Encouraging Climate Change Adaptation through Payment for Environmental Services: Case Studies in the Pacific Region of Costa Rica

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

During the last decade, climate change has prolonged droughts and increased rainfall intensity, which has resulted in an increase in the number of flash floods and tropical storms. These events are affecting Costa Rica's agriculture sector and are impacting the country's food security. The main objective of this study was to evaluate farmers' local knowledge and perceptions about climate change and determine the impacts of the payment for environmental services (PES) programme on assisting farmers to integrate information and use innovative technologies to adapt to climate change. Research indicates that although climate change is affecting Costa Rican agriculture, there are adaptation strategies to help alleviate the negative impacts. Farmers in two geographical areas were interviewed to evaluate their integration of climate change information into land management practices. The two areas were Esparza, in the northern part of the province of Puntarenas, and Durika, in southern Puntarenas, Costa Rica. Farmers interviewed in Esparza were chosen based on their involvement in a PES project developed by Centro Agronómico Tropical de Investigacíón y Enseñanza (CATIE). Farmers in Durika were chosen because they practice sustainable agricultural techniques that more formally integrate climate change information. Results showed that the PES project was a successful approach to encourage farmers to adapt to climate change. Farmers in Durika and Esparza mentioned the importance of financial incentives combined with improved knowledge and understanding of climate change to encourage adaptation. Important adaptation strategies implemented in Esparza included the use of agroforestry, *Brachiaria spp*. grasses, water conservation and protection, and supplements. Based on the success of CATIE's project combined with comments made from farmers in Durika, recommendations are made to improve this project and extend information into the rest of the country.

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Chapter 1 Introduction

1.1 Background

Throughout the world, global climate patterns are changing in ways that are creating anxiety among scientists, researchers, and the general public. According to McCaffrey (2006), editor of the journal *Global Climate Change,* climate change is going to be one of the most important and most difficult challenges humanity must face through the 21st Century. Strategies are developed in many parts of the world to mitigate the release of greenhouse gas (GHG) emissions, and to help different sectors adapt to climate change (Mendelsohn, 2006). The Food and Agriculture Organization of the United Nations (FAO) states that agriculture is one such sector where the effects of precipitation and temperature change could be devastating both for small-scale farmers who depend on agriculture for food and income as well as for global food security as a whole (Kruse, 2005). As a result, strategies are designed to help farmers adapt to the impacts of climate change and, in some cases, to reduce levels of atmospheric carbon dioxide (CO_2) (Oelbermann et al., 2004; Oelbermann et al., 2006).

1.2 Climate Change in Costa Rica

Developing countries are expected to feel the impacts of climate change more severely than more developed countries because of their dependence on natural resources and limited capital available to adapt (Fritschel, 2006). Because of the nature of climate change, the potential impacts on temperature and precipitation are difficult to predict, and changes within a specific region are even more difficult to forecast (IPCC, 2005). This makes it challenging for researchers to give precise figures on the actual future impacts of climate change in a given area. This also complicates the evaluation of how various sectors can, and are, adapting to climate change.

Costa Rica is an example of a developing country feeling the impacts of climate change. Many organizations, including Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) and the Centre for International Forestry Research (CIFOR), have begun examining different aspects of climate change and is impacting on various sectors within the country (Vignola, 2005; TroFCCA, 2006).

The Centro Agronómico Tropical de Investigacíón y Enseñanza is an example of one such organization. It is a graduate and research institute located in Turrialba, Costa Rica, and is well known globally for its work in tropical agriculture and forestry. A proportion of CATIE's research focuses on climate change adaptation as well as how agriculture can be used to offer environmental services, such as reducing levels of atmospheric CO_2 (CATIE, 2007). One major project CATIE is currently involved with is the payment for environmental services (PES) project, where farmers are paid for implementing environmental services on their farms. This project is minimally associated with climate change adaptation; however, climate change mitigation is a major part of it, specifically the use of carbon sequestration.

The Centro Agronómico Tropical de Investigacíón y Enseñanza and the Centre for International Forestry Research (CIFOR), an international organization conducting research in Costa Rica, developed the project Tropical Forest and Climate Change Adaptation (TroFCCA). This project is funded by the European Commission and works in several regions of the world, including Costa Rica, to develop adaptation strategies that help reduce the overall impact of climate change (TroFCCA, 2006).

1.3 The Impact of Climate Change on Costa Rica's Agricultural Industry

Agriculture is one of the major economic bases for Costa Rica, along with tourism and the export of electronics (World Factbook, 2006). The main agricultural products produced in Costa Rica are coffee, pineapple, bananas, sugar, corn, rice, beans, potatoes, beef, and timber (World Factbook, 2006). Twenty percent of the population is involved in agriculture and it represents approximately nine percent of the country's Gross Domestic Product (GDP) (World Factbook, 2006). In Costa Rica, agriculture occurs at the commercial level, including large scale farms such as Del Monte and Dole, and on a subsistence level (World Factbook, 2006). As the climate continues to change, people involved with small-, medium-, and large-scale agriculture are potentially facing many negative repercussions (Fritschel, 2006).

Farmers in tropical regions are affected by many variables, many of which are intensified by increasing climatic changes. For example, changes in climate will affect the economy of the region, including inputs (pesticides and fertilizers), outputs (produce), market access and prices of commodities. Other environmental factors impacted by climate change include the availability of water and concerns with flooding, drainage, and drought. Soil fertility, pests and disease, and weed infestations may also affect agricultural productivity in the event of climate change (Verchot et al., 2007). The relationship between these factors and climate change are poorly understood (Verchot et al., 2007). Other indirect stress factors such as land access; education and knowledge of climate change and alternative farming techniques; and accessibility to adaptation technology also provide a challenge for agricultural producers in tropical regions, including Costa Rica (Verchot et al., 2007).

As mentioned, CATIE is currently working on a PES project with farmers in a specific area in Costa Rica. These researchers have not studied the potential for the PES project to also support and encourage farmers to adapt to climate change. This evaluation is essential as the PES project could provide a means of financially supporting farmers, especially poorer farmers (Pagiola et al., 2005), in implementing climate change adaptation strategies on their farms and reducing some of the limitations and challenges these farmers are currently facing when implementing adaptation methods.

1.4 Research Questions

This research asks the following questions: Is the PES project improving farmers' local knowledge about climate change and encouraging them to integrate existing information as well as develop innovative technologies to reduce the impact of climate change on their farms? To be able to answer these questions, the following questions were formulated to provide a basis for the survey questions:

1. What climatic changes are currently observed by agricultural producers in Costa Rica?
2. How are farmers’ perceptions of climate change influencing how they are adapting to climate change?

3. How influential is the PES programme in encouraging producers to implement climate change adaptation strategies?
4. How does the adaptive capacity compare between farmers involved in a PES programme and producers who are practicing sustainable agricultural methods with more specific integration of climate change information?
5. How can this information be used to improve the PES programme in Costa Rica in a way that will successfully help farmers adapt to climate change?

To answer these questions, a survey was developed and an analysis was completed based on farmers' observations and understanding of climate change, how they are adapting to climate change, and how to further encourage and support their adaptation. Additionally, recommendations were made to further improve producers' awareness about climate change through the PES programme.

It was predicted that farmers participating in PES as well as those practicing sustainable agriculture will have noticed changes in climate over the past twenty years as a result of global climate change. Despite the fact that PES focuses on the implementation of environmental services, it was expected that farmers using these methods will have also found benefits in the event of climate change and that the payments for implementing these strategies will have encouraged further climate change adaptation. It was expected, however, that improvements can be made to link environmental services with climate change adaptation, and that education programmes should build on this relationship.

1.5 Research Objectives

The primary purpose of this study was to determine how well CATIE's PES project encourages farmers to increase their adaptive capacity to climate change. This information benefits academic institutions, including CATIE, and governmental and non governmental organizations interested in implementing a PES project. Based on this purpose, the three objectives of this project are: 1) to determine how farmers perceptions of climate change influence their adaptation; 2) to determine how a sustainable agricultural model can be used to improve PES and the ability of PES to promote climate change adaptation; and 3) to develop methods to reduce the limitations associated with implementing adaptation strategies. Information has been presented to CATIE related to the effectiveness of their PES project to provide information about climate change and encourage implementation of adaptation strategies. Governments and academic institutions in other nations will also benefit from this study because climate change is impacting all countries, and any strategies that can help encourage adaptation in agriculture are essential.

1.6 Rationale

Today, agricultural producers face a growing number of issues associated with the negative impacts on food production. These impacts include a shift away from traditional agricultural practices resulting in soil erosion and loss of cropland area, in addition to environmental challenges such as falling water tables and rising temperatures (Brown, 2004). Food is scarce in many parts of the world as a result of changing climate patterns (Brown, 2004). In Costa Rica, many communities depend on agriculture for economic sustainability and, for many producers, the only source of income is to sell produce at the local market.

Past research efforts have concentrated on assessing how climate change will impact producers (Smit, 2002), but now the focus has shifted to how farmers are adapting to climate change (Smit, 2002; Berkhout, 2006; Falconi, 2007). Agricultural researchers and rural extension personnel are currently developing strategies to help producers adapt to climate change, including the use of agroforestry for soil and water conservation and conserving biodiversity (Smit, 2002; TroFCCA, 2006; CATIE, 2007).

The goal of this research is to take current knowledge of climate change adaption one step further by determining if PES can be a successful tool to integrate climate change information into an agricultural community. Based on the success of this project, recommendations were developed to extend this information into the rest of the country.

One of the major issues influencing the implementation of adaptation strategies in agriculture is the producers' perception and understanding of climate change. If producers do not believe climate change is happening, or they do not believe they will be affected by climate change, they may be unwilling to talk with researchers and governments and incorporate climate change adaptation strategies that have been developed. Therefore, it is essential to determine whether producers believe in climate change as well as to continue to facilitate the integration of climate change knowledge into farming practices.

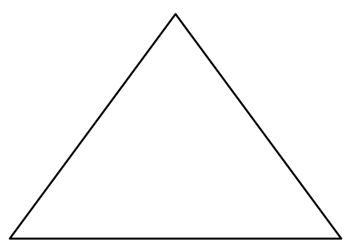
1.7 Contributions of Research

Empirically, this research provides two case studies with two different groups of farmers in Costa Rica: one group is directly involved in a PES project and the other is involved in sustainable agriculture, and is not involved in any PES project. Although no other studies such as this have been completed in Costa Rica, understanding how farmers are learning and understanding information associated with climate change is essential as climate change continues to grow as a threat (IPCC, 2001). Theoretically, this research contributes to the growing body of literature on environmental services and climate change adaptation strategies, specifically how farmers are integrating climate change strategies into their farming methods. By opening discussion with farmers participating in PES and those practicing sustainable agriculture, lessons can be learned on how to further integrate climate change adaptation into agricultural practices. Thus, this study provides an assessment of the PES project as a method to encourage climate change adaptation by farmers and evaluates its potential usefulness as a transferable model to other communities.

Chapter 2 Methodology

After successfully obtaining ethics clearance from the Office of Ethics Research at the University of Waterloo, farmers in two areas of Costa Rica were asked about their observations and perceptions of climate change, how they are currently adapting, and their incentives for adapting in order to determine their adaptive capacity to climate change. This information was compared with information from academic literature and from CATIE including past theses and interviews with researchers and government officials to determine if these farmers truly are improving their adaptive capacity. A methodological approach was followed involving quantitative and qualitative data collection. From the results, recommendations were made to improve CATIE's PES project and to integrate this information through the rest of Costa Rica. Triangulation is achieved through a literature review, interviews with academics and researchers, and surveys of producers (Figure 2.1).

Information from Literature



Survey/Interview of Producers

Interviews with academics and researchers from CATIE and with the local representative from the Ministry of Agriculture

Figure 2.1 – Triangulation used in this research.

2.1 Literature Collection

Primary information was gathered through a literature review to determine the type of research conducted previously relating to climate change, adaptation strategies, and environmental services. This literature included an examination of surveys related to climate change in general as well as information specific to the agricultural sector in tropical areas. The literature consisted of a search of academic journals, academic websites, government documents, and past theses and peer-reviewed publications from CATIE.

2.2 Data Collection in Esparza

Esparza, Costa Rica was chosen as a study site because there is currently a PES project in place. The PES project (implemented by CATIE) made Esparza an ideal location to evaluate the ability of PES to encourage climate change adaptation. As a result of the PES project, CATIE had collected extensive information about the region including the demographics of the farmers, detailed maps of the study area, and land use and biophysical changes that have taken place as a result of the implementation of PES. This information from CATIE was used for this research study and was obtained using past theses and research projects from CATIE, a database of information collected by CATIE, as well as with interviews of academics conducting the PES project and a local representative from the Ministry of Agriculture. The information provided by CATIE added more depth to the surveys and interviews conducted in this study.

Participants were selected based on their participation in the PES project. Researchers from CATIE had divided 136 farms into three groups: The first was a control, the second received PES, and the third received PES and technical assistance (Santos, 2004). Fifty producers (out of 105) participating in the second and third groups were chosen using simple random sampling. This method minimizes sampling error and all farmers had an equal chance of being selected (Palys, 1997). Participants were asked questions based on four different themes that help to answer the overall research questions: 1) background and farming experience information not already collected by CATIE researchers; 2) observations and perceptions about climate change; 3) effects of climate change on production; and 4) adaptation strategies producers are implementing and the results of implementing these strategies (Appendix A). The questionnaires were developed with the help of Dr. Muhammad Ibrahim and Dr. Claudia Sepúlveda.

The surveys took place from May 7 to May 15, 2007 and were completed in Spanish. They were conducted by a representative from the Ministry of Agriculture as well as by rural extension officers from CATIE. Textual data was collected by this author. This included information provided by the farmers that elaborated on the questions in the survey, as well as visual observations of the farm. This textual information was used as part of the qualitative analysis.

Farmers from the second and third groups were chosen for the interviews because they are directly involved in CATIE's PES project. Evaluating the impacts of this project on the farmers' knowledge, perceptions, and actions is a key component to this research. As a result, it was determined that interviewing farmers actively participating in the project would provide the most insight into the effectiveness of this programme, while the control group established by CATIE would not provide any comparative data useful for this particular study.

2.2.1 Strengths and Limitations

One challenge associated with conducting in person interviews with the farmers is that the results may be biased and potentially skewed because the participants may be responding to the questions by saying what they think is the right answer rather than what they believe (Palys, 1997). Farmers may not be willing to provide their true thoughts on the issues, especially if they feel it may threaten their partnerships with CATIE or other outside networks. Increasing the number of farmers surveyed and creating an environment that encouraged farmers to provide honest responses helped mitigate this limitation. Creating an honest environment by providing a description of the study before beginning the interview and ensuring farmers were comfortable with each question helped participants understand the type of information needed so there was no confusion in their responses. Also, conducting the interviews as a discussion rather than a set of questions and answers increased the comfort of both parties and allowed for more information to be attained.

One advantage of conducting in person questionnaires and interviews is that respondents were able to reply directly to the questions (Palys, 1997). The participant was able to ask for clarification on any of the questions, as well as elucidate their answers. This method also allowed the survey to be done orally in a case where an individual was illiterate. In the rural areas of Costa Rica, this is a possible concern. Another advantage to conducting individual surveys is that the participants do not feel threatened by others. In a group setting, such as a forum, this can be an issue (Palys, 1997).

2.3 Data Collection in Durika

Durika, Costa Rica was chosen as the second study site because of the sustainable agricultural methods practiced by the community. Because their agricultural methods combine climate change mitigation and adaptation, they offered an interesting contrast to Esparza, where the focus is simply on climate change mitigation through PES. The inclusion of adaptation into sustainable agricultural methods provided insight into how PES can be improved to further enhance the adaptive capacity of the farmers involved. Background information about the community came from Durika's website and academic literature specific to the region around Buenos Aires (20 km west of Durika).

The Durika members were chosen to be interviewed based on their role in the community. Five members of approximately thirty individuals were chosen to be interviewed. Because of the commune style of the community and the fact that it is one large farm, surveying five people with different backgrounds was determined to provide the information needed to establish how the community was adapting. Except for the community leader, the participants were chosen using stratified random sampling. The community leader, also the founder of Durika, was automatically selected because of his role in the community and his knowledge of how the community has adapted over time. The rest of the community members were divided into four groups including: ecologists, professionals and business people (including doctors and bankers), professors, and people born outside of Costa Rica. One member from each group was randomly selected and asked questions based on three different themes that provided further insight into the responses by producers in Esparza. This information was valuable to help answer the overall research questions. These included: 1) observations and perceptions about climate change; 2) adaptation strategies they are implementing and the results of implementing these strategies; and 3) the adaptive capacity of local farmers outside Durika (Appendix B). Because less research has been done in this area, the interview questions were open ended resulting in a dataset of textual information. These questions were developed with the help of Dr. Muhammad Ibrahim and Dr. Claudia Sepúlveda. The interviews took place between May 17 and May 28, 2007 and were conducted in English with all except for the community leader. His interview was conducted in Spanish, and was interpreted by this author as well as a fellow community member. The rest of the individuals interviewed were fluent in English, therefore, this was a practical means of conducting the interviews.

The research questions for Durika and Esparza are not the same because of the differences in the farmers' knowledge and their participation in different environmental programmes. For example, Esparza is part of CATIE's PES project. Many of the questions asked to these farmers are specifically related to this project. In Durika, however, farmers are not associated with PES and are practicing a different type of agriculture. As a result, they have different motives for implementing adaptation strategies.

2.3.1 Strengths and Limitations

When conducting in person interviews in Durika, the advantages and disadvantages as well as the strategies designed to overcome the disadvantages are similar to those in Esparza. Members of Durika may feel that if they do not provide the 'right' answers, their relationship with the institutions they are associated with may be threatened. Again, this was overcome by creating an honest environment and ensuring the participants understand the purpose of the questions being asked. Similar to in Esparza, the interviews were conducted as discussions, rather then as a set of questions and answers.

A further limitation with this research site is that there is little information available. Because no studies have been completed specifically related to Durika, general background information was difficult to attain. To overcome this limitation, academic literature about Buenos Aires and the surrounding indigenous populations was collected. Buenos Aires is located about 20km from the community, and the indigenous populations spread into the mountains near Durika. This information provided context to Durika. Satellite imagery was also used to determine the impact of the sustainable agricultural methods on the landscape in the area. This information was used to help verify some of the claims made by the Durika members interviewed.

2.4 Data Analysis

The information collected in Esparza and Durika was analyzed based on the farmers' perceptions of climate change, their observations, how well they are adapting to climate change in their region, and what they believe will help improve the implementation of adaptation strategies. The data collected in Esparza was used to evaluate farmers' success in implementing PES and determine how the programme can be improved, based on farmers' experiences. The data collected in Durika was used to provide further insight into how to integrate climate change adaptation with mitigation from a sustainable agriculture perspective. This information was valuable in developing recommendations to improve PES.

The qualitative data was analyzed using NVIVO, (QSR International, Melbourne, Australia). NVIVO software is used to manage code, analyze, and report text data. The qualitative data from the surveys in Esparza and the interviews in Durika were entered into NVIVO. The information was coded and analyzed to bring out the common themes.

The major advantage to using NVIVO instead of analyzing the qualitative data manually is that the information is in electronic form. As a result, queries can be used to bring out ideas raised by the participants. Other sources of information, such as journal articles and government documents were also linked electronically to the information from the interviews. This helped determine the significance of the points raised by participants. The greatest limitation to using NVIVO is that numerical data entered into Microsoft Excel cannot be analyzed in NVIVO with the qualitative data. This limits the use of this tool because non-textual data play an important role in qualitative analysis (Bandara, 2006). Once the qualitative and quantitative data were analyzed, the results were combined and important trends were recorded. Participants' names are not revealed to maintain anonymity.

Chapter 3 Climate Change Predictions and Adaptation: A Review of the Literature

Academic literature has played a primary role in determining how climate change is affecting Costa Rica and the adaptation strategies that exist for farmers to address these changes. There is a huge body of literature on the impacts of climate change on different systems and the effect of these changes on agriculture (IPCC, 2001; Enquist, 2002; Ramirez, 2005; Williams, 2006). Recently, there has been a shift in climate change research from the impacts on agriculture to how agriculture can adapt (Smit, 2002; TroFCCA, 2006; CATIE, 2007). Researchers are beginning to advocate the use of PES to address issues such as climate change (Corbera et al., 2006). As far as this researcher is aware, no studies exist that examine the impacts of a specific PES project on encouraging farmers to adapt to climate change. This study fills this gap by demonstrating its use to encourage farmers to adapt to climate change based on farmers' experiences with a PES programme compared to farmers not involved.

3.1 Climate Change Implications and Predictions

Climate change is causing serious impacts on both social and natural systems (IPCC, 2001). Vegetation patterns throughout Costa Rica are affected by changes in climate (Enquist, 2002). Species distribution and ecosystem function, which refers the processes and interactions within an ecosystem and include processes such as the water cycle and mineral cycle, are both closely linked to climate. For example, changes in species range, species extinction, biome shifts, altered disturbance regimes, and biogeochemical cycling are a few of the challenges facing ecologists resulting from climate change (Williams, 2006). These alterations will impact the types of plant or crop species able to grow in certain locations as well as the plant productivity. Therefore, crops typically grown in a specific region may begin to decrease in productivity and their resilience to pests and diseases may decline. These declines impact animals dependent on certain plant species because they will have fewer resources. This may lead to potentially serious consequences on agricultural production throughout the country

The greatest challenge in understanding climate change is the number of impacts, such as the result of precipitation changes on vegetation, and feedback loops (Vignola, 2005). An example of a positive feedback loop in the tropics is the impact of rising temperature on tropical forests. As the temperatures increase, tropical forests increase the amount of CO_2 released into the atmosphere, thereby increasing the rate of climate change and further increasing temperatures (Graham, 2003). These feedback loops are complex and many of the interactions are understudied or unknown (Vignola, 2005). This complexity makes it difficult to predict regional changes and the impact these changes are going to have on different biophysical aspects.

Four main components affected by climate change have been assessed in this project. These components were chosen based on their importance to agricultural systems, either directly or indirectly. The selected components are the effects of climate change on: 1) temperature and precipitation patterns; 2) soil characteristics; 3) the distribution of vegetation; and 4) the distribution of beneficial species, pests, and diseases. These four aspects impact the decisions made by producers regarding crop selection and production methods. Understanding how climate change will affect these systems can also reduce the overall cost of implementing climate change adaptation strategies (Füssel, 2007).

3.1.1 Temperature and Precipitation

Temperature and precipitation are two of the primary dictators of the quality and quantity of crop grain yield in a given year. Variations in either temperature or precipitation can significantly alter the fate of plant productivity. Climatic variations or local weather patterns (microclimate) occur naturally and differ from climate change. Ocean currents; natural cycles, such as the 35 year cycle for cyclonic activity; air surface temperatures; and the trade winds are all associated with naturally occurring climate variability on a regional scale (Ramirez, 2005). There are also microclimates, which cause local variations in weather patterns. This can be caused by distance from large bodies of water, elevation, changes in vegetation cover, or from local land management practices. Climate change is a trend that involves changes in precipitation and temperature (Ramirez, 2005).

There are many climate change models currently being used to predict the impacts of climate change on temperature and precipitation throughout the world. The most common and well recognized are Atmospheric General Circulation Models (AGCM's) (IPCC, 2007b; Met

Office, 2007; Niggol Seo, 2007). Examples of these models include PCM: National Center for Atmospheric Research, USA; CSIRO: Australia's Commonwealth Scientific and Industrial Research Organization; and CCC: Canadian Centre for Climate Modeling and Analysis, Canada (Niggol Seo, 2007). ACGM's provide a course level of data and are designed to be used on a global scale (Met Office, 2007). Regional climate variations can be determined using Regional Climate Models (RCM's). These have a higher resolution and therefore take into account some of the local features in a given area. Although this has improved the accuracy of local climate projections, there is still a great deal of uncertainty surrounding the results.

The Intergovernmental Panel on Climate Change (IPCC) is the most widely recognized climate change institution. It was initiated by the World Meteorological Organization (WMO) and by the United Nations Environmental Programme (UNEP) (IPCC, 2008). The purpose of this organization is to assess the latest scientific, technical, and socio-economic literature on climate change in order to determine the risk of climate change throughout the world and includes an assessment of predicted and observed climatic changes, and methods to adapt to and mitigate these changes (IPCC, 2008).

In its most recent document, the IPCC claims that temperature increases throughout the world are expected with the greatest increases in temperature occurring at higher northern latitudes (IPCC, 2007a). The warming trend throughout Latin America is expected to be an upward linear trend and precipitation is expected to decrease as a result of climate change (IPCC, 2007b). There is a great deal of uncertainty, however, in the precipitation values because of the expected increase in tropical storms. These storms may carry more moisture with them, causing more intense rains (IPCC, 2007b).

Unfortunately, climate models cannot yet accurately predict the impact of climate change at the local level (IPCC, 2001), and many argue that the climate is just too complex to be able to make accurate predictions with models (Giles, 2007). This creates challenges when trying to understand the impacts of climate change on various sectors in order to develop effective climate change adaptation strategies (Füssel, 2007). Despite this, climate observations and past climate data have provided some insight into the potential threats of changing temperature and precipitation on soil, flora, and fauna.

3.1.2 The Effect of Climate Change on Tropical Soil

Weathering processes, including the influence of precipitation and temperature have played a key role in the formation of diverse tropical soils. Some soils are fertile and thus more suitable for agriculture, while other soils are not as productive (Sanchez, 1999). Soil fertility is affected by changes in temperature and precipitation as well as elevated CO_2 levels (Sanchez, 2001). Longer dry seasons result in a slowing of soil processes such as decomposition (Sanchez, 1999). Drought conditions limit the productivity of vegetation, resulting in a lower input of organic matter to the soil, which reduces microbial activity and nutrient availability (Yavitt et al., 2004).

Additionally, tropical soils are also prone to erosion, especially when the soil is exposed and subjected to heavy rainfall events. High rainfall results in nutrient leaching causing the soil to become infertile with time (Sanchez, 2001). An increase in temperature and humidity may also result in an increase in soil organic matter decomposition and nitrogen mineralization (Vignola, 2005). A decrease in precipitation, however, is predicted to increase the rate of nitrogen to nitrate transformation (Vignola, 2005). Although more research is needed to determine the impacts climate change will have on tropical soils, the decrease in precipitation expected for the Pacific Region of Costa Rica (IPCC, 2001; Ramirez, 2005) is expected to impact vegetation patterns and therefore agriculture as a result of a loss of soil fertility based on research by Sanchez (2001) and Vignola (2005).

3.1.3 The Effect of Climate Change on Tropical Vegetation

In Central America, there is an expected shift in vegetation towards xeromorphic (plants adapted to drought conditions), pyrophytic (fire prone species), and species-poor plant communities as a result of a decrease in precipitation and an increase in temperature (Vignola, 2005). Precipitation patterns are thought to greatly influence vegetation patterns (Enquist, 2002). In fact, flowering, fruiting, seed dispersal, and seed germination are thought to be highly dependent on the climate of the region (Bazzaz, 1998). Small changes in wet and dry seasons may cause significant impacts on the lifecycle of certain plant species (Bazzaz, 1998). These changes will alter the distribution and diversity of the flora and fauna in many regions (Bazzaz, 1998; Enquist, 2002; Vignola, 2005).

Enquist (2002) conducted research on the impact of climate change on tropical vegetation. He found that vegetation at higher elevations is susceptible to changes in temperatures while vegetation at lower elevations is susceptible to precipitation changes. Related to this, researchers in Monteverde, Costa Rica found that cloud mist is increasing in elevation, which is causing plants in lower elevations to have less access to water ultimately decreasing their productivity (Mayell, 2001).

Changes in climate also influence pollinators and seed dispersers (Bazzaz, 1998), further affecting vegetation and vegetation patterns in Costa Rica. Bazzaz (1998) also suggested that an increase in temperature will result in a decline of stomatal conductance, increasing the leaf surface temperature to potentially lethal levels (1998), ultimately resulting in plant mortality. As such, a change in vegetation patterns will affect which crops and tree species are able to grow in particular regions. As such, farmers need to be aware of how vegetation patterns are changing to ensure they plant crops that are best adapted to a changing climate.

3.1.4 The Effect of Climate Change on Beneficial Species, Pests, and Diseases

Agricultural production is expected to decrease by 30% in the tropics through this century as a result of an increase in crop pests and diseases (Sanchez, 2001b). These pests and diseases are increasing as temperatures in the tropics continue to increase and precipitation decreases (Sanchez, 2001b). Species in Costa Rica are more sensitive to temperature variations than higher latitude species because temperatures closer to the equator vary less at daily, seasonal, orbital, and tectonic timescales (Williams, 2006). Tropical species are also more narrowly endemic because the size of a species range decreases closer to the equator (Rapport's Rule) (Williams, 2006). Developing adaptation strategies must involve and understanding of species dynamics and how they will be affected by climate change.

Amphibians are currently under intense study because of their sensitivity to changes in precipitation and temperature (Science Daily, 2006). Research has shown that amphibian populations are declining due to epidemic diseases and precipitation changes thought to be caused by climate change (Science Daily, 2006). An increase in the skin *Chytrid* fungus, which is fatal to amphibians, combined with changes in precipitation and temperature have caused a decline in frogs, such as the harlequin frog (*Atelopus varius*), toads, such as the golden toad (*Bufo periglenes*) and anoline lizards (*Norops spp*.) (Schoville, 1999; DeGroot, 2000; Walther et al., 2002; Science Daily, 2006).

Bird populations have been monitored in the cloud forests around Monteverde in order to determine the impacts of a dryer forest on birds that normally reside in cloud forests, and birds that do not (Kirby,1999). Higher in the mountains there has been an increase in the number of birds that normally reside at lower elevations, including the toucan (Kirby,1999; Fenn, 1999). Researchers have been able to determine that birds in lower elevations are moving into higher elevations due to changes in climate patterns rather than habitat destruction in the lower elevations (Fenn, 1999).

Because of the complexity of animal interactions in tropical areas, little information is known on how the declining amphibian populations and changing bird populations are going to influence other species. According to Fenn (1999), changes in climate are going to impact host-parasite and disease-vector relationships. Essentially, animals will be subjected to changing predator-prey relationships as their predators, prey, and disease population's change. Some of the species being impacted by these changes may be beneficial to agriculture, or they may be pests. The limited information on these species relationships creates challenges for farmers to develop adaptation strategies.

The direct impacts of climate change on agricultural pests are difficult to predict, even if exact changes in climate could be determined (Scherm, 2000). This is caused from the fact that as certain conditions become favourable for a species, others may become unfavourable (Scherm, 2000). With uncertainty of the impacts in climate change, this increases the difficulty to predict how pests will be impacted (Scherm, 2000).

Over the past several years, researchers and producers have observed an increase in certain insect species that are damaging to agriculture, such as the whitefly (*Aleyrodidae*) (International Centre for Tropical Agriculture, 2001). This species is particularly damaging to commercially valuable crops such as cassava (*Manihot esculenta*), sweet potatoes (*Ipomoea* *batatas*), beans (*Glycine max*, *Phaseolus vulgaris*) tomatoes (*Lycopersicon esculentum var. esculentum*), peppers (*Capsicum spp*.), potatoes (*Solanum tuberosums*), eggplant (*Solanum melongena*), squash and melon (*Cucurbita spp*.) (International Centre for Tropical Agriculture, 2001). Whiteflies have been known to destroy the entire plant and eradicate an entire crop for that season (International Centre for Tropical Agriculture, 2001).

Producers must be aware that some beneficial species that help to protect the crops are disappearing. For example, as amphibian populations decrease, insect populations may increase, leading to more insect infestations in crops and an increase in insect-spread diseases in animals. More information about the relationships among species is needed to allow producers to adapt their agricultural methods according to changes.

3.2 Climate Change Adaptation in Agriculture

Creating an agricultural system that is resilient to climate change is largely dependent on adaptive capacity. Adaptive capacity involves the existence of institutions and networks that learn and store knowledge and experience, have flexible problem-solving techniques, and balance power among interest groups (Walker et al., 2007). A system with high adaptive capacity is able to use knowledge and problem-solving techniques to moderate potential damages, take advantage of opportunities, and cope with any negative consequences, and is therefore more resilient (Gallopin, 2006). Adaptation refers to the specific adjustments made in environmental and human systems in response to actual or expected climate change effects. It includes anticipatory, reactive, autonomous, spontaneous, and planned strategies that can be public or privately organized (Gallopin, 2006). Improving adaptive capacity includes "thinking ahead". Methods are used to reduce the impacts of climate change prior to the time the effects are actually felt (Gallopin, 2006).

The resilience of a system is dependent on its adaptive capacity. In social-ecological systems, resilience is defined as the extent to which a system can absorb a disturbance before that system radically changes to a different state. It includes the capacity to self-organize and to adapt to the emerging circumstances (Adger, 2006; Gallopin, 2006). Social resilience is the ability of groups and communities to cope with stressors and disturbances, such as social, political, and environmental changes (Adger, 2000; Gallopin, 2006).

Research is showing that changes in climate are significantly impacting soil resources in addition to vegetation and animals (Bazzaz, 1998; Fenn, 1999; Kirby, 1999; Enquist, 2002; Sanchez, 2001; Vignola, 2005). These impacts are expected to continue to increase as long as the climate continues to change (IPCC, 2001). Because agriculture is part of the natural system, these changes will directly influence current agricultural practices (Verchot et al., 2007). Since the abandonment of traditional agriculture (farming used by small-scale farmers associated with pre-industrial peasant agriculture (Thurston, 1997)) several decades ago by most agricultural producers, Costa Rica has faced problems associated with soil erosion and soil nutrient depletion resulting from single crop cultivation (Oelbermann, 2004). Cabrera et al. (2007) mention that changes in climate affecting crop yields combined with uncertain prices will impact economic returns for farmers. Adaptation strategies must therefore be developed that are resilient to these changes while ensuring farmers have the resources to implement them.

Currently, many adaptation strategies are promoted throughout the world, including agroforestry, the combination of trees or shrubs with crops and/or livestock which integrates economical and ecological interactions between components (Oelbermann, 2004, and Molua, 2005); and increased crop diversity through mixed agricultural methods, such as combining crops and livestock (Convention on Biological Diversity, 2003; Lotter, 2006). Many of these adaptation strategies also serve as environmental services, such as sequestering carbon, which ultimately helps to reduce the concentration of atmospheric CO_2 and methane (CH_4) and thereby help to mitigate climate change (Conventional on Biological Diversity, 2003; Oelbermann et al., 2004).

Nitrous oxide (N_2O) per unit of weight has 296 times more impact on climate change than per unit of weight of CO_2 over a 100 year period (IPCC, 2001). Nitrous oxide is produced through soil processes, including nitrification and denitrification (Freney, 2004). In soils, N_2O production is dependent on many factors including temperature, pH, land use practices, irrigation practices, and fertilizer rate (Freney, 2004). Forests produce less N_2O than land cleared for agriculture. In Brazil, N_2O emissions increased by a factor of two when a forest was clear-cut.

Pastures in this same area were found to have three times the N_2O production when compared to adjacent forests (Freney, 2004). As a result, agroforestry methods are a way of reducing N_2O emissions (Freney, 2004).

Supplements provided to animals are commonly used by farmers as a way to provide nutrients to their animals during years with poorer quality fodder. Although supplements have always been used, their use is expected to increase as changes in climate reduce the forage quality. For example, some farmers use supplements to improve or maintain milk production when food is in short supply, particularly in the dry season (Moran, 2005). As the dry season becomes more intense, supplement use is expected to increase. The primary supplements used by farmers in Esparza are sugarcane (*Saccharum officinarum*); molasses, a thick syrup by-product from processing sugarcane into sugar; and commercial concentrate, a feed supplement containing a combination of energy and protein supplements with minerals (Moran, 2005).

Basing this research on solely one factor, such as climate change, could leave the system vulnerable to other stressors. These stressors could include economic decline in certain areas of production, poverty, other unforeseen stresses caused by environmental changes, technology, and other social and demographic processes (Adger, 2006). Policies must therefore look at the multi-level nature of vulnerability and promote resilience at different scales (Adger, 2006) and adaptation strategies must encourage protection from more than one perspective.

3.2.1 Climate Change Adaptation Research throughout the World

Climate change adaptation research is currently taking place throughout the world. Recent studies have shown the importance of integrating policies and sustainable practices with adaptation (Nyong et al., 2007; Bouwer and Aerts, 2006; Halsnæs and Shukla, 2008). One climate change adaptation project in Africa examines the fact that climate change adaption must be integrated with sustainable agriculture (Nyong et al., 2007). In this project, researchers examined how indigenous knowledge can complement western knowledge in developing strategies to adapt to climate change. They also found that many of the effective adaptation strategies also serve as climate change mitigation strategies (Nyong et al., 2007). Although indigenous populations have been using their traditional knowledge to mitigate and adapt to climate change, there is a need for formal climate change adaptation policies (Nyong et al., 2007). This combination provides structure and ensures the indigenous knowledge is being implemented effectively (Nyong et al., 2007).

Another study examining climate change policies in Brazil, China, and India found that governments in these countries were having success integrating development, environment, and climate policies, as well as combining climate change mitigation and adaptation (Halsnæs and Shukla, 2008). In China, for example, climate change policies are embedded in their sustainable development and energy policies (Halsnæs and Shukla, 2008). Although the integration of ideas, policies, and concepts is increasingly seen by many climate change adaptation researchers as important, further implementation is necessary (Nyong et al., 2007).

3.3 Payment for Environmental Services

The current economy is not designed to account for natural capital, including solar energy, water, living organisms, fossil fuels, and the services they provide in ecological systems (Daly and Farley, 2003). As a society, we give up ecosystem services in order to increase the flow of man-made capital. This human-made capital contributes to a growing economy (Daly and Farley, 2003). Unfortunately, we have little understanding of ecosystems and the role they play in providing us with natural services, such as clean air, clean water, and energy (Daly and Farley, 2003). In agriculture, for example, producers increase their productive land, for crops and cattle, by reducing the diversity on the farm in order to increase their overall production. This diversity may contribute to the success of their farm by protecting water needed for irrigation or by providing habitat for beneficial species. Developing a means to account for the importance of these environmental services and identify a value for the benefits they offer is essential to encourage producers to integrate them into their farming decisions.

There is a growing body of literature about the integration of environmental services by land owners in order to promote environmental management (Greig-Gran, 2005; Redondo-Brenes, 2005; Corbera et al., 2006; Department of Sustainable Development, 2006). These environmental services include carbon fixation, hydrological services such as water conservation and protection, increasing biodiversity, and improving scenic beauty (Greig-Gran, 2005;

Redondo-Brenes, 2005). To encourage rural landowners to implement these environmental services, PES is being implemented by governments and agencies throughout Latin America, including Costa Rica, Mexico, Columbia, and El Salvador (Pagiola et al., 2005), and around the world. In 2005, there were an estimated 287 forest environmental services ongoing or proposed projects throughout the world (Greig-Gran, 2005). The purpose of these projects is to encourage landowners to implement environmental services through the use of monetary incentives. Farmers often receive more money by converting forests into pastures for cattle rather than leaving it as a forest. The PES programme rewards farmers for maintaining forest areas and practicing conservation (Pagiola et al., 2005). Monetary values are established for each environmental service implemented and the landowner is paid for the service (Department of Sustainable Development, 2006). The scheme is most effective when the benefit of the environmental service is high and the cost to implement the service is low (Department of Sustainable Development, 2006).

In 1997, the Costa Rican government initiated a PES programme throughout the country (Department of Sustainable Development, 2006). This is the most extensive PES programme in the world (Pagiola et al., 2005). Launched by the National Financing Fund (FONAFIFO), the programme was developed to encourage small- and medium-scale farmers to implement practices that provide environmental services (Department of Sustainable Development, 2006). The programme started with US$14 million as payments to farmers. Money for this programme comes from a 5% tax on fossil fuel use (80%) combined with sales of certifiable tradable offsets (CTO's) to foreign investors (20%) (Redondo-Brenes, 2005; Department of Sustainable Development, 2006). A benefit to implementing environmental services is that many also act as climate change adaptation strategies (Corbera et al., 2006). Some of these recommended strategies include agroforestry, increasing biodiversity, and water recuperation and conservation (CIAT, 2001). Over the last two decades, PES has played a significant role in increasing the number of tree plantations in Costa Rica, particularly on small- and medium-sized farms throughout Costa Rica (Redondo-Brenes, 2005). This has the combined benefit of preventing erosion during extreme rainfall as well as providing habitat for animals and increasing biodiversity.

There is some controversy about how the PES programme is currently implemented (World Resources, 2005). One of the greatest concerns is the ability of poorer farmers to access this programme (Corbera et al., 2006). There are several reasons why the poor may have difficulty participating in the PES project. These include:

- Insecure land tenure;
- Restrictions on land-use;
- High transaction costs; and
- Lack of credit and start-up funds.

Ownership of land is required in order to determine who is eligible for funding. Many poorer farmers do not have full ownership over their land or their land tenure is insecure. As a result, they cannot benefit from these payments (Pagiola et al., 2005; World Resources, 2005, Corbera et al., 2006). There is also evidence in Columbia that politically powerful groups have taken over land previously owned by poorer farmers as a result of PES making the land more valuable. In Costa Rica, however, research suggests that PES is actually increasing the security of land tenure because forested land is no longer considered “idle” and therefore is protected against land invasions (Pagiola et al., 2005).

Participation in a PES system also means restrictions are placed on farming techniques. Initially, agroforestry was not considered an environmental service. When this changed in 2002, more farmers did begin accessing the programme (World Resources, 2005). Some small- and medium-scale farmers, however, have decided to continue to opt out of the PES programme in order to ensure they can continue to make enough income from their farming (World Resources, 2005). Contract and monitoring programmes, such as those used to ensure farmers are implementing environmental services, can further burden small-scale farmers (World Resources, 2005). Also, in Costa Rica many farmers have not been able to gather sufficient amounts of income from the payments to warrant changing their current farming techniques. Initial costs to implement new agricultural methods to promote environmental services are often quite expensive for farmers making it challenging to adopt some of these practices, especially in the first few years (World Resources, 2005). These concerns impact how producers, especially small-scale producers, are implementing environmental services on the farms.

Pagiola et al. (2005) developed strategies to improve access of this programme to poorer farmers. These include keeping transactions costs low, increasing flexibility to address issues related to insecure land tenure or lack of land titles, providing technical assistance to those who need it, and encouraging and financially supporting community organized programmes that cover a broad range of conservation strategies (Pagiola et al., 2005).

There are many recommended strategies included in the environmental service programme. The ones discussed in more detail for this research include livestock management, including the use of grasses, forage, fodder banks, and seed banks; agroforestry; and water recuperation and conservation techniques, all of which help farmers to adapt to a changing climate. These strategies increase biodiversity, improve scenic beauty, improve water quality or quantity, and/or sequester carbon and are described in more detail below.

3.3.1 Livestock Management

Livestock management, including the sustainable management of grasses and forages and the implementation of fodder banks and seed banks are adaptation strategies that help to ensure the animals are receiving enough food during times of unfavourable weather, such as extreme droughts or floods. Selecting grasses and forages that tolerate drought and flood conditions is essential to ensure animals are receiving adequate food throughout the year. Fodder banks ensure farmers have food for their animals during intense weather conditions that damage their pastures. Seed banks provide farmers with seeds that are most adapted to their current weather conditions. Each one of these strategies is explained in more detail below.

3.3.1.1 Grasses and Forages

Almost all forages are perennial species, and are typically harvested for animal feed. In many cases, they also protect against soil erosion (Stür, 1995), reducing the impact of raindrop splash during intense rainfalls, which are predicted to increase as a result of global climate change (IPCC, 2001). The type of forage grass species chosen can also play a role as an environmental service by sequestering carbon, maintaining soil fertility and increasing biodiversity in addition to maintaining soil stability by preventing erosion (CIAT, 2001). The monetary costs and benefits associated with planting each grass species for pasture are illustrated in Table 3.1. The internal rate of return (IRR) refers to the payments and income that occur at regular periods which totals the interest rate received for the investment (CIAT, 2001).

Table 3.1 – Costs (labour and capital) and benefits of *Hyparrhenia rufa*, *Brachiaria spp*., and *Cratylia argentea* in Costa Rica (Adapted from CIAT, 2001)

Pasture	Labour Input (man-days/ha/yr)	Labour Costs (US$/ha/yr)	Capital Input (US$/ha)	Stocking Rate (AU/ha)	Milk Production (kg/head/day)	IRR[a] (%/yr)
Hyparrhenia rufa	3	30	-	0.9	4	-
Braciaria Spp.	7	70	250	1.3	5	9.4
Cratylia argentea	19[b]	190	395	2.5	6.0	12.3

a – Lactating herd is 60% in Costa Rica
b – Labour input only during dry season

Although *H. rufa*, also called Jaragua, is native to South Africa, it has become widespread throughout Central America (FAO, 2005). It is a perennial plant that ranges from 60-240 cm in height. *Hyparrhenia rufa* is drought tolerant and has good disease resistance. It can withstand periodic flooding, but not permanent flooding. *Hyparrhenia rufa* must be periodically grazed down or burned or there will be a formation of tussock and bare ground. On a 10 percent moisture bases at floral initiation, *H. rufa* contains 3.65 percent crude protein, 33 percent crude fibre, 33.55 percent nitrogen-free extract, 1.63 percent ether extract and 16.5 percent ash (FAO, 2005).

Brachiaria spp. are a family of grasses that thrive in Costa Rica, despite the fact that some regions have high acid soils. The most common species being implemented throughout tropical areas include *B. brizantha*, *B. decumbens*, and *B. humidicola (*Holmann, 2000). *Brachiaria decumbens* is being replaced by *B. brizantha* and *B. humidicola* because they are more resistant to drought (CIAT, 2001). Detailed information about these three *Brachiaria* species is given in Table 3.2.

Table 3.2 – Information about the three common *Braciaria Spp*. used on farms in Latin America (adapted from Cook et al., 2005).

***Brachiaria* Spp.**	**Soil Requirement**	**Moisture Requirement**	**Temperature Requirement**	**Light Requirement**	**Grazing Tolerance**
B. brizantha	- pH 4-8 - Grows on acidic soils with high aluminum - Needs medium to high soil fertility	- Adapted to humid and sub-humid tropics - Can survive in dry season of 3-6 months	- Grows up to 2000 m above sea level - Survives light frost	- Prefers moderate light	- Tolerates defoliation
B. decumbens	- Can grow in low pH (3.5) with high aluminum - The roots are finer and longer allowing for greater uptake of P and N - It will not grow in clays subject to waterlogging	- Grows well in humid tropics and warm subtropics - Tolerates dry season of 5 months - Tolerates short term flooding but not temporary waterlogging	- Most productive in lowland humid tropics - Prefers temperatures above 19ºC - Leaves are burnt off by frost, but the plant is not killed	- Most suited to more open pastures - Can tolerate some shade	- Very tolerant to heavy grazing - Shade reduces tolerance to grazing
B. humidicola	- Can survive in low pH (3.5) and high aluminum - Can also survive in cracking clays and high pH soils coralline sands - Grows in low fertile soils and high fertile soils - Grows in waterlogged soils	- It has a wide range of moisture tolerance (600-2 800 mm per year) - Requires reasonably well distributed rainfall - Can survive moderate dry season of over 6 months - Extreme dry seasons cause plant to turn brown - Relatively tolerant to short term flooding and poor drainage	- Prefers tropical lowland environments - Low productivity in cool seasons - Poor frost tolerance	- Grows best in full sunlight, but can tolerate moderate shade	- Prefers moderate to heavy grazing - Does not do as well under low grazing

For cattle producers, *Brachiaria spp.* are valuable because these grasses have a high protein content, are easily digested by the cattle, and the cattle seem to enjoy the taste (CIAT, 2001). Environmentally, *Brachiaria* spp. resists trampling and heavy grazing, which tends to be a problem with natural grasses and *H. rufa*. It also suppresses weeds and helps to maintain soil moisture and fertility, in addition to acting as an important carbon sink (CIAT, 2001), serving the dual purpose of an adaptation measure to climate change and an environmental service.

Cratylia argentea is a type of legume native to the Amazon basin, central Brazil, and parts of Peru and Bolivia (Sanchez, 2006). It is a deep rooting plant that can act as a climber as a young plant, grow into a tree of up to six metres in height, or be a completely prostrate plant (Sanchez, 2006). *Cratylia argentea* recovers very well after being cut and can be cut several times in a year. Because of its deep roots, this species is very drought tolerant. During the dry season, *Cratylia argentea* has high leaf retention and high regrowth capacity (Sanchez, 2006). It must be planted by seed. Trials of vegetative propagation were unsuccessful. Because of this, it has a low ability to spread and become a weed (Cook et al., 2005).

Cratylia argentea is a good shrub for protein banks. When combined with sugar cane, it can be used as a protein supplement during the dry season for all animals, and especially milk cattle (Holmann, 2000). Unfortunately, *Cratylia argentea* has a slow initial establishment rate and unless the seeds are stored in optimal conditions, they lose their viability (Cook et al., 2005). The characteristics of this plant, such as deep roots, make it a useful plant for farmers to use on their farms to combat some of the challenges of climate change, such as heavier drought conditions.

3.3.1.2 Fodder Banks and Seed Banks

Fodder is another word for animal feed and includes different types of food such as grass, hay, silage, and roots (Jones, 2005). The number of animals a particular farm can maintain, or the carrying capacity of the farm, is dependent on the amount of suitable fodder that can be produced annually for the herd (Jones, 2005). Fodder banks consist of trees or shrubs, which are often legumes in addition to leguminous grasses. Some of the legumes also fix atmospheric nitrogen, making them a protein rich feed (Roshetko, 1994). The woody plants have relatively deep roots which allow them to reach soil nutrients and moisture that grasses and herbaceous plants cannot access (Roshetko, 1994). As a result, they are able to maintain their foliage well into the dry season. The purpose of fodder banks is to provide food to animals during the dry season when forage is scarce. Although they do not provide all of the feed requirements for the animals, fodder banks are a useful method to supplement available dry season forage (Roshetko, 1994).

There are costs associated with using fodder banks. The first is the need for fencing to ensure cattle are kept out of areas set aside. Initial labour costs to clear land (if necessary), and reseeding and maintenance of the land are also a potential issue (Taylor-Powell et al., 1986). There are also long-terms costs because of the need to potentially decrease the herd in order to be able to set aside land for the fodder bank. This could decrease the amount of money the farmer would have been able to get from the herd had he or she not implemented the fodder bank (Taylor-Powell et al., 1986; Jones, 2005).

The overall benefits of implementing fodder banks are difficult to assess. Ensuring fodder remains high enough to maintain the herd is essential. Profits do not come from a large number of poorly fed animals. It is much better to maintain a healthy smaller herd (Jones, 2005). This is why setting aside land for fodder banks is important, especially as the climate becomes more unpredictable and the number of severe weather events increases.

Seed banks are a collection of viable seeds (Greene, 2001). Farmers collect seeds from the most successful plants of the season and use them in the following season. This allows producers to only plant the highest quality seeds that are adapted to the most current climatic conditions (Greene, 2001). This technique allows farmers to improve their chances of harvesting a successful crop as the temperature and precipitation continues to change. It is also low cost and easy to implement by farmers, making it an ideal adaptation strategy.

3.3.2 Agroforestry

Agroforesty refers to a system where trees are intentionally grown on the same site as agricultural crops and/or livestock in order to increase production yield (Hubbard et al., 1998). Agroforestry was first introduced to help maintain productivity of crops, land, and cattle with minimal or no external input of nutrient resources (Fritschel, 2006; Verchot, 2007). Recently, this system has also been found to reduce atmospheric CO_2 through carbon sequestration in the tree and soil components (Oelbermann, 2004a; Fritschel, 2006; Verchot et al., 2007). According to the IPCC, agroforestry offers the greatest potential of all land use types for carbon sequestration (Verchot et al., 2007). By converting pastures (Figure 3.1) and monocrop row crops into an agroforestry system, the amount of carbon stored in the above ground biomass increases (Verchot et al., 2007).

Figure 3.1 – Trees in an agroforestry system near Esparza, Costa Rica, protecting the pasture from heavy rains and preventing soil erosion.

The vulnerability of an agroecosystem to climate change can be greatly decreased with the implementation of an agroforestry system. Trees help to regulate the hydrological cycle during periods of flooding or drought, thereby protecting the system from extremes (Verchot et al., 2007). Agroforestry systems also increase agricultural output per unit area of tree/crop/livestock; protect crops and livestock from damaging winds; and increase financial diversity and flexibility through the addition of new products (Molua, 2003).

According to Oelbermann (2004b), one type of agroforestry system, called alley cropping, helps to maintain or improve grain yield and sequesters a significantly greater proportion of carbon in the soil when compared to a monoculture system. The use of fruit trees complements and increases the farm profit level as the fruit can be sold locally or commercially, depending on the size of the farm (Molua, 2003).

Improved fallow is another method farmer's use that is associated with agroforestry. Fallow is used by farmers as a way to allow pasture and crop areas to rejuvenate naturally by giving them a "rest" period or a period where no crop or grass production takes place (Wilkinson, 2007). Improved fallow refers to the deliberate planting of fast-growing trees, shrubs or vines in rotation with crops in order to improve soil fertility in areas of nitrogen (N) deficiency (Franzel, 1999; Wilkinson, 2007). Using improved fallow allows farmers to reduce the length of the fallow period (Wilkinson, 2007). The benefits of using improved fallow include enhanced soil fertility, reduction in weeds, breaking of hard soil particles, regulation of soil temperature, shade, protection from wind, reduction in erosion, encouragement of beneficial soil microorganisms, and the break-up of rocks and other barriers that may hinder root growth (Wilkinson, 2007).

Live fences refer to living trees that are planted to replace fence posts. They are used to separate pastures from: 1) other pastures, 2) roads, and 3) natural areas (Harvey et al., 2005). Live fences are common throughout Costa Rica and Latin America (Harvey et al., 2005). A study completed by Harvey et al. (2005) mentions that the shade produced by the live fences helps to reduce heat stress on the cattle, particularly in the dry season. This results in an increase in cattle weight, milk production, and reproductive rates. This study also showed that farmers are aware that the trees must be maintained because too much shade decreases grass growth, which decreases overall productivity on the farm (Harvey et al., 2005). The cost of erecting a living fence in Costa Rica is approximately US$610/km (Pagiola et al., 2004). Agroforestry systems help protect land and animals from many of the adverse conditions resulting from climate change, such as increased rain intensity and drought conditions. Therefore, they make important adaptation strategies for farmers.

3.3.3 Water Conservation and Protection

The quantity of water available in any given region is directly dependent on temperature and precipitation (Mata and Budhooram, 2006). Changes in temperature and precipitation caused by climate change are expected to have significant impacts on water resources (Mata and Budhooram, 2006). In tropical regions, the more vulnerable populations tend to live upstream of more populous areas. Farmland upstream is typically much less productive and the terrain is more variable due to an increase in mountainous areas (Kosoy et al., 2006). According to the World Meteorological Organization (WMO), countries must develop policies that effectively address drought management. These policies should emphasize preparedness and incentives to adapt water management strategies, insurance, relief, and regulation, in that order of priorities (WMO, 2006). Currently, much more research is needed to determine the impacts of climate change on water resources in specific regions and the impact these changes are going to have on the different sectors (Mata and Budhooram, 2006).

There are some projects that look at the impact of climate change on water and how regions and sectors can and should adapt. One such study compares the impacts of future water availability for agriculture and its ability to provide ecosystem services in five different regions throughout the world (Rosenzwelg et al., 2004). They found that the water-rich areas of their study can adapt to climate change as long as technology continues to improve irrigation and drainage techniques and better water management techniques are developed, including water demand control. Dry areas, however, are expected to be faced with harsh obstacles if they wish to continue to expand agricultural productivity to meet the growing food demands (Rosenzwelg et al., 2004).

Mata and Budhooram (2006) suggest that climate change mitigation and adaptation must be combined when looking at water resources. One issue with the agriculture sector is that regions that are suffering due to lack of water will need to develop new farming techniques, including improved irrigation and water storage techniques that capture water during the wet season for use during the dry season. If this does not happen and productivity continues to decline, farmers may expand their agricultural land, which in turn will require more water (Mata and Budhooram, 2006). In their findings, they highlight the importance of reinstating streamflow monitoring, developing a better understanding of climate processes, and improving information and education programmes (Mata and Budhooram, 2006).

3.3.4 Adaptation and Environmental Services Summary

All of the strategies mentioned above add environmental services to the farm by increasing biodiversity, improving scenic beauty, improving water quality or quantity, and sequestering carbon. These also serve as climate change adaptation strategies. As a result, these strategies are important to the farmers because they increase the farms' resilience to climate change as well as providing other environmental and social benefits. The focus of the PES programme has been on the implementation of environmental services for environmental reasons. Links have been made with the use of environmental services as climate change adaptation strategies (Corbera et al., 2006). The PES project organized by CATIE in Costa Rica focuses primarily on the use of PES to promote environmental management (Pagiola et al., 2004). This research bridges the gap between the use of PES and climate change adaptation, providing a potential means of further encouraging farmers to adapt to climate change.

Chapter 4 Study Sites

This investigation took place in Costa Rica, which is located in Central America between Nicaragua and Panama. Costa Rica was chosen because of the extensive work by CATIE in developing adaptation strategies for producers, in association with their PES project. As a result, Costa Rica serves as a good study site to evaluate the success of these strategies and determine what can be learned as other countries begin to develop climate change adaptation strategies.

4.1 Climate Patterns in Costa Rica

In Costa Rica, easterly trade winds and the terrain are the key components influencing the climate (Ramirez, 2005). It rains almost all year on the Caribbean side of Costa Rica. Conversely, the Pacific side has a distinct wet season, from May to November, and distinct dry season, from November until May (Ramirez, 2005). Oscillations with different spatial and temporal scales result in climate variations throughout Latin America. The El Niño-La Niña inter-annual cycles, and intra-annual fluctuations, such as the Madden Julian Oscillations (MJO), are examples of large spatial scale variations that impact Costa Rica's climate (Ramirez, 2005).

Current evidence suggests that climate change is significantly impacting Costa Rica. For example, Pedro Sanchez (2001) suggests that there is an expected increase in rainfall variability as well as an increase in the number of extreme weather events as a result of climate change. Current research is showing that there is a warming trend throughout Central America (Ramirez, 2005). The HadCM2-IS-92a model, used by TroFCCA, predicts that by the year 2100, Costa Rica is expected to see an increase in temperature between 0.6 and 3.5ºC, a decrease in precipitation ranging from 0.4 to 46.3%, and a decrease in cloud cover between 0.5 and 23.8% (TroFCCA, 2006). Using the climate models Hadley's HADCMGHG and HADCMGHS HADCM2, TroFCCA predicted climate conditions for selected years between 2010 and 2100 (Ramirez, 2005) (Table 4.1).

Table 4.1 – Climate scenarios using the models Hadley's HADCMGHG and HADCMGHS HADCM2 in Costa Rica. The values represent a simulation of results of Costa Rica's climate at a CO_2 concentration of 323ppmv, based on the assumption that atmospheric CO_2 concentrations will double by 2075 (adapted from Ramariz, 2005).

Climate Scenario	Pessimistic		Optimistic		Timeline
Climatic Elements	**Precipitation (%)***	**Temperature (˚C)****	**Precipitation (%)***	**Temperature (˚C)****	**Year**
Pacific Basin	-12.1	+1.2	-10.0	+1.0	2030
	-18.5	+1.9	-13.7	+1.4	2050
	-33.9	+3.4	-18.2	+1.6	2100
Caribbean Plains	-11.8	+1.2	-9.8	+0.9	2030
	-18.1	+1.7	-13.4	+1.2	2050
	-33.1	+3.0	-17.8	+1.6	2100

* Negative values denote a decrease in the precipitation received in each of the given regions in Costa Rica.
** Positive values denote an increase in temperature in each of the given regions in Costa Rica.

The IPCC (2001) has predicted similar results to those reported by Ramirez (2005). Their research suggested that under elevated atmospheric CO_2 concentration, the Pacific region may experience the greatest impact of climate change with a temperature increase of approximately 3ºC by 2100, and a decrease in precipitation of 25%. Climate predictions by the IPCC in the Caribbean region differ from Ramirez (2005). The IPCC has predicted that this region may experience the same increase in temperature, but a slight increase in precipitation (IPCC, 2001).

These temperature and precipitation changes are going to affect farmers throughout Costa Rica. Farmers in various regions will adapt differently to these changes based on their economic, social, and environmental circumstances. Inequalities related to access to resources and information between the wealthy and the poor, and among different regions, will play an important role in impacting how well farmers address these changes.

4.2 Boundaries of the Study

This study has been limited to small- and medium-scale farms (smaller than 60 ha). The purpose of the study is to focus on how small- and medium-scale farmers are attempting to overcome the impacts of climate change. This means the large-scale farms, such as the Del Monte pineapple plantations located around Buenos Aires, were not considered.

The focus of this study was on how farmers involved in PES are adapting to climate change. Therefore, farmers participating in the extensive programme designed by CATIE were the ones chosen to be surveyed. Information from a second sustainable community was gathered through interviews as well. This information was used to determine if improvements should be made to improve the adaptive capacity and overall resilience of farms involved in PES. Farmers in the rest of Costa Rica were not surveyed as a result of this methodology.

4.3 Introduction to Study Sites

Two locations were selected as focus areas. These areas include the region around the town of Esparza (09°59' N and 84°38' W), located in the northern part of the province of Puntarenas, and the village of Durika, located about 20km east of Buenos Aires (09°15'N and 83°15'W) in the southern part of Puntarenas (Figure 4.1). The region around Esparza was selected because this is where CATIE initiated the project relating to silvopasture practices and PES in 2002. Therefore, this site provides information about the effect of PES on farmers' knowledge associated with climate change as well as the impact on various farming techniques. The community of Durika was chosen because they practice sustainable agriculture, which includes many specific climate change adaptation strategies. As a result, their methods combine climate change adaptation and mitigation versus PES which focuses on climate change mitigation. Also, the incentives in Durika for adapting to climate change are directly related to their desire to improve their overall sustainability, rather than to receive monetary incentives. This offers an interesting perspective on improving methods to encourage farmers to adapt through a programme such as PES. The geographical differences between the two study areas are illustrated in Table 4.2.

Figure 4.1 – Map of Costa Rica illustrating the two study areas. (Courtesy of the University of Texas Libraries, The University of Texas at Austin, 2008).

Table 4.2 – Characteristics of the study sites in Esparza and Durika.

Characteristics	Esparza (and surrounding region)	Durika
Latitude and longitude	09°59' N and 84°38' W	09°10'N and 83°20'W
Average annual precipitation (mm/y)	1500-2000	3500
Mean annual temperature (°C)	27	Rainy Season: 10-22 Dry Season: 6-27
Elevation above sea level (m.a.s.l.)	50-1000	1400-2800
Mean Hours of sunshine	Nov-Apr: 10 hours/day May-October: 6 hours/day	Jan-Feb: 7 hours/day Mar-Apr: 6-7 hours/day May-Oct: 3-5 hours/day Nov-Dec: 5-7 hours/day
Time of dry season	November-April	November-April

4.4 Study Site #1: Esparza

4.4.1 CATIE's Payment for Environmental Services Project

In 2002, a PES pilot project was initiated in farming areas with degraded pastures throughout Central and South America. Quindío, Columbia; Matiguás-Río Blanco, Nicaragua; and Esparza, Costa Rica were the three study areas chosen (Pagiola et al., 2004). Farmers participating in the project received payment for the environmental services they generated, including increasing biodiversity and carbon sequestration. Researchers from CATIE evaluated each farm to determine the number of points received based on the baseline data for that particular farm and the type of service implemented. This payment was received over a two or four year period, based on the increment of environmental services provided relative to the baseline situation for that particular farm (Pagiola et al., 2004). The farmers who received payments over two years were paid US $70 per increment of environmental services implemented. Farmers who received payments of four years were paid US $50 per increment.

There are many research institutes and organizations involved in this project. It was developed by the Regional Integrated Silvopastoral Ecosystem Management Project (RISEMP) and was funded by the Global Environmental Facility (GEF) (Pagiola et al., 2004). This project improves upon the existing PES programme in Costa Rica by valuing land use changes differently depending on the region. The current programme in Costa Rica pays all participants the same amount for conservation of an existing forest. This system fails to recognize the varying levels of services different land uses can provide (Pagiola et al., 2004). The RISEMP PES project is designed to correct these issues as well as to determine whether farmers were more prepared to implement land-use changes to promote biodiversity and conservation with the use of financial incentives. Centro Agronómico Tropical de Investigacíón y Enseñanza is conducting the research in Costa Rica.

4.4.2 Characteristics of Esparza

The study area in Esparza is approximately 432 km^2 and includes the following towns and cities: Esparza, Artieda, Angostura, Salitral, Salinas, Miramar, Marañonal, San Jerónimo, San Juan, Sabana Bonita, Mesetas, Macacona, San Miguel, Cerrillos, Guadalupe, Peñas Blancas (Zamora-Lopez, 2006). There are 136 participants involved in CATIE's study, 105 are receiving payments, the rest are in the control group. This area is characterized as a wet sub-humid tropical region with a mean temperature of approximately 27ºC and a precipitation amount ranging between 1500-2000mm/year (Zamora-López, 2006). The elevation ranges from 50-1000 metres above sea level (Santos, 2004). There is a distinct wet (May to October) and dry season (November to April). The primary agriculture systems include beef, dairy, fruits, rice, and sugar cane production. There are also several protected areas in this region including Arenal, La Fortuna, Zapotal, part of Monteverde, and Alberto Brenes biological reserve (Zamora-López, 2006).

Producers in the Esparza region are relatively secure in their economic status. Many of the farmers visited have televisions, phones, and/or computers. Some farmers also have digital cameras. The mechanization of each farm varies. Some have a high degree of mechanization, while others farm in a less mechanized way. One example of this is with two different dairy farmers. One has a fairly large mechanical milking operation, while the other has only a few cows and milks them by hand.

In terms of the farmers surveyed in this study, the main type of farming is a combination of dairy and beef at 62%; followed by beef at 20%; mixed crop-livestock farming, at 14%; and a specialization in calves for breeding stock at 8% (Figure 4.2). The mean farming experience for this group is 32 years, with a maximum of 65 years and a minimum of 9 years. The information gathered from the producers for this study is based on their experiences on their farms. As a result, the longer they have been working on their farm, the more information they have based on their experiences with climate.

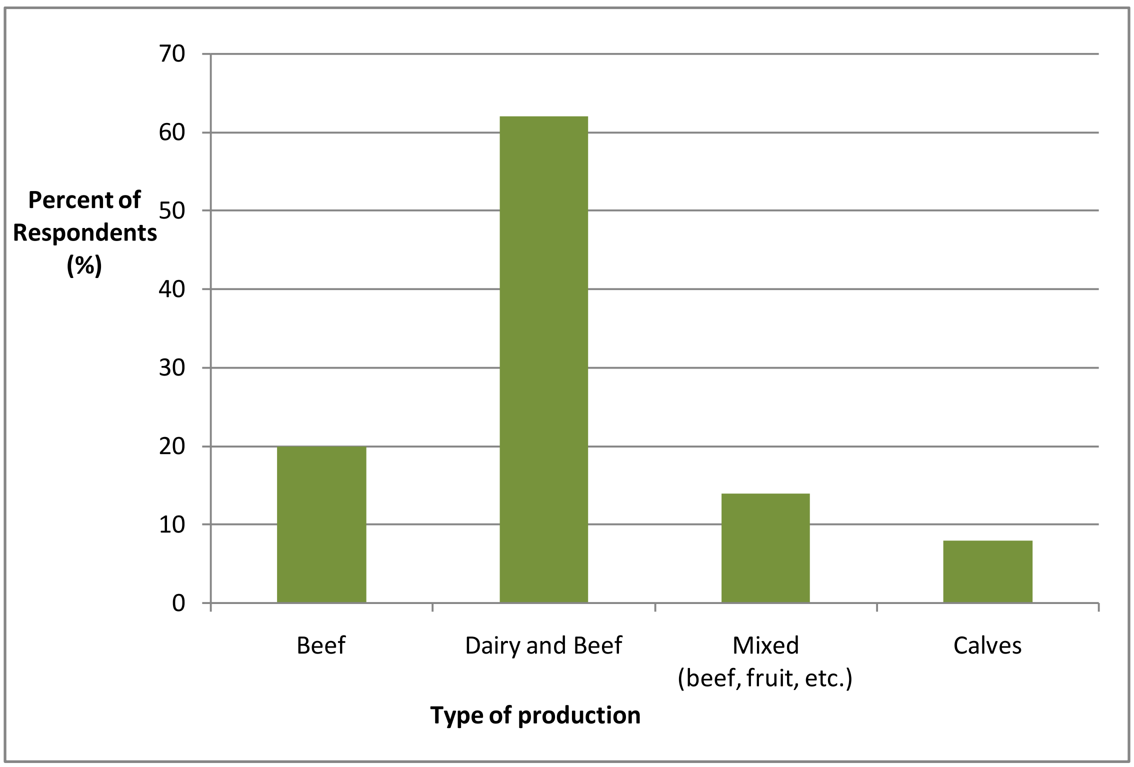


Figure 4.2 – The major types of production by the producers surveyed in Esparza are: beef; a mix of dairy and beef; mixed beef; fruit and vegetables; and a specialization in calves for breading stock.

4.5 Study Site #2: Durika

In the southern region of Costa Rica, the focus was on producers in the Talamanca mountain range southeast of Buenos Aires, Costa Rica in a community called Durika. Durika has a population of 30 individuals and is located in the foothills of the Talamanca mountain range. The landscape is made up of deep canyons and ridges, with few flat areas (Durika, 2006). This region is also characterized by a distinct wet and dry season. Rainfall is approximately 3,500 mm per year, most of which occurs during the wet season (May to November). The temperature ranges from 10-22°C in the wet season and 6-27°C in the dry season. The elevation ranges from 1400 to 2800 metres above sea level and the community is at 1650 metres above sea level. This area is affected by trade-winds predominant from the North to Northeast. During the dry season, they can reach speeds of up to 97 km per hour (Durika, 2007).

The agricultural land surrounding Buenos Aires is dominated by large scale pineapple plantations. At higher altitudes near Durika, there is a shift away from pineapple production to cattle ranching. Similar to Esparza, cattle production is prominent throughout this region. Unlike Esparza, there is very little agroforestry. Much of the land has been cleared for cattle, and there is very little integration of trees into farming practices. Because of the lack of trees, sections of mountain sides have been eroded (Figure 4.3).

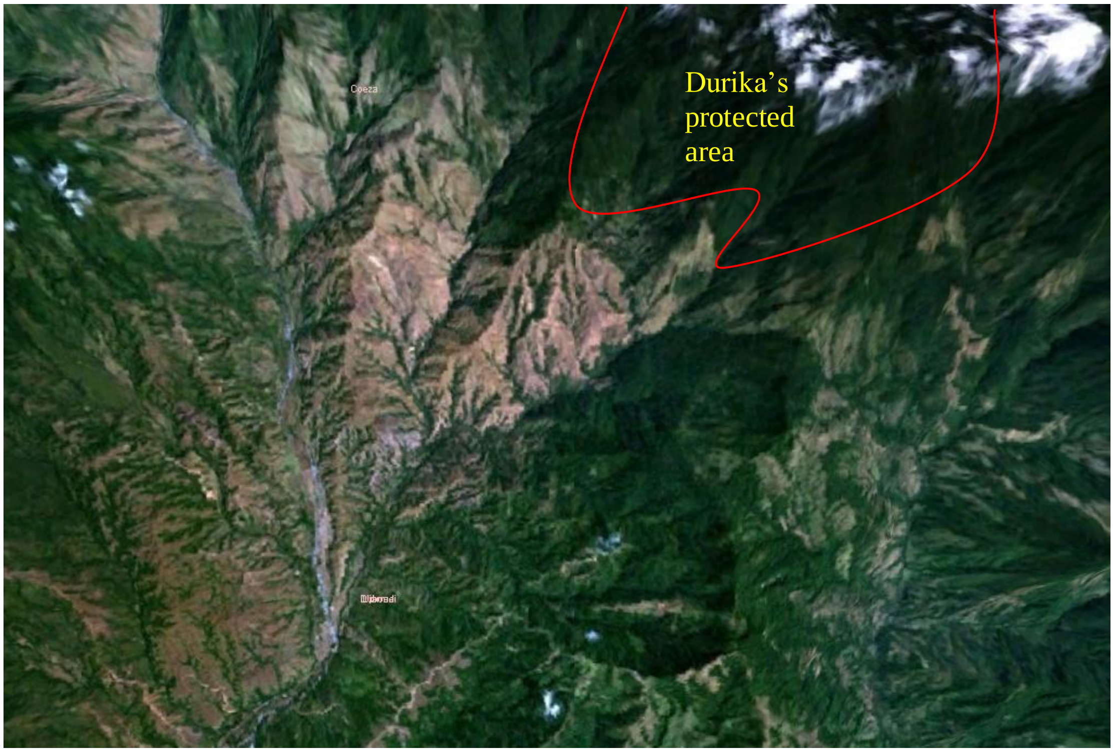


Figure 4.3 – This satellite imagery shows part of the land owned by Durika as well as the land owned by local farmers. The land owned by Durika is well forested (dark green), while the land on the farms nearby is showing the effects of deforestation and erosion caused by poor farming practices (brown). (NASA, 2005)

Durika is a sustainable agricultural community (Durika, 2006). This community is comprised of ecologists, professors, doctors, and other professionals from Costa Rica who developed this sustainable agricultural community as a way to restore some of the degraded land caused by poor agricultural practices (Durika, 2006). Their primary agriculture combines goats, fruits, vegetables, and coffee (Durika, 2007). The objectives of the community include the following:

- Establish a self-sufficient community.
- Improve the quality of life of Durika members.
- Extend the social, productive and cultural capability among all members.
- Create social and community programs.
- Instill in the members the need to share in a healthy, peaceful and well intentioned way.
- Protect the environment and the eco systems that exist in the area.
- Promote the establishment of environmental education programs.

- Promote scientific investigation in different areas.
- Promote the rational management of land.
- Rescue the legends and traditions of the local indigenous population.
  (Durika, 2007).

Over the past decade there has been a significant loss in the number of smaller farms in this region. Many have been purchased by large scale farmers for pineapples, bananas, and sugar cane. The small- and medium-scale farmers in this region practice slash and burn agriculture for cattle production and to grow coffee, beans, and corn on a small-scale (Durika, 2006). As a result, many of the mountains are deforested (Figure 4.4). Based on discussions with the community leader, the land where Durika is currently located was once a cattle farm. As a result of clear-cutting practices and the severity of the slope, the land degraded to the point that the farmers were forced to leave. The land was then purchased by a few Costa Rican citizens who founded the Durika community. Their intent was to reforest this degraded land and develop sustainable agricultural practices. Unlike farmers in the area, Durika members began farming with knowledge of ecological principles, climate change, economics, and sustainability and used that to reforest the land and develop their agricultural methods. They also moved in with the hopes of educating local farmers on more sustainable agricultural techniques as well as helping preserve some of their local traditional knowledge and indigenous culture. Their practices involve a combination of climate change mitigation and adaptation strategies.

Chapter 5 Esparza Results and Discussion

5.1 Farmers' Perceptions of Climate Change

Farmers in Esparza involved in PES have undertaken many land use changes as a result of the PES project, including implementing agroforestry systems and planting *Brachiaria spp*. (Zamora-Lopez, 2006). For example, in 2003, prior to the PES project, on farms where *H. rufa* was the primary grass in the pastures, 4.8% had no trees. On farms where *Brachiaria* grass was dominant, 2.3% had no trees. In 2004, after the PES project was initiated, all farms had planted trees in their pastures (Zamora-Lopez, 2006). After only one year, the benefits of the PES project were observed in Esparza and, since then, these changes have continued (Zamora-Lopez, 2006).

No baseline data was collected in Esparza about farmers' knowledge and perceptions of climate change or if they were implementing any adaptation strategies prior to the PES project. The fact that after only one year of working with farmers through CATIE's PES project, the amount of degraded land decreased 15.3% (Zamora-Lopez, 2006) and farmers had converted areas with few or no trees into areas of agroforestry does suggest that even if farmers did understand what climate change was prior to the programme, they did not have enough information to adequately adapt their farming practices. The incorporation of carbon sequestration into the environmental service programme also promotes the idea of providing farmers with information about climate change, particularly how their agricultural methods can be used to reduce atmospheric CO_2. Farmers are therefore receiving additional information about climate change, which again supports the idea of improving farmers' knowledge about the issue.

Current data from Esparza shows that 90% of the farmers' surveyed claim to understand what climate change is and how it is caused. In defining its cause, farmers used a variety of words including "deforestation", "forest fires in the rainforest", "human-made contamination", and "poor management". Almost 80% of the farmers believe that climate change will impact, or is having impacts on their farm and their family. Only 6% of the farmers believe that climate change is caused by natural processes. These results are expected considering carbon sequestration is one of the four main environmental services, which helps to reduce atmospheric CO_2. Approximately 56% of the farmers mention that they have received most of their information about climate change from CATIE. Another 34% mention the Costa Rican Ministry of Agriculture (MAG) as their primary source of information. This suggests that many farmers in Esparza have improved knowledge of climate change as a result of their involvement in the PES programme and the social networks they have established as a result of the programme.

The Climate Change Action Fund, initiated in 1998 in Canada, had similar results to those in Esparza. In an evaluation of the project, Natural Resources Canada determined that public outreach and education contributed to increasing public awareness about climate change (Natural Resources Canada, 2005). A study by the International Food Policy Research Institute (IFPRI) completed in 2007, examined farmers' perceptions of climate change and how these perceptions influence adaptation in countries in Southern Africa. They also found that education greatly improved the farmers overall understanding of climate change and how it affects their farms (Nhemachena and Hassan, 2007). Therefore, there is evidence to suggest that the PES project has played an important role in providing farmers in Esparza with background information on climate change.

5.2 Farmers' Climate Change Observations

During the past decade, producers observed many climatic changes throughout the region. Almost all farmers (98%) noticed that the temperature has increased over the last decade, while 70% mentioned rainfall has become longer in duration and more intense during the wet season. Another 78% have observed negative impacts due to extreme drought conditions during the dry season, including a decrease in their production yield and the water available to their animals as well as their family. As a result of the increased intensity of the dry season, 82% of the producers surveyed indicated that rivers and streams throughout the area are becoming dryer earlier in the dry season compared to 10 years ago, resulting from a combination of prolonged dry seasons and increased temperatures. The decline in the number of streams is increasing despite the fact that farmers say there has been an increase in the intensity and duration of rain during the rainy season.

These results are similar to those found by the TroFCCA models and the IPCC's research, which show that the Pacific region in Costa Rica is expected to experience a decrease in precipitation (TroFCCA, 2006; IPCC, 2001). Observations by producers of increasing ambient temperature are a reflection of the accuracy of the modeled predictions. Although farmers are noticing that when it does rain the rains are more intense, the overall precipitation throughout the year is decreasing. This is having negative impacts on their farms.

Farmers attribute the increase in temperatures to a decrease in overall crop production, a decrease in food available for their families and their animals, a decrease in the weight of their animals, a decreased dairy production, and a loss of harvest (Table 5.1). According to farmers, a prolonged dry season leading to drought conditions causes a decrease in forage production; reduced carrying capacity on the farm and therefore a reduction in the number of animals; a loss of harvest; a decrease in the quality and quantity of milk production; less water for humans and animals; and depletion of streams and brooks that run through their farms (Table 5.1).

Table 5.1 – Observations related to quantity and quality of available food and water as a result of increased temperatures and prolonged drought in Esparza, Costa Rica.

	Hotter Temperatures				
	Decreased Production	Decrease in Food	Loss of weight of animals	Decreased milk production	Loss of Harvest
Percent of farmers who observed trend (%)	72	76	80	72	38

	Prolonged Dry Season					
	Decreased available food (forage)	Loss of animal	Loss of Harvest	Decreased milk production and quality	Less water (for humans and animals)	Decrease in volume or depletion of brooks
Percent of farmers who observed trend (%)	72	76	46	74	54	64

Based on the surveys and interviews, farmers who live in the same local area reported similar climate data as their close neighbours. For example, farmers near the Pacific Ocean focus on an increased intensity of rains, while farmers in the mountains mentioned that droughts during the dry season are much more severe. The differences of observed increases in temperature and intensity of precipitation varies over larger areas. Trends observed in temperature and precipitation, however, were consistent throughout the study area. This information implies that climate models can only be used as a guideline. For farmers to adapt, they need to be prepared to deal with extremes in temperature and precipitation, rather than relying solely on general trends predicted for the entire pacific region of Costa Rica. Research completed by Rughooputh (1997) from the University of Mauritius suggests that developing climate change scenarios must take into account local variations, including microclimates. Understanding historic local climate data is also important when developing climate change scenarios (Natural Resources Canada, 1996). When trying to find specific historical climate data for Esparza, however, no information was available. This is problematic for researchers looking to determine the climate change trend for the region.

Farmers are divided between those who have observed an increase in pests or diseases affecting the crops or animals and those who have not. Locusts (*Schistocera spp.)* were mentioned by 38% of the farmers as the biggest pest problem that has increased over the past ten years. The Central American Locust (*Schistocerca piceifrons*) is the greatest threat that ranges through Central America and the northern regions of South America. Locusts can decimate an entire plant, and ultimately the entire field of crops. When the locust population is high, they consume very large quantities of crops and move over long distances in a short period of time (Department of Agriculture, Forestry and Fisheries, 2007). An increase in rainfall causes an increase in locust outbreaks (Department of Agriculture, Forestry and Fisheries, 2007). The farmers mixed responses suggests that based on farmers observations, there is no clear link at this point between increased locust outbreaks and current climatic changes in Esparza. This parallels research conducted by the Australian Government on locusts throughout tropical regions (Department of Agriculture, Forestry and Fisheries, 2007). They found that locust populations do increase with increased rainfall, however, none of their research has shown a connection between climate change and increased locust populations (Department of Agriculture, Forestry and Fisheries, 2007). Because increased rainfall increases locust outbreaks, the fact that the Pacific region of Costa Rica is expected to see a decrease in precipitation (IPCC, 2001) suggests that there is likely to be a decrease in locust populations. According to the IPCC (2001), however, changes in El Nino frequency will cause unpredictable changes in the timing, location, and extent of locust outbreaks, due to more extreme fluctuations in temperature and precipitation patterns. More specific research is needed to determine the potential impacts of climate change on locust populations and what this is going to mean to farmers as the climate continues to change.

Producers also noted an increase in snake populations. The increase was observed to a greater degree by farmers in the mountains. Several mentioned that there were snake varieties in their fields that had not been there before and that previously these snakes were generally found much closer to the coast. Although no scientific evidence could be found to support these observations, the movement of certain snake species to higher elevations is similar to findings of certain bird species moving to higher elevations, such as the toucan (Kirby,1999 ; Fenn, 1999). Conversely, researchers studying amphibian populations, which are closely related to reptiles, have failed to find a change in distribution of amphibian populations. Changes instead are primarily associated with the timing of their breeding (Corn, 2005). Although there have been no observed impacts by the farmers from the shift in snakes, changing population dynamics are expected to cause potentially significant ecological changes due to changes in predator-prey relationships (Boye and Klingenstein, 2006; Crick, 2006). Further research needs to look at changes in population dynamics and the overall impacts on agricultural systems.

5.3 Adaptation Strategies

All of the farmers participating in CATIE's project have integrated environmental services into their farming methods. Many of these farmers also recognize the use of these strategies as climate change adaptation methods. Many farmers have also integrated strategies not associated with the PES project, such as the use of supplements. Although the use of supplements was implemented prior to the farmers' knowledge of climate change, similar to the use of environmental services, many farmers in Esparza recognize their use as a potential method to adapt to climate change. When farmers were asked specifically about what strategies they have found useful during increased drought conditions, they cited several environmental services and general farming practices (Table 5.2). These strategies are addressed in more detail below.

Table 5.2 – Percent of farmers surveyed in Esparza who have mentioned the use of a particular adaptation strategy to address the issue of increased drought conditions. Most of these strategies are part of the environmental service programme or were already being implemented by the farmer prior to their knowledge of climate change.

<table>
<tr><th>Land-use and farming changes</th><th>Improved Pasture</th><th>Maintain trees</th><th>Fodder banks</th><th>Practice conservation of forage</th><th>Use Supplements</th><th>Select animals more resistant to drought</th><th>Suppress fires (especially in sugar cane production)</th></tr>
<tr><td>Percent of Farmers (%)</td><td>100</td><td>96</td><td>56</td><td>14</td><td>90</td><td>76</td><td>78</td></tr>
<tr><th>Water Protection</th><th colspan="2">Irrigation</th><th colspan="2">Protection of streams, rivers, springs</th><th colspan="3">Capture and storage water</th></tr>
<tr><td>Percent of Farmers (%)</td><td colspan="2">22</td><td colspan="2">96</td><td colspan="3">42</td></tr>
</table>

5.3.1 Improved Pasture

All producers in Esparza who participated in this research have planted *Brachiaria* grass in their pastures. Research by Holmann et al., (2004) indicates that as more information became available about *Brachiaria* grass species during the 1990's, more farmers throughout Costa Rica began purchasing seed. The annual growth rate in *Brachiaria* species seed sales throughout Costa Rica was 39% between 1990 and 2003 (Holmann et al., 2004). In 2003, 18.8% of the country's pastures were *Brachiaria spp.* (Holmann et al., 2004). The primary grass used in Esparza is *B. brizanth,* which is native to Africa. It is highly resistant to spittlebugs and provides good ground cover and weed suppression (Cook et al, 2005). For farmers, *B. brizantha* has a high seed production potential, making it easy for them to continue its growth on their farms (Cook et al., 2005).

Most of the farmers in Esparza are enthusiastic about the benefits of planting this grass in their pastures. Observed benefits of *B. brizantha* include reduced soil erosion, increased drought resistance, increased forage production, increased number of animals supported, improved maintenance of animal weight, increased dairy and beef production, and improved the health of the calves (Table 5.3).

Table 5.3 – Benefits observed from the use of *Brachiaria brizantha* by producers in the Esparza region of Costa Rica.

Observation	Percent of Farmers (%)
Less erosion	96
More drought resistant	100
Produces more forage in drought	98
Supports more animals	100
Animals maintain weight	92
Animals produce more dairy and/or beef	92
Calves are in better health	96

Of the 31 surveyed farmers who are involved in dairy production, 58% observed an increase in milk production during the dry season as a result of giving their cattle *Brachiaria spp*. The average increase in production observed among these farmers is approximately 26%, with one farmer measuring an increase of 70%. This information correlates with the research that shows *Brachiaria* has a higher protein content and improves milk production when compared with *H. rufa*. (CIAT, 2001; Cook et al., 2005). Observations by producers in Esparza also parallels research completed by Holmann et al., (2004), where they found that additional milk production in Costa Rica due to the adoption of *Brachiaria* exceeded 437 000 tonnes in 2003. This is equivalent to a 55.5% increase in national production (Holmann et al., 2004).

5.3.2 Fodder Banks

Fodder banks are used on 56% of the farmers surveyed. This is a very large number compared to the rest of Costa Rica (Pagiola et al., 2004). Pagiola et al. (2004) found that fodder banks are almost entirely non-existent in Costa Rica, with only 7 of the 110 producers surveyed in their study using a fodder bank with an average of less than 1 hectare. This suggests that farmers working with CATIE in Esparza are encouraged to use fodder banks. The producers in Esparza who are using fodder banks mention they are useful when there are problems with forage production as well as to address issues of drought.

5.3.3 Supplemental Animal Feed

Most of the farmers (90%) use supplements to help the animals get the nutrients they need, especially during drought conditions. They are using sugarcane, molasses, urea, and commercial concentrate. The farmers mentioned that the use of supplements is important to ensure their cattle are getting the nutrients they need, especially during times of severe drought or floods when crops do not have high nutrient levels (Moran, 2005; Bundaberg Molasses, 2007). Farmers in Esparza are also finding they are using more supplements to offset the reduced quality of food for their animals. During extreme droughts, many farmers indicated that they need to supplement the fodder banks to improve the nutrient levels.

5.3.4 Agroforestry

Of the producers in Esparza surveyed, 96% have integrated trees on their farms (Table 5.2). Of these farmers, 100% are using trees for wood for construction and fuel, 98% are using the trees for shade for the pastures and the animals, and 69% are using the trees for fruit production. Some producers are also using trees to help offset some of the issues associated with drought and flood conditions. The trees they planted have helped during dry phases by shading the soil and livestock. A few farmers (6%) discussed the connection between planting trees on slopes to prevent the soil from eroding and protection of rivers and streams. Many tree species were listed by the farmers as beneficial during dry phases for maintaining foliage and providing food to cattle during the dry season (Table 5.4). More information is provided about these species in Appendix 3.

Table 5.4 – Tree species listed by farmers as best for maintaining tree foliage and best for feeding animals during drought conditions.

Tree species that best maintain foliage during drought conditions	Tree species that are best to feed to the animals during times of extreme drought
Higueron (*Ficus hartwegii*)	Guacimo
Guacimo (*Guazuma ulmifolia)*	Guayaba (*Psidium friedrichsthalianum* Ndz)
Almendro (*Dipteryx panamensis)*	Madero Negro (*Gliricidia sepium*)
Guanacaste (*Enterolobium cyclocarpum)*	Guanacaste
Mango (*Mangifera indica* L.)	Mango
Nance (*Byrsonima crassifolia* HBK)	Coyol (*Acrocomia aculeata*)

Live fences are also common through this region (Figure 5.1). Every farmer interviewed in this study uses a live fence. These results are consistent throughout Costa Rica. A study by Harvey et al., (2005), found that in Costa Rica, over 80% of the farmers they surveyed used live fences (Harvey et al., 2005). Therefore, Esparza is typical of the rest of Costa Rica.

Farmers in Esparza mentioned that their living fences offer shade for the animals and pasture grasses. They also discussed that live fences are an economical way to separate pastures. This again corresponds with the findings from Harvey et al. (2005), where they found that most of the farmers they surveyed used live fences to separate pastures. The rest separated pastures from roads, and a small number sectioned off forest and riparian zones (Harvey et al., 2005). Many farmers also discussed the fact that they implemented live fences primarily because they offer environmental services by sequestering carbon and increasing biodiversity. Therefore, they receive financial incentives as part of the PES project. No farmer in Esparza discussed the use of live fences foliage as cattle fodder. Harvey et al. (2005) found only 10% of the farmers they surveyed used live fences for fodder. This suggests that farmers throughout Costa Rica, including those in Esparza, are not aware of all the benefits possible with live fences. Providing more information about live fences and the benefits they have for agricultural producers will encourage other farmers to implement these strategies. This is a strategy that has many merits and should become more widespread (Harvey et al., 2005).

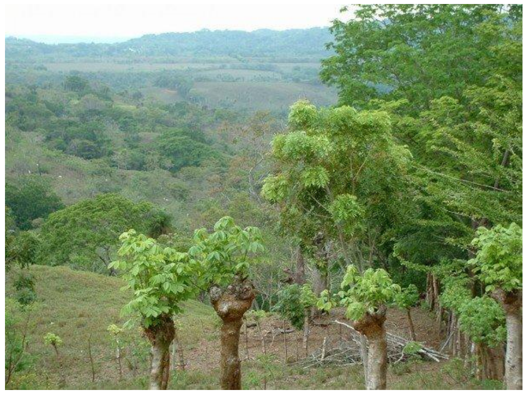


Figure 5.1 – A living fence with *Erythrina poeppigiana* on a farm in Esparza, Costa Rica.

5.3.5 Water Conservation and Protection

Water capturing and storage technology has been implemented by less than 50% of producers throughout the region (Table 5.2). Many of the farmers implementing water storage strategies developed the methods on their own (Figure 5.2).

Figure 5.2 – This farmer in Esparza is capturing water in a storage tank. The water stored is used for irrigation and watering the animals.

Water protection is far more prevalent than capturing and storing water. This study found that 96% of the farmers have implemented strategies to protect water sources on their farms. Some of the strategies included planting trees near the rivers to prevent soil erosion into the water and building fences to keep cattle out of water sources to prevent soil erosion and contamination down-stream (Figure 5.3). In Southern Africa, IFPRI mentioned that water conservation can provide important additional sources of water that can be used to deal with drought situations (Nhemachena and Hassan, 2007). They found that farmers in their study areas were increasing water conservation techniques (Nhemachena and Hassan, 2007), in ways similar to farmers in Esparza. Much more research is needed to improve water resource management in a climate change environment (Mata and Budhooram, 2006).

Figure 5.3 – These farmers in Esparza are in the process of installing a fence to protect the riparian zone by preventing cattle access to the stream. This protects water quality and also prevents streambank erosion.

5.4 Developing a Climate Change Plan

Most of the producers involved in CATIE's PES project (62%) do not have a long-term climate change plan in place for their farm. Of the farmers surveyed, only 28% who understood what climate change is and believe it will have major impacts on their farm and their family, have a climate change plan. A long-term climate change plan is essential for farmers to ensure they are able to benefit from the opportunities available with climate change and mitigate the negative impacts into the future. Having a contingency plan will reduce financial loss if unexpected weather does occur (IPCC, 2001). One farmer surveyed who does have a long-term climate change plan suggests that farmers without a plan to deal with climate change are going to be facing many more challenges than those who do have a plan (Anonymous 3, 2007).

Some farmers in Esparza are researching information about climate change in order to begin planning for the future. Based on discussions with farmers, 50% are seeking information about climate change because they are expecting changes in climate will force them to make major adjustments on their farms, including planting different crop species or finding new sources of water for their animals and for irrigation. Another 12% are obtaining information expecting that they will be required to make small changes on their farms to offset the impacts of climate change. The remaining 38% feel the changes will be too small that it is not worth researching information specifically related to climate change. These farmers believe that the adaptation strategies they have already implemented associated with the PES project will provide enough protection from any impacts that do occur.

Farmers who are seeking out information about climate change, including how it is caused, impacts on agricultural systems, and strategies to adapt are primarily using CATIE (56%) and the Ministry of Agriculture (MAG) (34%) as a source of information. Farmers who researched the issue gave more detailed responses about what climate change is and how it will affect their farms and families. One such response was that climate change is a “change in the Earth’s atmosphere caused from deforestation and industries” (Anonymous 1, 2007). An example of a response by a farmer who has not sought out information about climate change described it as seasonal changes. He said climate change is “the changes in the climate of the seasons each year” (Anonymous 2, 2007). The more information received by farmers about climate change, the more understanding they have on the issue and the more likely they are to adapt and create a long-term adaptation plan (Nhemachena and Hassan, 2007).

5.5 Implications of Climate Observations and Adaptation Strategies by Farmers in Esparza

Most of the farmers in Esparza, as well as the IPCC and TroFCCA have recorded changes in temperature and precipitation over the past few decades as a result of climate change.

Some farmers have mentioned these changes have impacted species dynamics on their farm, specifically relating the locust populations and snakes. The impact of climate change on flora and fauna need much more research (Füssel, 2007, Sivakumar et al., 2008). Understanding what changes are expected to occur can significantly improve the ability of farmers to adapt as well as decrease the overall cost of adaptation (Füssel, 2007).

As farmers become more educated about climate change, they may want to access historical climate data that they can use to help plan their farming methods each year. Historical information is incredibly useful for farmers to be able to develop a climate trend on their particular area (Cabrera et al., 2006). A study on dairy farmers in North Florida suggests that some farmers are interested in accessing past climate data (Cabrera et al., 2006). All farmers in this study that did use historic climate data used it for cropping systems to determine what crops to plant, when to plant, which fields to use, and to determine the drainage and irrigation system needed for that year. Some producers also used this information for milking rotations, planning of breeding times, and for nutrient management (Cabrera et al., 2006). Although farmers in Esparza did not specifically mention the desire to access historical climate data, many may find it valuable when it does become available for similar reasons as those in North Florida. This improved access to climate information will help the farmers make better decisions on their farms regarding the agricultural methods (Nhemachena and Hassan, 2007), as well as increase the understanding of climate change thereby improving adaptation (Füssel, 2007). Based on discussions with producers, three themes emerged to help encourage farmers to adapt. These include: 1) market incentives, based on what is in demand; 2) increased adaptive capacity; and 3) direct financial incentives, including credits and PES.

Market incentives were mentioned by 70% of the farmers in Esparza as a potential strategy to encourage further climate change adaptation. Market research suggests that farmers base their farming decisions on profit and yield (Adger, 2001). These farmers will therefore freely change their crops given the suitability of certain species to climate change. For reasons other than climate change, these farmers will be given incentives to adapt (Adger, 2001).

Increasing farmers’ adaptive capacity is another important incentive raised by farmers to adapt to climate change. In Esparza, 84% of the farmers mentioned that limited adaptive capacity is a major limiting factor to adaptation. The adaptive capacity to climate change is increased by improving social networks with institutions and organizations that provide information about climate change (Walker et al., 2007). These institutions must work with the farmers in order to assist in the development of strategies that moderate potential damages and provide opportunities to benefit from climatic changes (Gallopin, 2006). Through the PES project, CATIE has helped increase the number of social networks in the area. They are connecting farmers to the Ministry of Agriculture as well as providing opportunities for farmers to connect with other farmers in the area and learn about their farming methods.

Farmers in Esparza who understand the issue of climate change and how it is affecting their farms and their families, and who understand that they need to adapt to protect their animals and crops are more motivated to adapt than farmers who did not understand the issue. This mirrors the findings in Southern Africa where farmers involved in extension programmes had increased understanding of climate change and, as a result, were more likely to adapt (Nhemachena and Hassan, 2007). The PES project has engaged farmers in the education process and improved their adaptive capacity by providing social networks and knowledge about environmental services and the role they play in climate change adaptation.

The implementation of financial incentives is another strategy mentioned by farmers in Esparza to encourage adaptation. These included the use of credits (52%) and the use of PES (86%). Adger (2001) argues that the perceptions of the impacts [of climate change] and costs of adaptation are going to be the primary determinant in participation in climate change programmes. The initial costs of implementing a fodder bank and costs due to time lags before benefits are achieved are the primary causes of farmers being discouraged from adapting these strategies (Pagiola et al., 2004). In Southern Africa, financial incentives allowed farmers to meet some of the transactions costs associated with the implementation of adaptation strategies (Nhemachena and Hassan, 2007). Farmers in Esparza who did not believe in climate change were encouraged to implement environmental services for financial gain. The incentives offered by the PES project and their increasing knowledge on the value of environmental services allowed them to understand and benefit financially through implementing these services. The incentives discussed by farmers in Esparza are illustrated in figure (5.4).

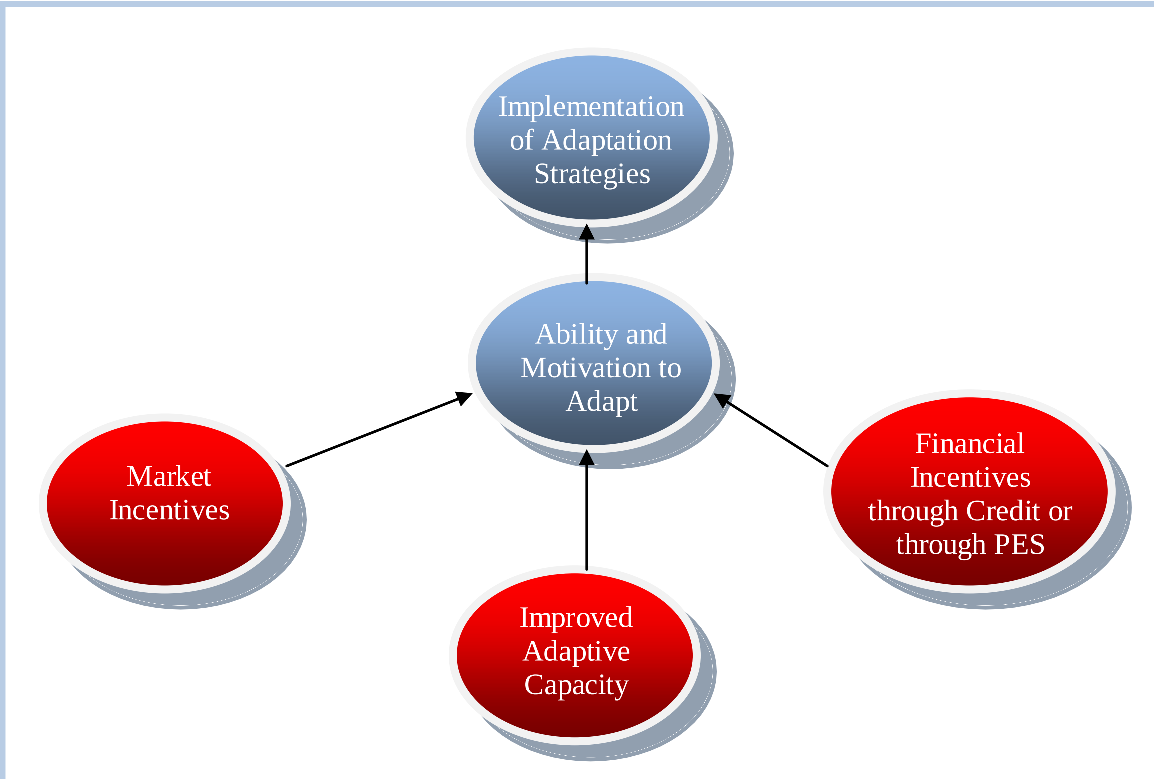


Figure 5.4 – Factors influencing farmers' ability and motivation to implement adaptation strategies. These are based on the qualitative discussions with farmers as well as the quantitative data collected in the surveys in Esparza.

The PES project developed by CATIE to improve farmers' awareness of environmental services has proven to be very successful at encouraging farmers to implement climate change adaptation strategies. Through this programme, farmers not only adapted the environmental services proposed by CATIE, they were also encouraged to develop their own technology specific to their farms based on their knowledge and experience.

Further information should be provided to farmers that relate climate change adaptation to the implementation of environmental services. This must include the development of a long term farm plan that takes climate change into account. Incorporating climate data into farming is essential for the sustainability of the system (Sivakumar et al., 2008).

Chapter 6 Durika Results and Discussion

No climate change adaptation data was collected in Durika prior to this study. The sustainable agricultural methods practiced in Durika were initiated because of the high degree of knowledge and education of the farmers about the benefits of sustainable agricultural practices and the farming methods that can help to improve degraded land. The social networks they have established with other organizations have helped them improve these methods.

6.1 Climate Change Observations

Farmers in Durika have noticed that in the last ten to fifteen years the climate patterns have changed dramatically. One farmer/ecologist claims that in the past 10 years, the climate has not been steady. He said that some years during the rainy season it rains much harder than usual, while in other years it does not rain at all. This farmer also mentioned that two years ago, in 2005, there was more than 5000 mm of rain during the year. He supplies daily weather information to the weather bureau in Costa Rica and has this information recorded. He also said that during that year, September, October, and November had the most rain observed in the area since the community was started. Last year (2006), however, the rainy season was almost like the dry season. Another farmer in Durika mentioned that in 2005 there was a day of intense rain that dropped almost 300 mm of precipitation in less than three hours. This rain caused landslides in agricultural fields as well as in the forested areas. According to this farmer, erosion from rain in the primary forest is incredibly rare. This was something the farmer had never seen before. The heavy rains in 2005 were also noted by the International Federation of Red Cross and Red Crescent Societies (International Federation of Red Cross and Red Crescent Societies, 2005). In September 2005, a weather bulletin was issued for many parts of Costa Rica, including Buenos Aires that warned about heavy rains. As a result of these rains, the Costa Rican government issued a state of emergency (International Federation of Red Cross and Red Crescent Societies, 2005).

In the dry season, Durika farmers noted that there was an increase in temperature. The increase in temperature does reflect the climate data from the IPCC and the models used by

TroFCCA. Accurate precipitation data has not been recorded in this area long enough to determine a trend. The one issue farmers mentioned related to the quantity and severity of precipitation is that precipitation varies greatly now compared to twenty years ago. Fluctuations and increased intensity of precipitation events are supported by IPCC (2001) and are associated with extreme weather events that are increasing in tropical regions (Magrin et al., 2007). Unfortunately, due to the lack of long-term temperature and precipitation data, conclusive evidence is unavailable (Magrin et al., 2007). This is a common problem throughout Costa Rica.

The ecologists in Durika have noticed changes in wildlife patterns and in vegetation that they have attributed to climate change. The Ferdelance snake (*Bothrops atrox*) usually resides along the coasts of Costa Rica. Within the past 2-3 years, they have observed this species in the mountains near Durika. This parallels observations by farmers in Esparza who have noticed snake species from lowlands moving up the mountains.

The numbers of frogs have also decreased significantly, especially along rivers. Ecologists claim that because the protected area of La Amistad International Park is located upstream of the community, development is not the issue affecting the frogs. Farmers have attributed the frog population change to climate change. The extensive research being done on the impacts of climate change on amphibians illustrates the importance of these observations. Researchers have observed declines in amphibian populations, and climate change is being blamed (Fenn, 1999; Schoville, 1999; DeGroot, 2000; Walther et al., 2002; Science Daily, 2006).

Currently, based on interviews with farmers from Durika, neither of these issues has posed a threat to their agricultural production. The farmers are vigilant to ensure the safety of their families and livestock, and no animal has been bitten by snakes to date. The change in frog populations has also not affected crops or livestock. One ecologist in the Durika community says, however, that these changes have happened very recently. Over the next ten years they expect to see many changes in the types of crops they can grow and the health of their animals as a result of the altered species patterns. As a result, they anticipate they will be forced to adjust their agricultural practices to address these changes. These results are reflected in several research studies that show shifting species populations are expected to cause potentially significant ecological changes due to changes in predator-prey relationships (Boye and Klingenstein, 2006; Crick, 2006).

6.1.1 Sustainable Agricultural Methods and Adaptation Strategies

In sustainable agricultural systems, understanding climate is essential (Sivakumar et al., 2008). According to Sivakumar et al. (2008), climate is one of the most critical factors determining the sustainability of an agricultural system. As temperature increases, soil degeneration and erosion increases and the potential for wind erosion increases. Less moisture accelerates these degenerative processes (Sivakumar et al., 2008).

The farmers within the Durika community are continually working to implement sustainable agricultural methods. These methods are designed to balance environmental health and economic and social needs. Within their agricultural methods, they are continually working to ensure their methods are resilient to change. Based on informal discussions with community members as well as the formal interviews, farmers in Durika understand climate change well and know the impacts it may have on their production. Unlike in the PES project, which focuses primarily on encouraging farmers to implement environmental services, climate factors play an important role in the development and implementation of the strategies implemented by Durika.

The primary initiatives implemented by Durika as sustainable agricultural methods that also serve as climate change adaptation strategies include the use of seed banks, agroforestry, water protection and conservation, and the use of supplements. Each of these is discussed in terms of their application within Durika.

6.1.2 Seed Banks

One of the projects farmers in Durika are currently working on is the use of seed banks to improve the quality of their crops. The seeds they are collecting are beneficial to them because they are adapted to their current climate conditions. If the seeds they plant fail to grow, they have back up seeds in the bank they use to help guarantee they grow sufficient crops for the year.

The concept of saving seeds is not a new one; it has been going on for over 200 generations (Shand, 1999). The idea behind saving seeds is that farmers are able to adapt their crops to suit the local farming conditions and their needs based on their seed collection each year (Shand, 1999). Seed banks are recognized as an important climate change adaptation strategy for farmers by providing seed diversity and providing raw genetic material to improve plant varieties (Malakata, 2007).

There is no specific data on the number of farmers saving seeds in Costa Rica. There is evidence that suggests that the number of farmers saving seeds throughout Latin America has declined over the past few decades (Arocena and Senker, 2003). Companies selling transgenic seeds to farmers have begun to force farmers to sign a contract stating that they will not save their seeds for the following years planting. This has had a significant impact on the number of farmers saving seeds throughout Latin America (Arocena and Senker, 2003).

6.1.3 Agroforestry

Successful and well-managed agroforestry systems diversify and promote sustainable crop production and provide erosion control and watershed services (Kanji et al., 2006). Agroforestry is important in Durika. Some of the trees growing in the area include oaks (*Quercus costaricensis*), Campano (*Nectamdra spp)*, Sweet Cedar (*Cedrela spp)*, Maria Cedar (*Calophyllum guatemalensis)*, Golden Fruit (*Virola sebifera)*, Avocados (*Lauraceas*, *Ocoteas*), Cerillo (*Symphonia globulifera)* and bananas (*musa)*. The trees offer fruit, protection from soil erosion, water protection, and shade for their animals. All the farmers in Durika mentioned the importance in maintaining trees on their land because of their location in the mountains. Without trees, many of their buildings and structures would be susceptible to destruction from erosion caused by heavy rains (Figure 6.1). All the farmers interviewed in this study mentioned that over the past few years they have been working to intensify their reforestation projects, especially as rain intensity during the wet season increases.

Figure 6.1 – This image is a picture of one of the goat sheds in Durika. All of the buildings in the community are located on a slope. As a result, farmers in Durika rely on trees to protect the soil from erosion and ultimately protect their structures.

6.1.4 Water Protection and Conservation

Water conservation strategies are an important aspect in sustainable agriculture. In a study completed by Pretty et al. (2003) examining sustainable practices household farmers were implementing in several regions in the world, including Costa Rica, they found that improved water harvesting and irrigation scheduling increased the number of crops that could be grown on the farm and increased water for irrigation (Pretty et al., 2003). More efficient water use played a significant role in increasing food production on these farms, and therefore the economic benefits felt by the farmers (Pretty et al., 2003). With an expected decline in precipitation in Costa Rica, Durika farmers mentioned they have increased their efforts to conserve and store water during the wet season, in order to ensure they have enough for their animals and themselves during the dry season.

Durika is very careful about protecting its water supply. There is one major mountain stream running through the community. Their agroforestry practices have helped to prevent soil erosion into water sources, thereby protecting water quality. They also capture rain water and overflow water during the rainy season that will last them through part of the dry season. During the dry season, they reduce their water use substantially and conserve as much as they can for their crops and animals.

6.1.5 Supplements

Similar to farmers in Esparza, farmers in Durika are using supplements in order to ensure their animals are receiving enough nutrients. When their forage quality is low during severe drought or flood conditions, this is especially important. The milking goats are fed molasses, urea, and concentrate as supplements. The quantity of supplements they are feeding their animals each year is increasing. They are attributing this increase to the decline of forage quality caused by changing climate conditions. Despite the fact that these farmers are working toward sustainable agriculture, they are still required to give supplements to the animals.

6.2 Implications of Climate Observations and Adaptation Strategies by Farmers in Durika

Data collected by farmers in Durika indicate an increase in temperatures and an increase in the variability of precipitation. These findings are supported by information from the IPCC (2001) and Magrin et al. (2007). As a result of the changes in temperature and precipitation, there have been observed impacts on snake and frog populations by ecologists within Durika. Although these ecological changes have not impacted their agricultural production, they are recent changes and expected to potentially cause issues in the future. The impact of climate change on flora and fauna needs significantly more research (Füssel, 2007, Sivakumar et al., 2008).

The lack of historical climate data in this region parallels the lack of data in Esparza. Durika does collect temperature and precipitation data; however, this information is not easily accessible by farmers outside the Durika community. Improving access to historical temperature and precipitation data as well as climate trends would be useful for all farmers (Cabrera et al., 2006; Füssel, 2007; Nhemachena and Hassan, 2007), including those in Durika.

The sustainable agricultural practices being implemented by Durika are improving the resilience of the system to climate change. A system with high adaptive capacity is able to moderate potential damages, take advantage of opportunities, and cope with any negative consequences (Gallopin, 2006). The implementation of seed banks, water protection and conservation methods, and agroforestry is improving the ability of the community to cope with climatic changes.

Part of the resilience theory suggests that combining different types of learning and improving social networks improves the adaptive capacity of the system and therefore, increases resilience. By developing partnerships with the National Institute for Learning (INA), the National Biological Institute (INBIO), the University of Costa Rica, and the Organization of Tropical Studies (OET) (Durika, 2007), Durika is pursuing a path of sustainability that fits with the resilience theory. The information they are learning from these social networks combined with their own experiences implementing new agricultural methods is promoting their resilience to climate change, as well as other potential challenges that may arise, such as economic decline.

Based on discussions with farmers in Durika, several themes emerged that encourage them to implement a particular climate change adaptation strategy (Figure 6.2). These include: 1) how the strategy improves the overall sustainability of their farm; 2) whether the strategy offers minimal risk in terms of decreasing production; 3) the type of information and support obtained from their social networks; and 4) financial support.

The first incentive is that the strategy also meets their goal of sustainable agriculture. They want to protect the environment while practicing their agricultural methods. They feel this is the best way to ensure their farming practices are resilient, not just to climate change but to other social, economic, and political factors that could affect them, including economic decline or changing markets. The concept of using sustainable agriculture in this way is reflected by policies currently being developed in England. The Countryside Agency in England is promoting initiatives that encourage sustainable agricultural methods alongside climate change issues. Similar to Durika, this agency promotes the idea that the issue of climate change should be addressed under the umbrella of sustainability (Lorenzoni et al, 2001).

The second incentive is that there is little risk for implementation. Essentially, they want to ensure that the new climate change adaptation strategy will not decrease their production or reduce their ability to feed themselves or their families. Even if it is only a temporary decline, this could impact the current well-being of the community members. They are concerned about this and account for it before implementing the strategy. If the adaptation strategy does not decrease production, they are more likely to implement the strategy. Research in Canada supports this demonstrating that producers make their farming decisions by considering more than just one issue. They look at many issues, including markets, profit, and the capital required to implement a particular farming practice (Wall and Smit, 2005). Therefore, the strategy must not hinder the farmers' ability to support their current needs.

The third motivation comes from Durika's social networks. Over the past 20 years, Durika farmers have increased the number of organizations from which they obtain information. These different organizations offer information and new technology that has helped them adapt to climate change. This new information provides them with incentive to adapt. Walker et al. (2007) and Gallopin (2006) both discuss the importance of improving social networks with institutions and organizations providing information about climate change. Having connections with institutions greatly enables farmers to adapt (Nhemachena and Hassan, 2007).

The final incentive that enables adaptation in Durika is financial incentives. They have received funding and support through grants and donations given to the community to help them adapt to climate change and implement some of their sustainability practices. Without these, they would not have been able to fund many of their projects, and therefore would not have implemented them.

Durika farmers initially began farming with some financial capital. This, along with grants and donations, has allowed them to implement many of their proposed strategies. Farmers outside of Durika, however, lack these funds. They are not receiving grants or donations, and most have little financial capital to invest in new strategies. The International Fund for Agricultural Development (IFAD) acknowledges the issue that small-holder farmers are not receiving the financial support necessary to allow them to implement climate change adaptation and mitigation strategies (Rahman, 2008). This is a major limitation as financial incentives allow farmers to meet some of the transactions costs associated with the implementation of adaptation strategies (Nhemachena and Hassan, 2007).

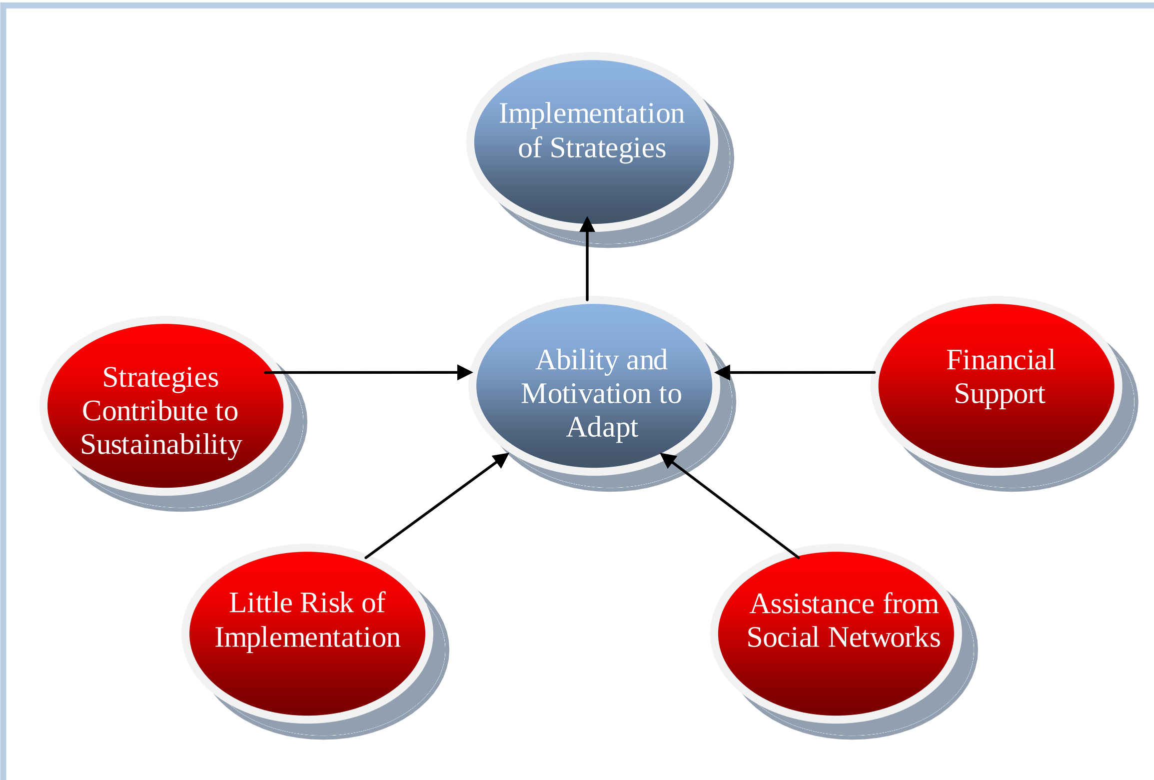


Figure 6.2 – Motivation to implement adaptation strategies, based on discussion with farmers in Durika.

Chapter 7 Implications of Climate Change Adaptation in Esparza and Durika

Climate change is affecting both Durika and Esparza. Producers' observations reflect predictions by many organizations including TroFCCA and the IPCC. Farmers in both areas have observed a general increase in temperature and decrease in precipitation. They also mention the increased intensity and severity of extreme weather events. Although there are differences in the exact amount of change, general trends have been observed in both areas.

Adaptive capacity to climate change is very closely associated with economic factors, particularly the amount of money the individual farmer has to adapt, as well as knowledge and access to information (Adger, 2001; Gallopin, 2006; Walker et al., 2007). Financial incentives and knowledge were cited in both Durika and Esparza as important in enabling them to adapt. To improve adaptive capacity, communities must have access to resources that enable them to implement income generating strategies. They also must have increased equity with other social groups and more involvement in the development of policies and specific adaption strategies (Nhemachena and Hassan, 2007). There are similarities and differences between the climate change programmes in place in Esparza and Durika. These relate to the strategies being implemented, the motivation behind implementing their strategies, and the networks developed with other organizations.

Table 7.1 – Similarities and differences between farming practices in Esparza and Durika and the support provided to each group of farmers.

	Esparza	Durika
Climate Change Programme	1. PES (mitigation)	1. Sustainable agriculture (mitigation and adaptation)
Motivation behind Implementation of Strategies	1. Approached by CATIE 2. Monetary incentives to implement environmental services	1. Initiated on own 2. Funding provided through grants and donations to implement strategies proposed by Durika members
Climate Change Adaptation Strategies	2. Agroforestry 3. *Brachiaria* Grass 4. Fodder banks 5. Water conservation and protection 6. Supplements	2. Agroforestry 3. Seed banks 4. Water conservation and protection 5. Supplements
Primary Sources of Support and Networks	1. CATIE 2. MAG 3. Local farmers	1. INA 2. INBIO 3. University of Costa Rica 4. OET

Some climate change adaptation strategies do have costs associated with their initial implementation. For example, planting *Brachiaria spp*. has an initial cost of US$250/ha (Pagiola et al., 2004). This cost, however, is offset quickly because fewer inputs, such as fertilizers and pesticides, are needed to maintain the grass and the cattle produce more milk during the dry season (Pagiola et al., 2004). One farmer in Esparza mentioned that anyone who looks at the initial cost of climate change adaptation and decides not to act is not fostering a sustainable farming strategy. He insists that the changes he has made are necessary to ensure he and his family are able to maintain economic stability through agriculture (Anonymous 3, 2007).

In CATIE's PES project, researchers, academics, and rural extension officers work directly with some of the farmers and offer technical support associated with environmental services, including which tree species are best to plant based on their farm characteristics and how to ensure the success of the trees. The environmental services covered in CATIE's payment programme have been demonstrated in many research studies throughout the world as well as in the PES project in Esparza as helping in climate change adaptation (Stür, 1995; CIAT, 2001; Greene, 2001; Jones, 2005; Mata and Budhooram, 2006; Verchot et al., 2007). The payments farmers receive through this programme have encouraged them to improve their agricultural methods (Zamora-Lopez, 2006). These improvements have led to observed benefits, including increased milk production as a result of planting *Brachiaria spp* and less erosion after implementing agroforestry systems.

The PES project is particularly useful in encouraging farmers who may not believe in climate change to adapt. In Esparza, 10% of the farmers surveyed do not understand how climate change is caused and 22% of farmers believe that climate change is not going to affect their farms and families. Despite this fact, all farmers have implemented more sustainable grasses, such as *Brachiaria spp* grass; 96% are maintaining or planting trees on their property; 96% are protecting water sources to ensure they have enough water during droughts; and 56% are using fodder banks. According to Zamora-Lopez (2006), land use has changed significantly in Esparza to encourage these new land uses after the implementation of PES and the amount of degraded land has decreased.

The sustainable agriculture practiced in Durika incorporates traditional agricultural methods with new technology and information and specific adaptive methods. They have learned some of the local indigenous knowledge and integrated that into their farming practices. Nyong et al. (2007) highlights the importance of combining indigenous knowledge and science in well structured climate change programmes. Durika farmers have integrated sustainable farming practices without the help of PES. They have done this through extensive prior knowledge of ecology, economics, climate change, and sustainable agriculture. They also have financial resources available to them through grants and donations, which has allowed them to expand their social networks and add to their knowledge. The greatest difference between farmers in Esparza who are part of PES and farmers in Durika who are practicing sustainable agriculture, is that in Durika, the farmers are not implementing strategies because of monetary reward. Instead, they are creating projects they feel will help the community's overall sustainability, and then seeking funding to help support these projects. This methodology does have potential to lead to greater overall resilience for farmers than those in Esparza. In Esparza, farmers may be more reluctant to implement climate change adaptation strategies that do not also serve as environmental services because they will not receive their monetary incentive. Farmers in Esparza cited PES as one of their primary motivations for adaptation. One farmer mentioned that without PES and the monetary incentives involved, he would not have implemented any environmental service strategies. This could lead to problems as new climate change adaptation strategies continue to be developed that do not fit into the environmental services programme. As a result, recommendations were developed to address this problem in CATIE's PES project and strategies were provided to integrate this programme into the rest of Costa Rica.

7.1.1 Recommendations for CATIE's PES Project

The PES project implemented by CATIE has proven to be successful in improving land use practices and building social networks farmers can use to address concerns related to environmental services as well climate change. Based on information from the farmers directly involved in the project as well as from farmers involved in a separate sustainable agriculture project, methods to improve the project were developed. These methods require a further integration of climate change adaptation into the PES programme in order to ensure farmers are building a more sustainable system that is resilient in a warming climate.

Table 7.2 illustrates a combination of what CATIE has done in their project and what needs to be improved based on discussions with farmers in both Esparza and Durika. This information should be used by academic institutions, non-government organizations, or by government officials who are looking to initiate a payment for environmental service programme. These recommendations are designed for implementation on a regional scale, as they are based on the project developed in the region of Esparza. With each region being unique, individual PES projects must be implemented throughout the country. In order to enhance resilience and decrease vulnerability, policy recommendations must carefully target specific issues, such as how prone the area is to erosion, the need for water conservation, or protection of resources, rather than making general policies for the entire country (Adger, 2001).

Table 7.2 – Recommendations for developing successful adaptation programmes based on CATIE's project and on discussions with producers. The italicized information is what has been added based on discussions with producers in Esparza and Durika.

	Action	Description
Stage 1	Gather social and economic information about the farmers and study digital maps of the farms	• Gather baseline data about current agricultural methods, amount of degraded land, and other factors that may be influenced by PES (for example, amount of forested areas and amount of erosion)
	Consult with farmers	• Set up meetings at a time that works for farmers (not during the growing season) • Keep the discussions open ended – allow farmers to voice their opinions and concerns • Determine what farmers are already doing and where they need science and expertise to help them • Educate farmers about environmental services and the role they play in sustainable agricultural systems • *Determine the main issues affecting producers and their farms and use this information to develop strategies that help mitigate these issues as well* • *Provide farmers with information about climate change, and contacts about where to get more information*
Stage 2	Initiate PES project and implement strategies	• Research and test potential strategies that may be useful for farmers • Foster an environment that encourages farmers to develop their own strategies and share their ideas with other community members • Develop strategies that offer multiple benefits (For example: Agroforestry protects soil from erosion and offers shade while also increasing biodiversity and providing fruit – a source of income for farmers) • *Provide additional funding (through grants or credits) to support all sustainable agricultural methods, including climate change adaptation*
Stage 3	Follow-up	• Continue regular consultation meetings to confirm the success of the implemented strategies and the need for more information about strategies • Evaluate the success of the programme by looking at land use maps and collecting more information from the farmers about their farm management practices • Make adjustments to the implementation of strategies as needed • *Educate farmers on the importance of developing a long term plan for their farms that accounts for climatic changes*

Important Notes:

- Ensure the technology is easily accessible by all farmers
- Ensure all farmers have the capacity to adapt
- Add any incentives possible that will encourage farmers to adapt (particularly financial incentives to reduce the initial costs)
- Integrate knowledge with technology to ensure farmers understand the issues and how the strategies will help them.
- Develop outreach programmes to ensure farmers can access the programmes
- *Integrate this information with all scales of farming (small-, medium-, and large-scale farming)*

(Adapted from Zamora-Lopez, 2006).

National policies must also encourage the implementation of PES projects throughout the country. Currently, there are issues related to access to information and resources that can be overcome through regional PES programmes. There are significant costs involved in CATIE's project. Millions of dollars were put forward to provide the monetary incentives as well as pay for the rural extension officers who offer the technical support (Pagiola et al., 2004). In Costa Rica, money raised from the gas tax and the sales of carbon credits has gone toward the national PES programme. This money should be shifted toward funding projects on a regional scale. The federal government must also support CATIE and other agricultural research centres and organizations so they can begin implementing the project designed by CATIE in other regions of the country. Support should come from assistance from the Ministry of Agriculture, as was done with CATIE's project, as well as from financial support. Disseminating the information into other parts of the country and encouraging farmers to communicate with other farmers nearby about their knowledge will help integrate it into the farming community quickly. These regional programmes will improve upon the national PES programme already in place by increasing farmers' accessibility to resources and information, which will lead to greater success in implementing and developing sustainable agricultural strategies.

Other countries can also use these recommendations as a guideline for developing or improving their own payment for environmental service programme. The specific environmental services put in place for each country can differ. For example, in Ontario, the Alternative Land Use Services (ALUS) programme is a pilot project initiated in Norfolk County in September, 2007 (Delta Waterfowl, 2007). This project varies from the one in Costa Rica in that the environmental services include wetland and riparian protection and providing upland and wildlife enhancement services (Delta Waterfowl, 2007). Despite the differences in the environmental services being protected, the framework of how it could be structure and funded recommended in this paper can help ensure its success.

Chapter 8 Conclusions and Recommendations

8.1 Conclusions

Climate change is a global issue affecting many sectors of society. In Costa Rica where agriculture is a key contributor to the nations GDP, organizations such as CATIE are working with farmers to develop strategies to help them adapt. The payment for environmental services programme has been suggested as a potential strategy to encourage adaptation and educate farmers about climate change. The success of CATIE's PES project was evaluated based on increasing farmers' awareness of climate change, encouraging adaptation, and creating networks to help further adaptation.

This research has provided a better understanding of climate change adaptation and the role PES can play in encouraging farmers to adapt. Empirically, the two case studies, Esparza and Durika, provided information about two different adaptation programmes in place in Costa Rica. Theoretically, this research combined several areas of research, including environmental services, climate change adaptation, and how to encourage farmers to implement new farming methods, in order to further the understanding of how farmers can adapt to climate change. Practically, this study assessed CATIE's PES project as a method to encourage adaptation to climate change and evaluated how well it can be integrated into other communities.

In Esparza, Costa Rica, farmers participating in CATIE's PES project were surveyed to determine: 1) background and farming experience information not already collected by CATIE researchers; 2) observations and perceptions about climate change; 3) effects of climate change on production; and 4) adaptation strategies producers are implementing and the results of implementing these strategies. This information was coupled information from past theses papers and reports from CATIE as well as with interviews of Academics from CATIE involved in the project and a local representative from the Ministry of Agriculture.

A second study site, Durika, Costa Rica, was selected because they practice sustainable agriculture techniques. They offered an interesting perspective on how the PES programme could be improved to integrate more sustainable practices. Participants were asked questions related to the following themes: 1) their observations and perceptions about climate change; 2) adaptation strategies they are implementing and the results of implementing these strategies; and 3) the adaptive capacity of local farmers outside Durika. This information was used in conjunction with satellite imagery and academic literature about the area in order to determine the success of their sustainable practices and the overall knowledge Durika members possess.

Results showed that based on information collected in the literature, as well as from surveys and interviews in Esparza and Durika, PES served as an important measure to encourage farmers to adapt to climate change. Although some producers, such as those in Durika, were able to adapt on their own, they recognize that they are the exception in Costa Rica, and stress the importance of developing more programmes to support smallholder farmers in isolated areas. The payment for environmental services programme offers a means to do this.

Through the implementation of environmental services farmers have been able to mitigate potential damages and take advantage of opportunities associated with climate change. Negative impacts have been alleviated through the implementation of adaptation strategies, such as planting *Brachiaria* grass. Dairy farmers are able to maintain milk production, or increase production in the dry season, even if there is an extreme drought. Beef farmers are finding their cattle are surviving the dry season in much better condition than in previous years.

Ecologically, many of the strategies being implemented by farmers involved in PES improve the diversity of their system, including implementing agroforestry techniques and diversifying their farms with mixed crop-livestock farming systems. They are also working to minimize water use and protect rivers and streams on their property, which will help them ensure water during drought and reduce the impacts of floods. The PES project has encouraged farmers to adapt strategies that will reduce their vulnerability, not only to climate change but to other potential threats, such as economic decline.

Recommendations were made to improve CATIE's PES programme. These involved further inclusion of climate change adaptation and sustainable agricultural methods into PES, as well as offering grants or credits to farmers who implement strategies that improve their adaptive capacity. Policy recommendations were also made that encouraged funding regional programmes versus funding a national programme. Due to regional variations in demographics, land characteristics, and resources, localized programmes will provide more benefit than large programmes. Making these changes will improve the resilience of agricultural systems in Costa Rica, which will ultimately help protect this valuable economic contributor.

8.2 Recommendations for Future Research

It is imperative that future research examine the implications of climate change on various ecological systems, including the impacts on flora and fauna, and on soil fertility. This will help develop a better sense of what adaptation strategies will work and decrease the overall costs of implementing climate change adaptation strategies.

Climate data must to be collected in different regions throughout Costa Rica and made available to farmers. Because of the regional variations associated with climate change, the lack of historical climate information makes it difficult to determine the trends in specific regions. As farmers begin to develop new farming methods, this climate information will be important to assist farmers in the development of their adaptation strategies.

Finally, future research also needs to incorporate studies on the perceptions of climate change by large-scale producers, such as the head of Dole and Del Monte, in Costa Rica. Because these companies are large contributors to Costa Rica's GDP and they supply food to other parts of the world, determining their perceptions of climate change and how they are adapting is important.

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Appendix A – Questionnaire for Producers in Esparza (Spanish)

DATOS GENERALES

1. **Nombre** ____

2. **Cuantos años se dedica a la actividad de agrícola o ganadera:**
……………………………………………………………………………………………..

3. **Sistema de producción:**

   a. Producción de carne ( )
   b. Sistema doble propósito (leche y carne) ( )
   c. Sistema mixtos (ganadería mas cultivos o frutales) ( )

CONOCIMIENTO Y PERCEPCIÓN SOBRE EL CAMBIO CLIMÁTICO

1. **¿Qué entiende ud por Cambio Climático?**
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   …………………………………………………………….....

2. **¿Sabe que causa el cambio climático?**

   NO ( )

   SI ( ) por favor explique

   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   ……………………………………………………………………………

3. **¿Cree que el cambio climático tiene efectos en su finca y la vida de su familia?**

   NO ( )

   SI ( ) Porqué ?

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………………………

4. ¿A nivel de su región o finca como se ha manifestado el cambio climático

a. Lluvias más intensas y prolongadas o tormentas ( )
b. Se siente más calor por efecto de temperatura ( )
c. Sequías más prolongadas los últimos años ( )
d. Otros ( )

5. Mencione como ha afectado el cambio climático en su región o finca?

Causas	Consecuencias	Observaciones
Lluvias más intensas y prolongadas o tormentas	Inundaciones. deslizamientos Pasto no crece, ganado no come mucho. Daños en la infraestructura Desborde de ríos y quebradas	
Más calor por efecto del aumento en la temperatura	Disminución de la producción Disminución de alimento Pérdida de peso de los animales Baja producción de leche Perdida de cosechas Quema en los cultivos	
Años con sequía prolongada	Disminución de alimento disponible (forraje) Pérdida de peso Pérdida de cosechas Baja producción y calidad de leche Escasez de agua (para consumo humano y animal) Aumento de incendios forestales Disminución del caudal o desaparición de quebradas o riachuelos	
Otros		

EFECTOS DEL CAMBIO CLIMÁTICO

1. **Como siente el calor en las últimos años comparado con 10 o 15 años atrás? (Encuestador: Explicar que se refiere a calor corporal)**

   a. Más intenso
   b. Igual que hace 10 años
   c. Menos intenso

2. **En las últimos 5 años, cuales años fueron los años que presentaron sequías más prolongadas:**

AÑO		**No. Meses**
a. 2002	( )	( )
b. 2003	( )	( )
c. 2004	( )	( )
d. 2005	( )	( )
e. 2006	( )	( )

3. **En años con mucha lluvia o fuertes sequías, ¿Cómo respondió su producción? realizó alguna actividad diferente a las tradicionales?**
   (Encuestador: Asegurarse que responde ambas preguntas)

   …………………………………………………………………………………………………

   …………………………………………………………………………………………………

   …………………………………………………………………………………………………

   ………………………………………………………………….....

4. E**n los últimos 10 años ha observado algún ataque masivo de plagas a los animales o a los cultivos?**
   NO ( )

   SI ( ), a que se le atribuye?

…………………………………………………………………………………………………

………………………………………………………………………………

Y en que año?...................

Recursos hídricos

5. **Como se ha observado los ríos, quebradas y nacientes en los últimos años comparados con hace 10 años?**

   En la época seca:

   a. Se secan más rápido Si ( ) No ( )
   b. Se mantienen el mismo numero de quebradas y nacientes
      Si ( ) No ( )

6. **Número de nacientes**

   Hace10 años atrás...Actualmente.......................................

7. **Condición de las nacientes**

   En que mes (es) se secaban sus nacientes hace 10 atrás:………………….

   En que mes (es) se secaban sus nacientes hoy: ………………….

ADAPTACIÓN AL CAMBIO CLIMÀTICO

Tomando en cuenta los cambios climáticos que ud ha observado en los últimos años, que cambio usted ha hecho en la finca

1. **¿Qué hace ud para reducir el problema de la sequía y producción de forraje, o problema de mucho lluvias**

   a. Problema de sequía?

   ....

   ....

b. Producción de forraje?

....

....c. Muchas lluvias?

....

....

2. **Tiene una planificación anual en su finca para enfrentar los problemas del cambio climático?**

NO ( )
SI ( )

3. **Señale cuales de las siguientes acciones, esta implementando en su finca para reducir los efectos de cambio climático?**

Para el problema de la sequía y alimentación del ganado

a. Establecimiento y/o siembra de pasturas mejoradas ( )
b. Mantener árboles en los porteros ( )
c. Siembra de bancos forrajeros ( )
d. Práctica conservación de forraje: ensilaje, heno ( )
e. Uso de suplementos (melaza, gallinaza) ( )
f. Selección de animales más resistentes a las sequías ( )
g. Ha suprimido las quemas ( )

Protección de agua

a. Uso de Riego ( )
b. Protección de los nacientes, ríos y quebradas ( )
c. Captación y almacenamiento de agua ( )

A nivel de potrero

a. Deja más árboles ( ) señale cuales:
Sombra ( )

Madera ( )
Frutas ( )
Otros (indicar)

b. Que especies de árboles son mejores para dar sombra en la sequía prolongada y porque?
…..
....
………………………………………………………………………………………
………………………………………………………………………

c. Que especies de árbol prefiere para alimentar el ganado en las meses seca y porque?
…..…..
....
....
....

d. En los años con mucha sequía o sequía prolongada usted vendió más animales en comparación con los años en que la sequía no estuvo tan fuerte,?........porque?
…..…..
....
....
....

4. Que ha observado en las pasturas mejoradas sembradas comparadas cuando tuvo pasto jaragua:

a. Más erosión ( )
b. Menos erosión ( )
c. Igual erosión ( )
d. No tiene pasturas mejoradas ( )

5. Si usted ha sembrado pasto mejorada, que ha observado en comparación con el pasto jaragua (natural)?

a. Es más resistente a las sequías (se mantiene más verde) **SI**( ) **NO ( )**
b. Produce forraje en la sequía **SI( ) NO ( )**
c. Soporta mas animales **SI ( ) NO ( )**
d. Animales mantienen su condición (gordos) **SI ( ) NO ( )**

e. Animales produce más leche y carne **SI ( ) NO ( )**
f. Terneros en mejor condición **SI ( ) NO ( )**

6. Mediante la alimentación de sus animales con pasto mejorado, que ha observado durante la época de sequía?

a. Están más flacos ( )
b. Menos flacos ( )
c. Mantienen su mismo peso ( )

7. Si ha implementado bancos forrajeros, que ventajas ha obtenido:

a. Toleran la sequía **SI** ( ) **NO ( )**
b. Produce en época seca crítica **SI** ( ) **NO ( )**
c. Es un bueno suplemento alimentario **SI** ( ) **NO ( )**

8. Con los cambios de tecnología (pastura mejorada, banco forrajera etc.), que observa en la producción de leche durante la época seca?

a. La producción es igual SI ( ) NO ( )
b. la producción se incrementó NO ( ) SI ( ), que porcentaje?.........
c. Las vacas producen durante todo la época seca SI ( ) NO ( )

9. Que beneficios observa en la protección de cuerpos de agua y nacientes?

a. El caudal se mantiene **SI** ( ) **NO ( )**
b. Ha disminuido la contaminación **SI** ( ) **NO ( )**
c. Agua con menos sedimentos o es más clara, comparada con nacientes sin protección **SI** ( ) **NO ( )**
d. Disminución de desbordes **SI** ( ) **NO ( )**
e. Otro (indicar):
……………………………………………………………………………………
……………………………………………………………………………………
…………………………………………………………………

10. Ha recibido capacitación sobre el tema de cambio climático, efecto del niño o de la niña y sus consecuencias sobre la producción ganadera o agrícola? Y quien se la ha brindado?
(Encuestador: asegurarse que responde ambas preguntas)

……………………………………………………………………………………………........

....…..................

....

11. Como califica la información o que está recibiendo?

a. Con poco anticipación para planificar
b. Mucho anticipación para planificar
c. No recibe ninguna información

12. ¿Cuáles son las principales limitantes que enfrenta para implementar acciones en la lucha contra la sequía y la variabilidad climática?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………………………………………………………………………

13. En su comunidad han conformado grupos de trabajo, asociaciones, u organismos locales para enfrentar el cambio climático, usted forma parte de ellas?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………………………………………………………………………

14. Que sistemas de incentivos se necesitan para reducir los impactos negativos del cambio climático?

PSA ( )

Crédito ( )

Capacitación ( )

Mercados ( )

Appendix B – Questionnaire for Producers in Durika (English)

Climate Observations in Durika:

1. What impacts have been seen resulting from climate change biophysically and ecologically in the area?
2. What observations have you observed resulting from climate change, and what are the impacts on agriculture

Adaptation in Durika:

3. What are farmers in Durika, doing to adapt?
4. Have you accessed any outside information to improve adaptation?

Adaptation outside of Durika:

1. How well do you believe the people in this region (outside of the Durika community) are adapting to climate change?
2. Are the farmers in this area adapting at all to climate change? If so, how? If not, why not?
3. Based on your experiences, what are the perceptions of local farmers on climate change?

Appendix C – Tree Species Identified by Producers in Esparza as Drought Resistant

Common Name	**Scientific Name**	**Description**
Higrueron (Strangler Fig)	*Ficus hartwegii*	This grows to 25-30 m with a diameter of 80cm. The fruits are 7mm in diameter. (Centro Nacional de Investigación de Café, N.D.)
Guayaba	*Psidium friedrichsthalianum* Ndz	Guayaba trees are small, growing to about 6-10 m high. The trunk is red-brown with gray patches. Flowers are white and fragrant. The fruit is round and has a yellow skin and a soft, white, acidic flesh. (Morton(1), 1987)
Coyol	*Acrocomia aculeata*	This palm has a large spiny stem that grows to about 20m and is 10-50 m in diameter. The fruit is yellowish green to yell, is between 2.5-5 cm in size, and is shaped like a globose drupe. This species is fire resistant. (Coppens d'Eeckenbrugge et al., 2001).
Madero Negro	*Gliricidia sepium*	This tree reaches heights of 60 feet. It has a narrow crowned, medium-sized, or sub-canopy. The wood is very hard and black or dark brown with a small fleck. The flowers are pink. This species is useful for its nitrogen fixation, and its resistance to insects and fungus. (Tropical American Tree Farms, 2007).
Nance	*Byrsonima crassifolia* HBK	Nance is a slow growng shrub that grows to about 10 m in height. Sometimes it can reach heights of 20 m. The flowers come from racemes which are red-hairy, 10-20cm long and 1.25-2 cm wide. The flowers are yellow then change to a dull orange-red. The fruit is fragrant is round and 8-12 cm wide. The skin is thin, and the centre is white, juicy, and oily (Morton(3), 1987)
Almendro	*Dipteryx panamensis*	This species is native to Costa Rica. It is a tall, dense tree that can grow to 150 feet in height. The bark is yellowish. It is a deciduous tree that loses it’s leaves

		following the dry season. It has purple flowers that bloom early in the summer (Rainforest Alliance, 2007).
Mango	*Mangifera indica* L.	The mango tree grows to between 10-30m in height. The roots can penetrate as much as 20 feet and the root system is wide spreading. Mango trees live to be centuries old, with some recorded over 300 years old. The fruit ranges in size between 6.25-25cm and weight 1.8-2.6kg. The fruit is very fragrant (Morton(2), 1987).
Guacimo	*Guazuma ulmifolia*	Guacimo grows is adapted to alluvial and clay soils, and grows in humid and dry tropical areas. It does not drop its leaves except in areas that are very dry. Guacimo is generally used for livestock fodder, particularly during the dry season. It can be grown easily by planting seeds or cuttings (Powell, 1997).
Guanacaste	*Enterolobium cyclocarpum*	Guanacaste trees have light gray bark, with vertical fissures that are reddish-brown. Foliage is shed in December and they remain without leaves for the first two months of the dry season. Flowers are globular. The flowers are fragrant. The Guanacaste fruits are large (Community Day School, N.D.).