's recollected information and knowledge about the case study (See figure 49).

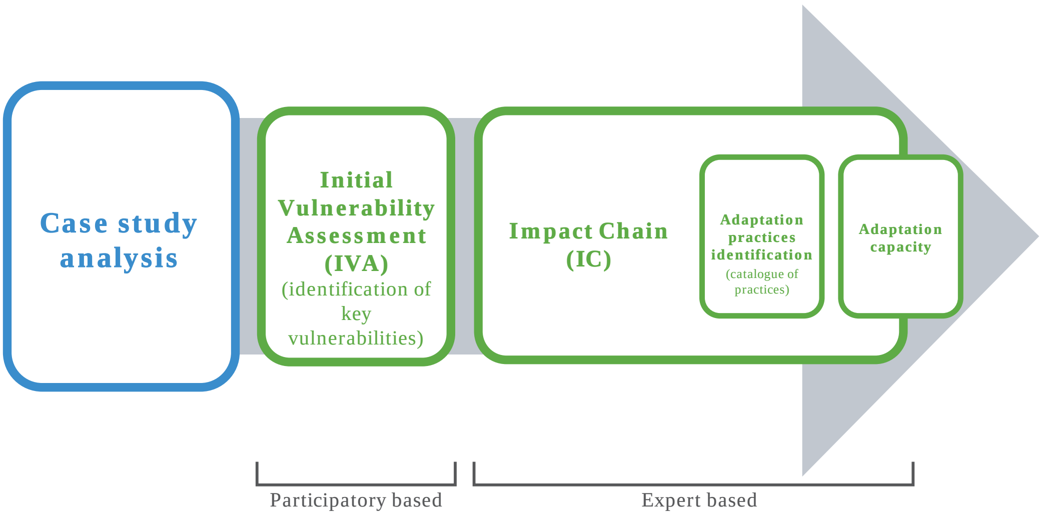


Figure 49: Adaptive capacity assessment process. Source: Author adapted from OXFAM 2016

5.2 Initial Vulnerability Assessment (IVA)

As part of the field research visit, a participatory workshop of two days was held in the house of one of the community leaders, with the purpose of conducting an initial vulnerability assessment (IVA) exercise. To do this, an open call was made to all members of the community few days before the event with the aim of gathering representation from all social groups. Even though the number of participants varied each day, in average 15 people participated in the activity which represents more than 10% of the community population.

The main purpose of the IVA is for the participants to analyse the exposure and sensitivity of a social group or a livelihood in relation to existing issues or hazards, as well, it aims at developing a "common understanding of the hazards that have posed and are likely to pose the highest risk to groups of community members in a landscape and their livelihoods" (OXFAM 2016, p.9). Therefore, the final outcome of this phase is the identification of the main issues and hazards affecting the community as well as the main social groups and livelihoods affected by it.

As a first step, a list of hazards and issues and social groups and livelihoods

Figure 50: Initial Vulnerability Assessment workshop collage. Source: Author

-identified from the site analysis- was proposed for analysis by the moderator to the participants in order to be discussed and voted according to their relevance (See table 4). Once the participants gave their justifications and reached a consensus about the final list, the process moved to the analysis of the exposures and sensitivities using a matrix in which the 'Hazards and Issues' are located in the X-axis, and the 'Social groups and Livelihoods' in the Y-axis.

On day 1 of the workshop the participants were asked to assess *exposure* by answering the question: What is the extent to which a social group or livelihood activity could potentially be affected or damaged by the occurrence of a hazard or an issue considering the present circumstances of the community? (OXFAM 2016, p.25). For this, the participants used a value scale from 3 to 0, being 3 the 'highest extent' and 0 the 'lowest extent'. On day 2 *sensitivity* was assessed using the same tools but this time answering the question: What was the actual impact of a hazard or issue on a social group or a livelihood activity over a period of 10 years in the past? (OXFAM 2016, p.25). After the participants reached a consensus (with the aid of the moderator) about the values of *exposure* and *sensitivity*, both results were combined in a matrix in order to show the *pre-vulnerability* value (See table 5).

Hazards and issues
Landslides
Drought/Rain levels reduction/Dry springs and streams
Tropical storms/tropical waves (increase of rain and wind intensity)
Wind
Temperature rise (warmer dry seasons)
Deforestation
Health issues/chronic diseases
Access to markets
Pests and diseases
Bad condition of the road
Lack of water for human consumption (includes difficult access to the resource)
Lack of community services
Access to education
Limited access to weather information
Limited access to climate change related information
Limited access to new farming practices and technologies
Final selection (blue)   Proposed by the researcher (green)

Table 4: List of identified hazards and issues. Source: Author

The second step of the vulnerability assessment is the development of impact chains for the 'Hazards and Issues' that were considered most relevant for the participants, or in other words, the ones that presented the highest values in the IVA matrix. 'Drought', 'bad conditions of the road', 'tropical storms', and 'temperature rise' were the hazards and issues that ranked higher and showed the highest levels of vulnerability across many social groups and livelihoods.

For the purpose of this thesis, some changes were made to the process of selection: firstly, 'drought' was merged with 'temperature rise' due to their intrinsic relation and similarity regarding its effects, and secondly, the issue of 'bad condition of the road' was discarded for the impact chain exercise since, being an infrastructural problem, escape the scope of analysis of this research. This however, does not intend in any way to undermine the relevance of addressing this problem -or any other pointed out in the IVA- and constitute an important reference for future research in the area.

Vulnerability		Hazards and issues									
		Drought/Rain levels reduction/Dry springs and streams	Lack of water for human consumption (includes difficult access to the resource)	Bad condition of the roads	Tropical storms/tropical waves (increase of rain and wind intensity)	Pests and diseases	Wind	Temperature rise (warmer dry seasons)	Limited access to climate change related information	Limited access to new farming practices and technologies	Total
Social groups and Livelihoods	Small scale farmers	2	3	2	3	2	1	2	3	2	**20**
	Youth (15 to 25)	2	3	2	2	0	0	2	1	2	**14**
	Elderly	2	3	2	2	0	0	2	2	2	**15**
	Housewives	2	3	2	2	1	1	1	0	0	12
	Crop yields: grains/coffee/vegetables/fruits	3	0	2	3	3	2	2	2	2	**19**
	Livestock/Small stock	2	0	2	2	1	2	1	1	0	11
	Tilapia aquaculture	3	0	1	0	1	0	1	2	0	8
	Harvesting and processing of Ojoche	1	0	1	3	1	2	2	0	0	10
	Total	**17**	12	**14**	**17**	9	8	**13**	11	8	

Table 5: Initial Vulnerability Assessment matrix. Source: Author with information provided by the workshop participants

5.3 Impact Chain (IC)

As explained in the 'Vulnerability Sourcebook': "An impact chain is an analytical tool that helps you better understand, systematise and prioritise the factors that drive vulnerability in the system under review" (GIZ 2015, p.58). While the IVA allows to identify which hazards affect any given system, the impact chain aims to reflect on the consequence of that hazard throughout the landscape in question, "in order to better understand how it propagates through a system via its direct and indirect impacts" (OXFAM 2016, p.30).

The structure of the impact chain used in this section is loosely based on the 'Key components of vulnerability' diagram shown in Chapter 2 however, it presents a significant modification from the vulnerability assessment methodology developed by Adelphi/EURAC, as it is not used to evaluate vulnerability factors (exposure, sensitivity and adaptive capacity) in a quantitative way but instead, it is used as a tool to identify the adaptation measures of the community in relation to the impacts affecting it the most.

Based on the IVA results which identified the hazards to which the community, and the socio-productive landscape, is most vulnerable to, two scenarios were analysed: 'Drought' (See figure 51-a) and 'Seasonal weather phenomena' (See figure 51-b). Both impact chains are focused on agriculture as this is the activity with the biggest impact in the landscape and, as shown in the IVA, the most vulnerable livelihood activity to these hazards.

It is important to consider that both cases have different temporal manifestations: while drought episodes are slow onset events that can last up to a decade, seasonal weather phenomena such as hurricanes or tropical storms are rapid onset events with durations of less than a month. The short and destructive nature of the latter heavily influenced the local farmers perception of the severity of the impact of this kind of events in comparison to the drought however, a goal of this exercise is not to compare or evaluate the degree of impact of one hazard over the other but instead to identify the areas that has been most affected.

5.3.1 Adaptation practices identification

The final outcome of IC exercise is to identify the actions being taken by the farmers to address each one of the observed impacts, to do this however, it was necessary first to recognize the agricultural practices used by the farmers in order to later establish a categorization of their functions. The result of this analysis is a catalogue in which each practice is characterized briefly based on its method of implementation, purpose of use, and origin (See table 6, 7, 8 & 9).

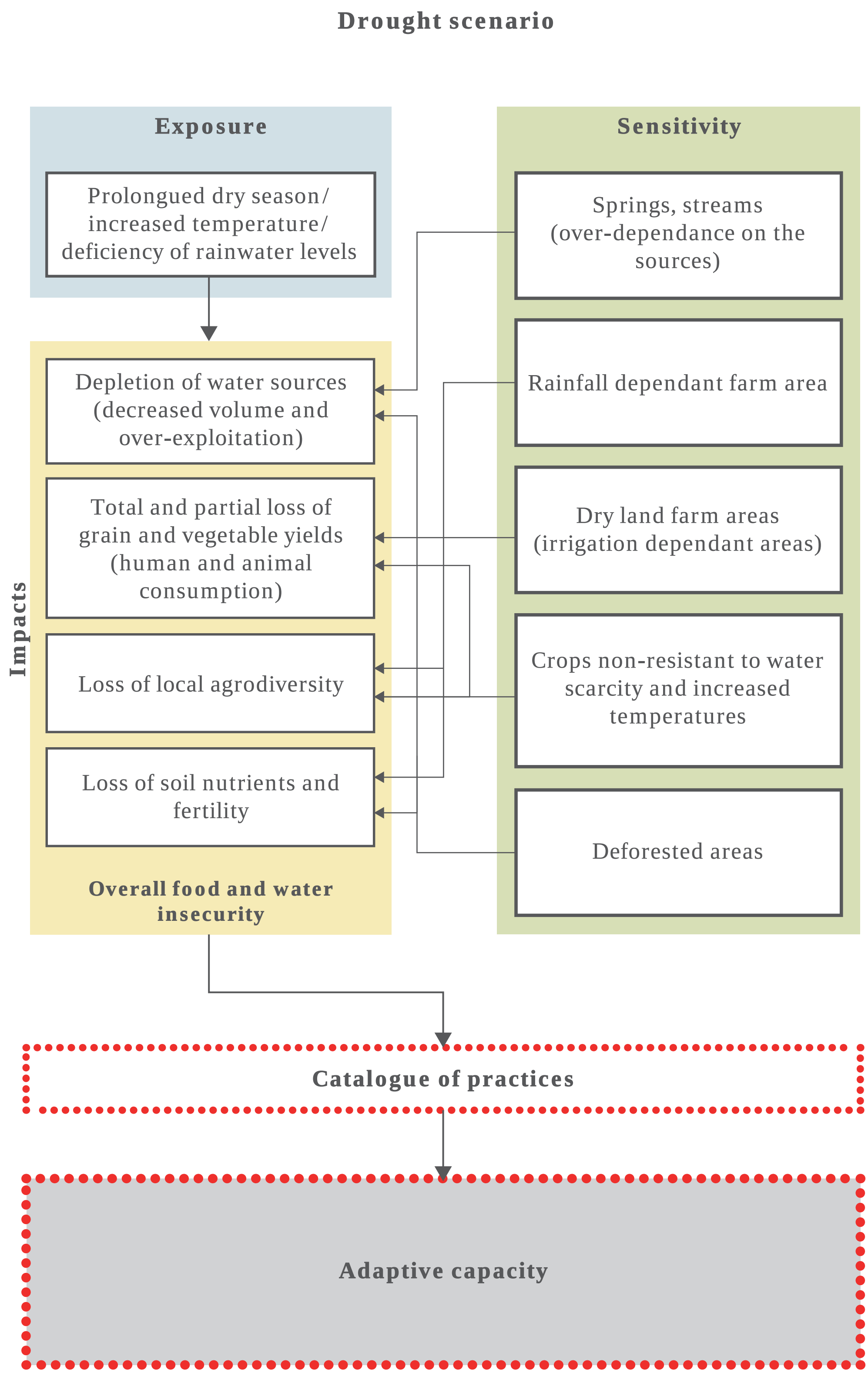


Figure 51-a: Drought impact chain scenario . Source: Author adapted from Adelphi/EURAC 2015

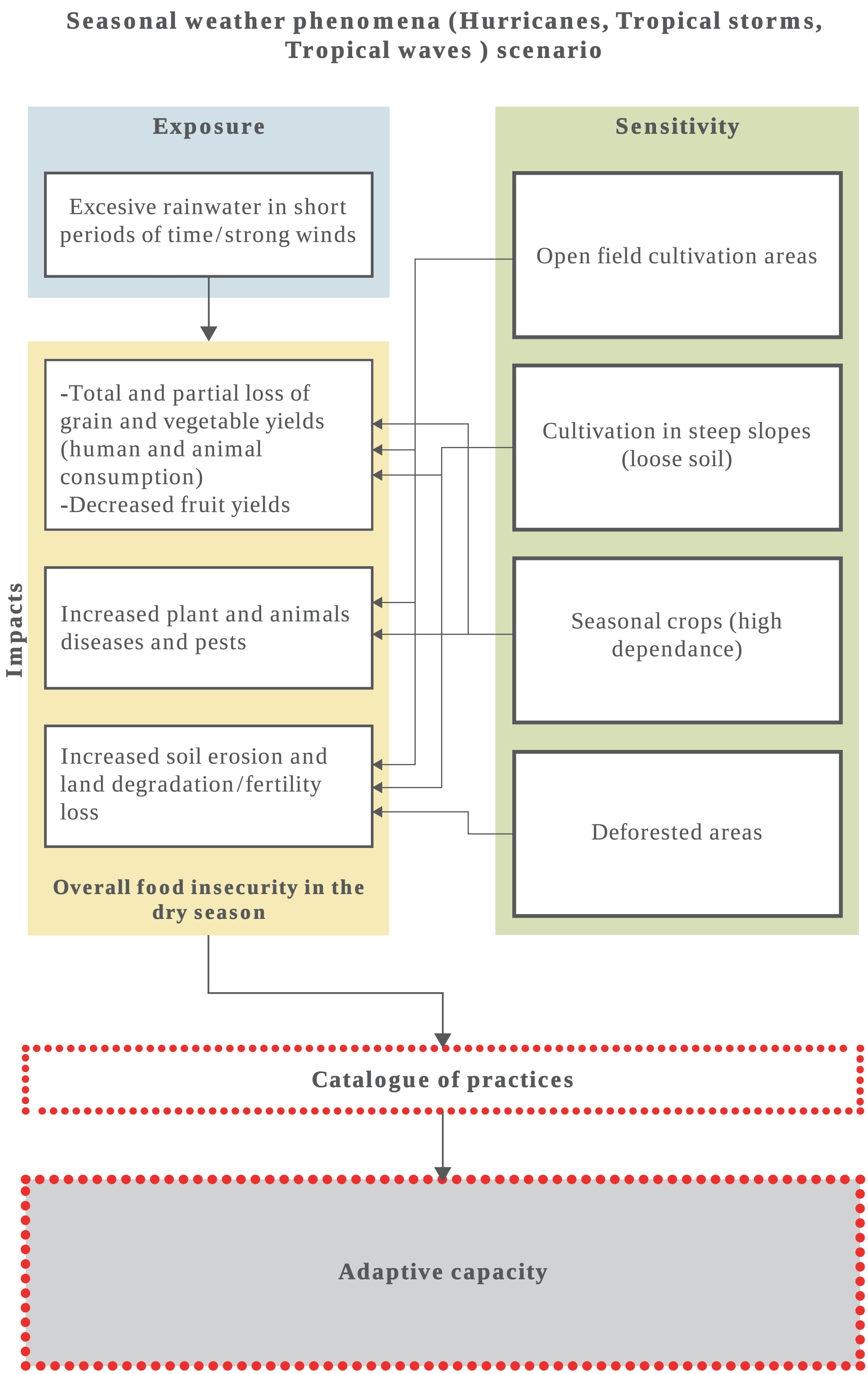


Figure 51-b: Seasonal weather phenomena impact chain scenario . Source: Author adapted from Adelphi/EURAC 2015

	Practice	Description	Origin
Crop rotation	 Figure 52: Crop rotation . Source: Author	Consists on alternating crops in the same field following a specific order. It is used to improve soil structure and as a pest control measure.	Local knowledge
Intercropping	 Figure 53: Intercropping . Source: Author	Consist on planting one type of crop among a different crop in a benefitial manner. Either to achieve a better use of resources or as a pest control measure.	Local knowledge
Polyculture	 Figure 54: Polyculture . Source: Author	Addition of new crops or cropping systems to the existing local ones in order to expand agricultural production and reduce the risk factor of crop failure.	External technical input and training
Rain water reservoir	 Figure 55: Rain water harvesting reservoir . Source: Author	Consist on the excavation of reservoirs with the purpose of harvesting rainwater during the rainy season to be used in the dry months.	External technical and practical support
Water tank	 Figure 56: Water tanks . Source: Author	Plastic tanks periodically filled with water from nearby streams or with rain water collected from the reservoir water during the dry season.	External technical and practical support

Table 6: Adaptation practices in Cerro Negro. Source: Author

Practice		Description	Origin
Drip irrigation	 Figure 57: Drip irrigation system . Source: Author	Alternative method of irrigation that allows water to drip slowly to the roots of the plants through a pipe system. Good water conservation measure.	External technical and practical support
Manual rotation	 Figure 58: Manual irrigation . Source: Author	Traditional irrigation technique that consist on watering the crops through the use of a water container or a hose.	Local knowledge
Seed preservation	 Figure 59: Seed preservation . Source: Author	Seed storage for the preservation of genetic diversity of a particular plant to be used at any time in the future.	Local knowledge
Home garden	 Figure 60: Home garden . Source: Author	Small scale production system of subsistence crops for the support of the household. It also includes the raise of small animals.	Local knowledge
Greehouse	 Figure 61: Greenhouse . Source: Author	Enclosed farming space isolated from external climatic conditions that allows the creation of controlled environments.	External technical and practical support

Table 7: Adaptation practices in Cerro Negro. Source: Author

Practice	Description	Origin
Slash/Mulch bean  Figure 62: Slash/Mulch bean. Source: Author	Consists of scattering bean seeds into weeds, then cutting and chopping the weeds so the scattered bean seeds are covered with a mulch of weeds.	Local knowledge
Organic fertilizers  Figure 63: Organic fermented fertilizers . Source: Author	Also known as 'bioles', it is a natural fertilizer alternative made from the fermentation of organic waste.	External technical input and training
Agrosilviculture  Figure 64: Agrosilvicultural system . Source: Author	Land-use system in which trees, shrubs, etc. are planted around or among crops in some form of spatial arrangement or predefined order.	Local knowledge
Silvopasture  Figure 65: Silvopastoral system . Source: Author	Practice of combining woodland (trees, shrubs, palms, bamboo, etc) with the grazing of livestock animals.	Local knowledge
Zero-tilling farming  Figure 66: Zero-tilling farming . Source: Author	Is a technique of growing crops from year to year without altering the soil through tillage to improves its water and nutrient retention.	External technical input and training

Table 8: Adaptation practices in Cerro Negro. Source: Author

Practice		Description	Origin
Shade mesh	 Figure 67: Shade mesh . Source: Author	Consists on a knitted polyethylene cloth that helps to protect the plants from the damage of direct sunlight and heat.	External technical and practical support
Plant nursery	 Figure 68: Plant nursery . Source: Author	Enclosed or semi enclosed space in which plants are being grown in controlled conditions until they are big enough to be planted in direct soil.	External technical input and training
Macro/Micro tunnel	 Figure 69: Macro/Micro tunnels . Source: Author	Metal framing covered with a lightweight polyethylene material that creates a tunnel like structure that protects the crops from the weather.	External technical and practical support
Living fence	 Figure 70: Living fences . Source: Author	Use of trees or bushes (alone or in combination of man-made elements) to create natural barriers. To divide roperty boundaries or production zones.	Local knowledge
Contour cropping	 Figure 71: Contour-base cropping . Source: Author	Consists of growing crops on following the contour of the terrain, across or perpendicular to a slope rather than up and down the slope.	Local knowledge

Table 9: Adaptation practices in Cerro Negro. Source: Author

5.3.1.1 Traditional knowledge practices

A quick analysis of the adaptation practices table allows to see a broad range of practices divided equally among local knowledge-based, and external knowledge-based. These findings, even though they show a positive attitude among the farmers towards the adoption of new knowledge, shed a light on the status of traditional knowledge preservation and its current relevance for climate adaptation in the community. Until now the locals have managed to achieve an adequate balance between local and foreign practices through a process of many years of experimentation however, interviews with the farmers revealed that some of these practices were abandoned through the years and readopted when they made the transition to organic agriculture, as this approach demanded more sustainable agricultural practices.

Despite the revival of certain traditional practices, it is evident that there is an ongoing process of loss of traditional knowledge in the community, either because younger generations lack to see the utility of such practices or, because they loose their relevance to address modern challenges. One good example of the former is a method of climate forecasting called ‚Pintas' which consisted on the prediction of the yearly climate behaviour by observing carefully the weather of each one of the first 12 months of the year. Even though there is no scientific proof of the effectiveness of the method, many farmers use to rely on this information to plan their yearly farming activities however, the practice gradually lost its credibility as the climate became more unpredictable. Regarding this matter, it was not possible to find any effective medium-term weather forecasting practices in the community. On the other hand, certain abandoned practices could prove to be of great value for the community if they were to be readopted, such as the use of natural pesticides, considering the limited pest control options available for organic agriculture. According to Manuel Arce, another local elderly, the use of natural insect repellents made from species such as tobaco (Nicotiana tabacum) or gliricidia (Gliricidia sepium) has been abandoned even though they proved to be very efficient against certain type of insects.

When asked which are the most effective resilience building measures available for the farmers, local farmer Miguel Martínez emphasizes on the importance of preserving the local seed species. He describes how they have tried in several ocassions to introduce certain foreign varieties with bad results and recognizes that the local seeds are the best adapted to the climate and the most resilient to shocks: „you have to work with what you know" (Martínez 2018). According to Martínez, some species of crops such as corn or bean, have been cultivated for more than 100 years by the farmers however, he also recognizes how other local varieties have been lost due climate change and to a combination of extreme climate events and the lack of a seed bank in the community as, in order to maximize production, every single seed is usually planted.

5.4 Adaptive capacity assessment

Based on the description and the purpose of each one of the identified practices it was possible to develop a categorization of the main actions that are being implemented in the community to address the impacts of drought and seasonal weather phenomena (See table 10). The list is very comprehensive as each one of the impacts is being addressed either by one or several of the actions however, until this point is not possible to know how effectively each one of this actions accomplishes its specific purpose. In order determine this, an assessment of the adaptive capacity to each scenario will be developed in the next section, based on an evaluation of performance of each one of the agricultural practices identified in the catalogue.

Crop rotation	Shade mesh
Intercropping	Drip irrigation
Polyculture	Manual irrigation
Rainwater reservoirs	Seeds preservation
Water tanks	Home gardens
Slash/Mulch bean	Greenhouse
Organic fermented fertilizers	Plant Nursery
Agrisilvicultural system	Macro/Micro tunnels
Silvopastoral system	Living fences
Zero-tillage farming	Contour-base cropping

Drought		
Rainwater harvesting	Increase of agrodiversity	Improvement of water management techniques
Improvement of soil moisture retention	Weather protected cultivation	Preservation of indigenous species

Seasonal weather phenomena		
Weather protected cultivation	Soil conservation in sloping cultivation lands	Pest control practices

Table 10: Adaptation practices vs adaptation actions. Source: Author

5.4.1 Methodology

The assessment was carried out using a matrix similar to the one used in the IVA. In the Y axis the adaptation practices are located while the X axis are located the scenarios 'Water scarcity and Temperature rise' (Drought scenario) and 'Increased rainfall and wind (Seasonal weather phenomena scenario), in the top row, and in the lower row the adaptive capacity actions. The assessment was done answering the question: How well does *any given practice* performs at achieving an *adaptation action*? (e.g How well does the practice of *zero-tillage farming* performs at *conserving soil moisture?*).

As in the IVA, a numerical value scale was used where 0 means very low performance, 1 is low performance, 2 stands for moderate performance, and 3 means good performance. As an aclaratory note, for the effects of the evaluation, the objectives 'Increase of agrodiversity' and 'Preservation of indigenous species' were combined into the objective 'Agrodiversity conservation' as the concept includes both aspects. Other evaluated aspects include the sectors in which these practices are implemented and roughly, a comparative representation of the cost of implementing each practice.

Shortcoming of the assessment process

Originally, the performance evaluation was intended to be developed with the members of the community as an extension of the IVA workshop however, due to logistical difficulties, this was not possible to achieve. Instead, an expert evaluation was done based on the information collected by the researcher which, includes several interviews to the farmers and observation of the implemented practices in a lapse of 6 days. Therefore, the evaluation here presented might be affected by the researcher's subjectivity or lack of information and might present significant variations from an evaluation made in a participatory setting.

5.4.2 The assessment

By analysing each one of the practices individually is possible to determine how much they support (or not) each one of the adaptive capacity actions being assessed, at the same time, the level of comprehensiveness of each practice on tackling several actions simultaneously is somehow reflected by referring to the overall score case however, it is visible that even the most comprehensive practices for each scenario (agrisilviculture for scenario 1 and greenhouse for scenario 2) fail to tackle all actions at once effectively, while other practices such as drip irrigation tackle few actions but in an outstanding way (See table 11).

Performance assessment

Adaptation Practices (Action / Scenario)	(1) Water scarcity/ Temperature rise: Soil moisture conservation	Rain water harvesting	Water management	Agrodiversity conservation	Sun/heat damage protection	Overall	(2) Increased Rainfall/Wind: Soil erosion protection	Disease/pest control	Rain/wind damage protection	Overall	Cost ($)	Sector: Crops	Sector: Livestock	Origin (External / Local)
Rainwater reservoirs	n.a	2	2	n.a	n.a	0.8	n.a	n.a	n.a	0	$$$	● In use	● In use	External technical and practical support
Water tanks	n.a	1	2	n.a	n.a	0.6	n.a	n.a	n.a	0	$$	● In use	● In use	External technical and practical support
Drip irrigation	3	n.a	3	n.a	n.a	1.2	n.a	n.a	n.a	0	$$	◐ Undeveloped		External technical and practical support
Crop rotation	3	n.a	2	2	n.a	1.4	3	2	n.a	1.6	$	● In use		Local practice
Polyculture	2	n.a	1	3	n.a	1.2	1	2	n.a	1	$	◐ Undeveloped		External technical input and training
Seeds preservation	n.a	n.a	n.a	1	n.a	0.2	n.a	n.a	n.a	0	$	◐ Undeveloped		Local practice
Agrisilviculture	3	n.a	3	3	2	2.2	3	1	2	2	$	● In use		Local practice
Micro/Macro tunnels	2	n.a	1	n.a	3	1.2	2	1	3	2	$$	◐ Undeveloped		External technical and practical support
Living fences	n.a	n.a	n.a	1	1	0.4	1	1	1	1	$	● In use	● In use	Local practice
Silvopasture	3	n.a	2	2	2	1.8	2	1	2	2	$		● In use	Local practice
Shade mesh	1	n.a	n.a	n.a	3	1	1	0	1	0.6	$$	● In use		External technical and practical support
Greenhouse	2	n.a	1	1	2	1.2	3	0	3	2.3	$$$	○ Abandoned		External technical and practical support
Intercropping	2	n.a	1	2	1	1.2	2	1	1	1.6	$	● In use		Local practice
Plant Nursery	n.a	n.a	2	2	3	1.4	n.a	1	3	1.3	$$	◐ Undeveloped		External technical input and training
Zero-tillage farming	3	n.a	2	n.a	1	1.2	3	2	1	2	$	● In use		External technical input and training
Manual irrigation	2	n.a	0	n.a	n.a	0.4	n.a	n.a	n.a	0	$	● In use		Local practice
Organic fermented fertilizers	2	n.a	1	1	n.a	0.6	2	n.a	n.a	0.6	$	● In use		External technical input and training
Home gardens	n.a	n.a	n.a	3	n.a	0.6	2	1	n.a	1	$	● In use	● In use	Local practice
Slash/Mulch bean	3	n.a	2	1	1	1.4	3	1	n.a	1.3	$	● In use		Local practice
Contour-base cropping	2	n.a	1	n.a	n.a	1.2	1	n.a	n.a	0.3	$	● In use		Local practice

n.a: non applicable; ● In use; ◐ Undeveloped; ○ Abandoned; Local practice; External technical input and training; External technical and practical support

Table 11: Adaptation practices evaluation. Source: Author with information provided by the farmers of Cerro Negro

After this preliminary analysis of results each action was analysed separately in a table in relation to the combination of practices attached to it. In this table each practice was allocated according to its performance value -from highest to the lowest- with the purpose of identifying strong and weak areas, as well as the diversity of practices available for the accomplishment of each objective.

5.4.2.1 Scenario 1: Water scarcity and temperature rise

'Water management' and 'Soil moisture conservation' presented the biggest variety of practices related to the adaptive action, with 16 and 15, respectively, (out of 20) and as well presented the highest number of practices that performed either very good or good. Interestingly enough, 5 out of the 6 practices that presented a very good performance for the action of 'Soil moisture conservation' are based in the farmers traditional knowledge, which shows a rooted adaptive capacity of the community to this aspect (See table 13). On the other hand, the local practice of manual irrigation presented itself as the only practice with a very poor performance value for the 'Water management' action. This case in particular is a good example of a practice deeply embedded in the culture which the farmers refuse to leave, despite having highly efficient alternatives available such as drip irrigation (See table 12).

'Agrodiversity conservation' as well presents a good variety of practices attached to it. The practice of polyculture, one of the best performing ones, is in part a direct result of the creation of the organic farmers association which has encouraged the introduction of new crop species, and in other part a result of climate change as the farmers have tried to introduce variations of known species in order to increase productivity. Less successful, but with immense potential for development, is the local practice of seed preservation which is currently practiced in a very rudimentary way and with inconsistent results (See table 14).

On the other side of the spectrum, the objective of 'Rain water harvesting' showed the least diversity with only two practices attached to it: the rain water harvesting reservoirs and the water tanks (See table 15). The case of the rainwater harvesting reservoirs is a special one as its recent implementation in 2009 was the first adaptation measure that tackled the issue of water scarcity in the dry season in an effective way. Nonetheless, the technology has its limitations -including its high cost-, and despite its importance for the community's resilience, the practice alone has not been enough to provide the farmers with enough water to guarantee secure productivity and employment all year round. This is certainly the weakest objective in term of diversity of practices and one of which requires

Water management (1.6)			
Good (3)	Moderate (2)	Low (1)	Very low (0)
Drip irrigation	Rain water reservoirs	Polyculture	Manual irrigation
Agrisilviculture	Water tanks	Micro/Macro tunnels	
	Crop rotation	Intercropping	
	Silvopasture	Organic fertilizers	
	Greenhouse*	Contour base cropping	
	Plant nursery		
	Zero-tillage farming		
	Slash/Mulch bean		
* Discontinued			

Table 12: Water management assessment. Source: Author

Soil moisture conservation (2.38)			
Good (3)	Moderate (2)	Low (1)	Very low (0)
Drip irrigation	Polyculture	Shade mesh	
Crop rotation	Micro/Macro tunnels	Greenhouse*	
Agrisilviculture	Intercropping		
Silvopasture	Organic fertilizers		
Zero-tillage farming	Contour-base cropping		
Slash/Mulch bean	Manual irrigation		
* Discontinued			

Table 13: Soil moisture conservation assessment. Source: Author

Agrodiversity conservation (2)			
Good (3)	Moderate (2)	Low (1)	Very low (0)
Polyculture	Crop rotation	Living fences	
Agrisilviculture	Silvopasture	Greenhouse*	
Home gardens	Plant nursery	Organic fertilizers	
	Intercropping	Slash/Mulch bean	
		Seed preservation	
* Discontinued			

Table 14: Agrodiversity conservation assessment. Source: Author

Rain water harvesting (1.5)			
Good (3)	Moderate (2)	Low (1)	Very low (0)
	Rain water reservoirs	Water tanks	
* Discontinued			

Table 15: Rainwater harvesting assessment. Source: Author

Sun/heat damage protection (1.8)			
Good (3)	Moderate (2)	Low (1)	Very low (0)
Micro/Macro tunnels	Agrisilviculture	Living fences	
Shade mesh	Silvopasture	Intercropping	
Plant nursery	Greenhouse*	Zero-tillage farming	
		Slash/Mulch bean	
* Discontinued			

Table 16: Sun/Heat damage protection assessment. Source: Author

more attention.

Finally, regarding the 'Sun/Heat damage protection' action, the most remarkable aspect is that all of the practices with the higher performance were introduced recently in the community by external institutions. The need of sun and heat equipment is closely related to the process of crop diversification which has brought to the community species not adapted to the climate conditions of the region and with it, the need of more controlled growing environments (See table 16).

5.4.2.2 Scenario 2: Increased rainfall and wind

The 'Soil erosion protection' action presented the highest diversity of practices from all the objectives for the scenario 2, including 14 out of the total 20 identified. As the 'Soil moisture conservation' objective it presents a high number of traditional knowledge-based practices ranking in the highest levels. This not only proves the effectiveness of the community's traditional knowledge in soil conservation practices but as well shows the influence of moisture on soil stabilization (See table 17).

Regarding the 'Disease/Pest control' action, the evaluation shows a lack of effective practices addressing the accomplishment of this objective. The fast transition of the community to organic agriculture and an over-reliance in the past to chemicals and pesticides has left the community defenceless against pests and diseases. This, was pointed out by the farmers as the most recurrent issue in the agricultural activity, affecting them almost regularly every year, in many cases to the extent of a total loss of the yields. The case of the greenhouse is good example of a technology that, even though, has a high potential for pest control, it ended up having a very poor performance due to bad handling and high costs of the equipment, which is the main reason why its use was discontinued (See table 18).

Finally, the 'Rain/Wind damage protection' action shows a very balanced set of

Soil erosion protection (2)			
Good (3)	Moderate (2)	Low (1)	Very low (0)
Agrisilviculture	Micro/Macro tunnels	Polyculture	
Zero-tillage farming	Silvopasture	Living fences	
Slash/Mulch bean	Intercropping	Contour base cropping	
Crop rotation	Organic fertilizers	Shade mesh	
	Home gardens		
	Greenhouse*		
* Discontinued			

Table 17: Soil erosion protection. Source: Author

Disease/Pest control (1)			
Good (3)	Moderate (2)	Low (1)	Very low (0)
	Crop rotation	Agrisilviculture	Shade mesh
	Polyculture	Micro/Micro tunnels	Greenhouse*
	Zero-tillage farming	Living fences	
		Intercropping	
		Plant nursery	
		Home gardens	
		Slash/Mulch bean	
		Silvopasture	
* Discontinued			

Table 18: Disease/Pest control assessment. Source: Author

Rain/Wind damage protection (1.75)			
Good (3)	Moderate (2)	Low (1)	Very low (0)
Greenhouse*	Agrisilviculture	Living fences	
Plant nursery	Silvopasture	Shade mesh	
Micro/Macro tunnels		Intercropping	
		Zero-tillage farming	
* Discontinued			

Table 19: Rain/Wind damage protection. Source: Author

practices supporting it, however, it presents certain particularities regarding the high-performance practices that need consideration: certainly the greenhouse proved to be one of the most efficient technologies for isolating crops from harmful environmental factors however, since its use was halted -due to high costs and pest control problems- it can not be considered as a currently available practice to address the issue. The plant nursery, on the other hand, is still an active practice that, as well as the greenhouse, allows the creation of controlled environments in a very efficient way but with its shortcomings. On one hand, it is only useful in the early stages of the plant -when is more vulnerable to environmental factors-, and on the other, it only covers a very limited area of the cropping land. The aforementioned aspects reveal a lack of highly efficient practices for the reduction of risk related to the harmful effects of intense rain and wind for open cropping fields (See table 19).

5.4.2.3 Findings

-A lack of efficient pest control practices, an undeveloped water harvesting and water management system, and lack of weather protection measures are the main weaknesses of the community while soil conservation actions represent its strenghts.

-Traditional knowledge-based practices are still very relevant and play a big role on the adaptation capacity of the community, showing a good level of performance in different categories of the assessment. Among these, agrisilviculture reveal itself as the one with highest amount of benefits attached to it.

-By confronting local practices against external practices is it possible to notice that, while local practices performed better for conservation purposes, external practices performed better for protection purposes. This aspect exposes a gap in the community's traditional knowledge regarding damage-reducing measures that need to be considered.

-The assessment shows an good level of awareness and response among the farmers regarding climate-related issues and its consequences on the landscape.

5.4.3 Societal environment

After having analysed the adaptive capacity of the socio-productive landscape based on the influence of the biophysical environment, a final step is to determine the influence that the societal environment has on this adaptive capacity. The main variables of the socio-economic system were assessed using a table which summarizes the most relevant socioeconomic aspects of each variable

Variable	Summary	Issue/Opportunity	Influence on the adaptive capacity of the community	Value	Value criteria	Value criteria
Labour force availability	Besides the children and those attending highschool, almost every every member of the family is engaged in some kind of labor. Men from 17 up are mostly engaged in agricultural practices. While the younger ones prefer to leave the community during the low seasons, the older ones -including- the elderly, stay in the community. Women are usually engaged in household tasks and the raising of small animals	.Temporary and permanent youth labor migration	.Reduced labor force has caused a reduction on the cultivated land over the years and a reduction of the productivity levels, damaging the economy of the community	**1** **Low availability**	0-Very low: No available labour force 1-Low: Least than one person per household works in the community 2-Moderate: At least one person per household works in the community 3-High: More than one person in each household works in the community	
Cognitive ability and linguistic capacity	.The vast majority of the inhabitants went to primary school (not all of them finished) and know how to read and write. .Since one year ago some teenagers were given the opportunity to go to highschool for the first time in the history of the community. .Some farmers have been able to receive special training related to new agricultural techniques	.Limited opportunities of education to those older than 17 years old .Knowledge gap in agricultural practices between farmers	.Access to education regarding climate change can give people the skills and knowledge to be better prepared for, and better able to recover and adapt from, natural hazards .Training on new sustainable agricultural practices has enhanced the adaptive capacity of the farmers	**2** **Moderate capacity**	% population that knows how to read and write 0-Very low: 1 to 25% 1-Low: 26 to 50% 2-Moderate: 51 to 75% 3-High:76% to 100%	% population with general knowledge about climate related hazards 0-Very low: 1 to 25% 1-Low: 26 to 50% 2-Moderate: 51 to 75% 3-High:76% to 100%
Availability of resources	.There is no public transportation service to the settlement, few inhabitants have motorized vehicles. The only transportation service available is the one that takes the teenagers daily to highschool .The closest services (health, post office, police) are located 8 km away from the community .There is electricity service .There is no water supply service	.Lack of transportation system in the community .Lack of basic services inside the community .Lack of water supply system	.Lack of efficient transportation has had a negative impact on trade and access to markets .The lack of health facilities has created a situation of health insecurity and aggravation of illnesses .Difficult performance of daily activities .The lack of a water supply service difficult the access to the resource in certain areas and affects its storage for the dry months	**0** **Very low availability**	% with available resources 0-Very low: 1 to 25% 1-Low: 26 to 50% 2-Moderate: 51 to 75% 3-High: 76% to 100%	
Technology & Communication system	.There is no telephone line or internet, people communicate with celphones but the signal is deficient .Most inhabitants own a cellphone but only few school children own a computer	.Lack of efficient communication services (internal or external) .Technological gap .No internal warning system in case of a disaster	.Affects the capacity of the community to call for assistance in case of an emergency .Reduced capacity of reaction in case of an emergency .It has a negative impact on the commercialization of the association .It has a negative impact on the modernization of productive activities	**1** **Low availability**	% of population with access to communication systems 0-Very low: 1 to 25% 1-Low:26 to 50% 2-Moderate: 51 to 75% 3-High: 76% to 100%	Existence of internal warning systems 0-Without 1-With, poor 2-With, moderate 3-With, good

Table 20: Socioeconomic variables asessment (1). Source: Author based on García et.al (no date)

Variable	Summary	Issue/Opportunity	Influence on the adaptive capacity of the community	Value	Value criteria	Value criteria
Degree of access to the communty	The settlement is located in the top of a mountain (680 m.a.s.l) with difficult access due to the topography and the condition of the road	.Bad condition of the access road	.Negative impact on movilization of goods, people and equipment in and out of the community, difficult access to markets .Diminished capacity of response and assistance in case of a disaster or emergency	**0** **Very poor**	0-Very poor: Dirt road, limited access 1-Poor: Gravel road, limited access 2-Moderate: Gravel road, all vehicles 3-Good: Paved road, all vehicles	
Strength or availability of support systems	There are several governmental and non-governmental institutions that has supported the community through the years in different sectors (agriculture, housing, health, etc.)	.Lack of governmental support .Lack of continuity of projects implemented .Creation of new external collaboration networks	.Stagnation of the development of community infrastructure .Increased dependance from external aid affects entrepeneurship and communal initiative .Has favoured the introduction of external adaptation capacity practices	**2** **Moderate availability**	Existence or availability of support systems 0-Without 1-With, poor 2-With, moderate 3-With, good	
Economic capacity	.The income of the farmers varies according to the season and levels of productivity .The income source is mainly agriculture followed by cattle raising. Secondary sources include the sell of animal farm products, the processing of ojoche, and the raising of tilapia .Few farmers have the economic capacity to afford more expensive climate adaptation technologies such as the rainwater harvesting reservoir	.High levels of poverty .Overdependence on agriculture as the main source of income .Unequal access to resources between farmers	.Reduced income and food security in the dry season .Lack of resources prevent the farmers to implement projects by the own .Reduced diversity of livelihood activities	**0** **Very poor capacity**	% population above the national minimum wage 0-Very poor: 1 to 25% 1-Poor: 26 to 50% 2-Moderate: 51 to 75% 3-Good: 76% to 100%	
Organizational capacity	Establishment of an organic farming association in 2002 that still operates today	.Lack of leadership and resignation of key members .Conflicts of personal interest among members of the association .Lack of collective vision	.Allowed the transition to organic agriculture and the adoption of more sustainable farming practices .Diversification of agricultural production .Higher credibility .Access to alternative markets with less competition .Unification of efforts and resources	**2** **Moderate capacity**	Existence of organized groups in the community 0-Without 1-With, poor 2-With, moderate 3-With, good	

Table 21: Socioeconomic variables asessment (2). Source: Author based on García et.al (no date)

encountered in chapter 4 and determines its influence on the overall adaptive capacity using a numerical ranking where 0 is very low, 1 is low, 2 is moderate and 3 is high (See tables 20, 21).

The results of the assessment shows an overall negative influence of the variables on the adaptive capacity of the community which, is a reflection of the difficult socioeconomic situation of the inhabitants of the micro-watershed and the entire Cerro Negro community. Almost all variables present unfavourable conditions that are detrimental to the adaptive capacity of the community, being the lack of infrastructure and services the areas that showed the lowest value. The bad condition of the road and the difficult access to the community in particular, was pointed out by the locals in several occasions as the one of the main limitations to the development of the community.

On the other hand, among the variables that showed a higher value, the organizational capacity of the community stands out as the main driver of progress as it has allowed, among other things, the development of the agricultural activity, a higher recognition in the regional market, as well as it has influenced other variables such as a enhanced access to external support which have helped to make the needs of the community more visible to the local authorities.

5.5 Overall results

The adaptation capacity assessment results show a moderate adaptation capacity of the socio-ecological landscape when social aspects are not considered. The scenario of the drought presented not only more diversity of actions for adaptation but also better performance of the practices analysed when compared with the seasonal weather phenomena scenario.

This numbers reflect a good level of awareness of the farmers to the existing

Soil moisture conservation (2.38)	1.85	1.71	1.35 Low (-)	1	Labour force availability (1)
Water management (1.6)					Cognitive ability and linguistic capacity (2)
Agrodiversity conservation (2)					Availability of resources (0)
Rain water harvesting (1.5)					Technology & Communication system (1)
Sun/heat damage protection (1.8)					Degree of access to the community (0)
Soil erosion protection (2)	1.58				Strength/availability of support systems (2)
Disease/Pest control (1)					Economic capacity (0)
Rain/Wind damage protection (1.75)					Organizational capacity (2)

Very low 0 — 0.5 — Low 1 — 0.5 — Moderate 2 — 0.5 — High 3

- + - + - +

Table 22: Overall adaptation capacity value. Source: Author

susceptibilities of the biophysical system and a moderate level of response to the hazards that affects their livelihoods. However, when overlapped with the values obtained from the socioeconomic variables assessment it is revealed the big influence of the societal environment on the overall adaptation capacity of the community (See table 22).

This has a direct impact on the development opportunities of the farmers who often times find their adaptation initiatives limited by physical, economical or infrastructural constraints (e.g the construction of a rainwater harvesting reservoir). The intrinsic relationship between this two realms need to be carefully taken into consideration when proposing the introduction of new adaptation practices in the community.

Figure 72: Farmers or Cerro Negro. Source: Author

Chapter 6: Conclusion

6.1 Introduction

The final chapter of this research will be divided in four parts:

-Proposal of recommendations for the enhancement of the future adaptive capacity of the socio-ecological productive landscape of the micro-watershed based on the findings encountered in the adaptive capacity assessments.

-Discussion part in which the research question formulated in the first chapter will be addressed in an attempt to answer it

-Proposal for further steps in the research based on the potential of transferability of foreign practices

-General conclusions summarizing the main findings of the research

6.2 Recommendations

The following tables present a summary of the best practices attached to each one of the adaptation actions according to the assessment results as well as recommendations regarding which practices hold potential to show a better performance if its use is redirected into certain specific purposes. As well, it present a brief descriprion of areas that could be improved in order to enhance the adaptive capacity of the community. This recommendations aim at a most efficient use of existing knowledge and resources trying to encourage self-sufficiency and less dependancy on external resources considering the economical and infrastructural limitations of the community. At the same time it recognizes the importance of external cooperation, specially in the form of training and introduction of new knowledge, which assimilation can be facilitated by the learning capacity of the farmers and their good disposition to adopt new knowledge. Finally, it suggests which institutions could be involved for the execution of each one of the recommendations based on the existing external contacts that have supported the community in the past (See tables 23, 24, 25, 26).

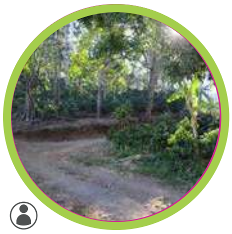
Good practice
Potential for development

Water management

Good practices

Drip irrigation

Agrisilviculture



Polyculture

What can be improved?	Who can be involved?
-In order to maximize water-use efficiency, the farmers should receive more training regarding the specific water demands of each crop based on its type, the type of the soil and the evapotranspiration rates.	-Ministry of Agriculture and Livesock (MAG) (training) -National University (UNA) (technical knowledge)
-The use of polyculture systems offer an untapped potential for the search of water-use efficiency crop species resistant to drought conditions.	-Ministry of Agriculture and Livesock (MAG) -National University (UNA)
-Water waste related to manual irrigation practices should be avoided specially during the dry season.	-Farmers (modification of behaviour)
-Afforestation of upper areas of the micro-watershed can improve recharge of aquifers and water volume of springs in the dry season.	-Livestock owners -Forest Financing Fund of Costa Rica (FONAFIFO)

Good practice
Potential for development

Agrodiversity conservation

Good practices

Home gardens

Polyculture

Agrisilviculture

Seed preservation

What can be improved?	Who can be involved?
-The practice of seed preservation hold immense potential for the preservation of agrodiversity which is not taken fully advantage of. The saving and storing of local crop varieties should be encouraged as a common agricultural management practice and as a measure for climate adaptation. More training is needed on viable methods and technologies that can be used by the community	-Ministry of Agriculture (MAG) (training) -FAO (technical knowledge -Farmers -Housewives

Table 23: Recommendations (1). Source: Author

Good practice
Potential for development

Sun/Heat damage protection

Good practices

Micro/Macro tunnels	Shade mesh	Plant nursery	Agrisilviculture
			

What can be improved?	Who can be involved?
-The development of the agrisilviculture practice with the purpose of enhancing the protection of crops to the harmful effects of radiation and heat can reduce the dependence of the farmers on costly external equipment and resources. More knowledge and training is required regarding the use of different tree/crop systems to control radiation, and how aspects like canopy structure, tree row orientation, tree spacing, solar path or the geographical location can be used in favour of the agricultural activity.	-National University (UNA) (technical knowledge) -Ministry of Agriculture and Livestock (MAG) (know-how and training) -Farmers

Good practice
Potential for development

Soil/moisture conservation

Good practices

Drip irrigation	Crop rotation	Agrisilviculture	Silvopasture
			
Zero tillage	Slash/Mulch	Terracing	
			

What can be improved?	Who can be involved?
-Retake the abandoned practice of terracing in high slope areas to reduce runoff speed and improve soil water retention.	-National Institute of Learning (INA) -Farmers

Table 24: Recommendations (2). Source: Author

Good practice
Potential for development

Rain water harvesting

Good practices

Rain water harvesting reservoirs

What can be improved?	Who can be involved?
-Further development of the rainwater harvesting concept, aiming at the diversification of water harvesting technologies (e.g roof top harvesting), specially for those farmers without the economic capacity to afford the construction of a reservoir.	-National University (UNA) (technical knowledge) -FAO (technical knowledge and training) -INDER (equipment)
-Exploration of different combinations of low-cost sun protecting practices with open air reservoirs in order to reduce water loss from evaporation in the dry season.	-Farmers
-Landscape interventions such as runoff water diversion canals can support the faster filling of big reservoirs specially in rainy seasons with decreased rainfall levels.	-FAO (technical knowledge and training) -Farmers

Good practice
Potential for development

Soil erosion protection

Good practices

Zero tillage

Slash/Mulch

Agrisilviculture

Crop rotation

What can be improved?	Who can be involved?
-Increase afforestation of grazing lands in order to reduce soil damage and erosion, specially in the upper areas of the micro-watershed	-Livestock owners -Forest Financing Fund of Costa Rica (FONAFIFO)
-Implement the practice of grazing land rotation to reduce soil erosion and promote pasture regeneration.	-Livestock owners
-Retake the abandoned practice of terracing in high slope areas for soil stabilization and erosion control	-Farmers

Table 25: Recommendations (3). Source: Author

Good practice
Potential for development

Disease/Pest control

Good practices

Intercropping

What can be improved?	Who can be involved?
-Strengthening of intercropping as a pest control measure in different variants: repellent intercrops, trap cropping or pull-push cropping.	-National University (UNA) (technical knowledge) -Farmers
-Re-exploration of the use natural pesticides made from local plant varieties that has been abandoned in the past.	-Farmers -Elderly
-Increased knowledge of wind currents and pest dispersal can be a strong criteria for the selection of cultivation areas or the location of wind barriers.	-University of Costa Rica (scientific knowledge) -Farmers

Good practice
Potential for development

Rain/Wind damage protection

Good practices

Micro/Macro tunnels

Plant nursery

Living fences

What can be improved?	Who can be involved?
-The development of the agroforestal systems with the purpose of enhancing the protection of crops to the harmful effects of intense rain and strong winds can reduce the dependence of the farmers on costly external equipment and resources. More knowledge and training is required regarding the use of living fences not only as land-use dividers but as wind-breakers using dense-foliage local tree and bush species .	-National University (UNA) (technical knowledge) -Ministry of Agriculture and Livestock (MAG) (training) -Farmers

Table 26: Recommendations (4). Source: Author

6.3 Discussion

The whole body of information obtained through the development of this research allow us to finally answer the research question posed in the first chapter of this thesis: '*Which are the linkages between the currently used agricultural practices based on traditional knowledge and the climate-adaptation capacity of Cerro Negro's socio-ecological productive landscape?*'. Based on the findings obtained from the assessment of the adaptation practices, which exposed the degree of influence that each practice has on the correct accomplishment of each adaptation action, it is possible to conclude that most of the practices based in traditional knowledge have a big weight on the overall adaptation capacity of the socio-ecological productive landscape specially for the actions that involve conservation of some type (water, soil and agrodiversity). However, it is also recognizable the inability of local practices to address properly key climate hazards such as crop damage from weather exposure and water scarcity, exposing the equal importance that external practices have had filling the gaps not covered by the knowledge of the locals.

In conclusion the adaptive capacity of the community is determined by the harmonious coexistence of local and external inputs confirming the important role that external cooperation has for the improvement of the climate change resilient capacities of remote rural communities in the North Pacific region.

6.4 Further research

The rainwater harvesting reservoirs is not only the most representative case of how the introduction of an external practice can impact positively the resilience capacity of a rural community, but as well supports the third objective of this research which, aimed at the identification of effective practices currently used in the community that are based on traditional knowledge coming from other parts of the world. The practice of water harvesting through the use of reservoirs dug in the ground has been reported in many parts of the world as a common practice dating from centuries ago in places experimenting seasonal droughts (See figures 52, 53).

Even though the introduction of the reservoirs was not done following a strict process of traditional knowledge transferability, it shows the underlying potential of this approach if done in a conscious and methodical way. The study of other regions of the world experimenting similar climate challenges as Cerro Negro could offer the opportunity of extracting universal principles of climate adaptation that could be introduced and tested in the community, as well as the opportunity to transfer new adaptation practices that could be contextualized in Cerro Negro, considering the existence of cultural and environmental similarities.

Figure 73: Rainwater reservoir in Cerro Negro. Source: Author

Figure 74: Jahnbora reservoir in India. Source: http://www.indiawaterportal.org/articles/rejuvenating-traditional-water-system-maharashtra

The use of the Köppen-Geiger classification system could be tested as an initial approximation to this approach which could help narrow down the process of search to the regions of the world sharing the same Tropical Savanna (Aw) climate type as the North Pacific region of Costa Rica, which presents the same pattern of precipitation and faces similar issues regarding seasonal drought (See figure 54). The next step would be, to access the database of documented traditional knowledge of the studied region looking at techniques that could be applied in similar topographical contexts and avoiding practices that require extensive labour force, high investment, or are simply against the cultural practices of Cerro Negro.

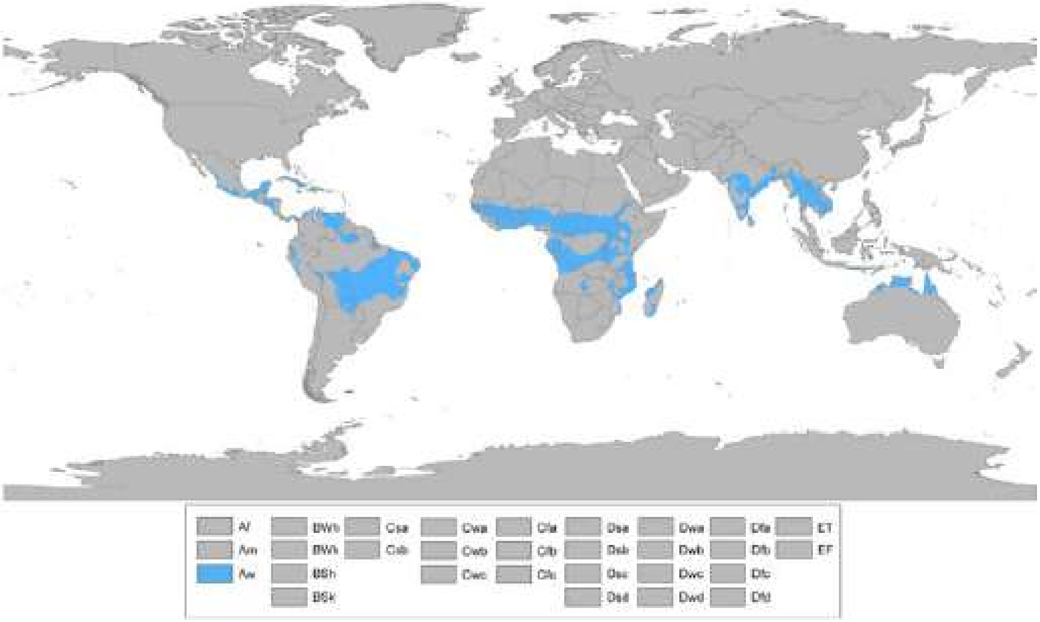


Figure 75: Tropical Savanna (Aw) climate zone map. Source: https://en.wikipedia.org/wiki/Tropical_savanna_climate#/media/File:Koppen_World_Map_Aw.png

6.5 General conclusions

-Community organization is a fundamental step to enhance resilience and to raise the voice of the needs of remote rural communities, to achieve this goal it is necessary first to modify common behaviours of excessive individualism among the small producers of the North Pacific region

-Farm clustering under a model of shared production and tasks allow a better distribution of efforts and resources under a common goal, reduce competition and creates reinforces communal identity.

-The level of resilience of Cerro Negro is determined by the interaction of internal environmental and socioeconomic factors as well as by external factors related to lack of governmental support, and change of market policies in past years.

-The socioeconomic situation of the community is the defining factor of the level of vulnerability to the negative effects of drought and seasonal weather phenomena. Even though the productive landscape showed moderate adaptive capacity to climate-related impacts, variables such as lack of infrastructure and lack of labour force, reduce exponentially the opportunities of the inhabitants to effectively cope and adapt. This limitation of economic resources has also prevented all farmers to adjust their farming practices equally.

-External cooperation certainly has a big impact on rural development in the North Pacific region, often-times fulfilling the role that local governments have neglected however, still a huge amount of financial, technical and institutional support is needed to improve the resilient capacities of the community and secure their livelihoods for future generations.

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نبذة مختصرة

في المناخات الاستوائية الجافة-الرطبة ، الإنتاج الزراعي لأصحاب المزارع الصغيرة مهدّد بشدة بسبب تغير المناخ. بالأخص في حالة كوستاريكا في شمال المحيط الهادي، فإن الأنماط غير المنتظمة لهطول الأمطار بالإضافة إلى شحّ المياه، والمرتبطة بظاهر النينيو المناخية، تؤثر على الغلة الموسمية للمحاصيل وتعرض سبل العيش والاستقرار الاقتصادي للمجتمعات الريفية النائية للخطر. من أجل توسيع فهم نقاط ضعف هذه المجتمعات واحتياجات التكيف فيها، أُجرِيَت دراسة في المجتمع الزراعي الجبلي في سيرو نيغرو في إقليم نيكويا. أجري مع المزارعين تقييم لنقاط الضعف من أجل وصف تأثر القدرة الإنتاجية البيئية-الاجتماعية وتحديد استراتيجيات التكيف القائمة لديهم واحتياجاتهم. المزارعون بالأخص معرضون للنتائج المترتبة على ندرة المياه، ارتفاع درجة الحرارة، وشدة هطول الأمطار وهبوب الرياح، والتي تؤثر على الأنماط الموسمية للزراعة وتقلّص من الإنتاج الزراعي إلى أدنى مستوياته. إن العديد من ممارسات التكيف المستندة إلى المعرفة المحلية والخارجية متاحة للمزارعين للحد المخاطر ونقاط الضغف، ولكن العوامل المتمثلة في تسارع هجرة الشباب، نقص الموارد المالية، وضعف توفّر البنية التحتية والخدمات، جميعها تؤثر بشكل كبير على قدرة التكيف الشاملة للمجتمع. إنه من الضروري زيادة الدعم الخارجي عبر توفير الخبرات والموارد لهذه المجتمعات من أجل زيادة مرونتها وقدرتها على التكيف وتأمين سبل العيش للأجيال القادمة فيها.

إقرار

هذه الرسالة مقدمة في جامعة عين شمس وجامعة شوتجارت للحصول على درجة العمران المتكامل والتصميم المستدام. إن العمل الذي تحويه هذه الرسالة قد تم إنجازه بمعرفة الباحث سنة ...

هذا ويقر الباحث أن العمل المقدم هو خلاصة بحثه الشخصي وأنه قد اتبع الإسلوب العلمي السليم في الإشارة إلى المواد المؤخوذه من المراجع العلمية كلٌ في مكانه في مختلف أجزاء الرسالة..

وهذا إقرار مني بذلك،،،

التوقيع: 

الباحث: جيان كارلو منيوز راميريز

التاريخ: 07.29.2018

البيئات الإنتاجية الصامدة للتغير المناخي: تقييم التكيف المناخي في مجتمع سيرو نيغرو، نيكويا، كوستاريكا

مقدمة للحصول على درجة الماجستير في العمران المتكامل والتصميم المستدام

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جامعة ....

تاريخ المناقشة:..............

الدراسات العليا

ختم الإجازة

أجيزت الرسالة بتاريخ:.............

موافقة مجلس الكلية .../.../...

موافقة مجلس الجامعة .../.../...

جامعة عين شـــــمس

جامعة شتوتجارت

07/29/2018

جامعة عين شـــــمس

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