Political Economic Barriers to Global Change Adaptations:

A Study of Agrarian Rural Development in Northwest Costa Rica

by

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ABSTRACT

This is a study of the plight of smallholder agriculture in Northwest Costa Rica. More specifically, this is the story of 689 rice farms, of an average size of 7.2 hectares and totaling just less than 5,300 hectares within the largest agricultural irrigation system in Central America. I was able to define the physical bounds of this study quite clearly, but one would be mistaken to think that this simplicity transfers to a search for rural development solutions in this case. Those solutions lie in the national and international politics that appear to have allowed a select few to pick winners and losers in Costa Rican agriculture in the face of global changes. In this research, I found that water scarcity among smallholder farms between 2006 and 2013 was the product of the adaptations of other, more powerful actors in 2002 to threats of Costa Rica's ratification of the Central American Free Trade Agreement. I demonstrate how the adaptations of these more powerful actors produced new risks for others, and how this ultimately prevented the rural development program from meeting its development goals. I reflect on my case study to draw conclusions about the different ways risks may emerge in rural development programs of this type. Then, I focus on the household level and show that determinants of successful adaptation to one type of global change risk may make farmers more vulnerable to other types, creating a "catch-22" among vulnerable farmers adapting to multiple global change risks. Finally, I define adaptation limits in smallholder rice farming in Northwest Costa Rica. I show that the abandonment of livelihood security and well-being, and of the unique "*parcelaro*" identities of rice farmers in this region define adaptation limits in this context.

DEDICATION

To those *parcelaros* who opened their homes and lives to me because they believed their story should be told. I have tried to tell that story.

ACKNOWLEDGMENTS

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CHAPTER 1

INTRODUCTION

This is a study of the plight of smallholder agriculture in Northwest Costa Rica. More specifically, this is the story of 689 rice farms, of an average size of 7.2 hectares and totaling just less than 5,300 hectares within the largest agricultural irrigation system in Central America. I was able to define the physical bounds of this study quite clearly, but one would be mistaken to think that this simplicity transfers to a search for rural development solutions in this case. Those solutions lie in the national and international politics that appear to have allowed a select few to pick winners and losers in Costa Rican agriculture in the face of global changes.

This story is told in part by the farmers, and by those tasked by the Costa Rican government to promote smallholder agriculture in the name of rural development. My choice to use the word 'plight' in this description of their story is not hyperbole. Faced with increasing aridity and a withering rice market, many of the farmers represented here have begun questioning the utility of smallholder agriculture in a globalizing world as their livelihoods are undermined. Agriculture and water managers are largely aware of these rural development failures, but are seemingly powerless to implement change. This powerlessness is largely a product of an institutional architecture designed through neoliberal politics driven by the International Monetary Fund (IMF) and the U.S. Agency for International Development (USAID) in Central America in the 1980s. However, the economic liberalization of Costa Rica is not to blame for the failure of this country's largest agrarian rural development program, although this is the popular belief among

Costa Ricans and policy-makers alike. Rather, the current economic model is the result of powerful actors exploiting the neoliberal policies to avoid risks of global changes and to profit at the expense of the overall population, particularly the poor.

In this study I describe the processes by which Costa Rica's largest agrarian rural development program ceased meeting the needs of its most vulnerable. I focus on the actions of a select group of politically powerful actors and describe how they were able to redistribute risks of trade liberalization and increasing drought. I show that through these processes the powerful were able to profit while the poor were made more vulnerable, and were often forced to abandon their livelihoods. I end with an analysis of smallholder farmer perspectives of their futures in this context.

1. Research context

Costa Rica has undergone sweeping economic reforms over the past three decades, but poverty rates have remained relatively stable at approximately 20% since the early 1990s (INEC, 2014). Equally disturbing, and perhaps more concerning is the fact that economic inequality has steadily risen across the country since 2000. Only three countries across Latin America have seen inequity increase over the past decade, and Costa Rica is among them (CEPAL, 2014). The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) reported that Costa Rica's Gini Index (a comparison of income distribution used to measure inequity) increased from 0.47 to 0.50 between 2000 and 2011. This trend is nowhere more apparent than in Guanacaste, one of the two poorest provinces in the country. Within Guanacaste, this trend persists even as the government continues to fund agrarian development projects with the goal of using agriculture to boost households out of poverty.

The Arenal-Tempisque Irrigation Project (*Projecto de Riego del Arenal-Tempisque*, PRAT) was established in 1983 by the Costa Rican government as the country's largest agrarian development project. Approximately 1125 farms benefit from the project; these farms primarily produce rice and sugarcane. In 2000, almost all smallholder farmers in the PRAT grew rice. The PRAT (Figure 1.1) supplies farmers with 100% of their irrigation water for five months of each year during the dry season (November-March), but due to prolonged drought in combination with a changing global rice market, smallholder farmers have suffered livelihood setbacks.

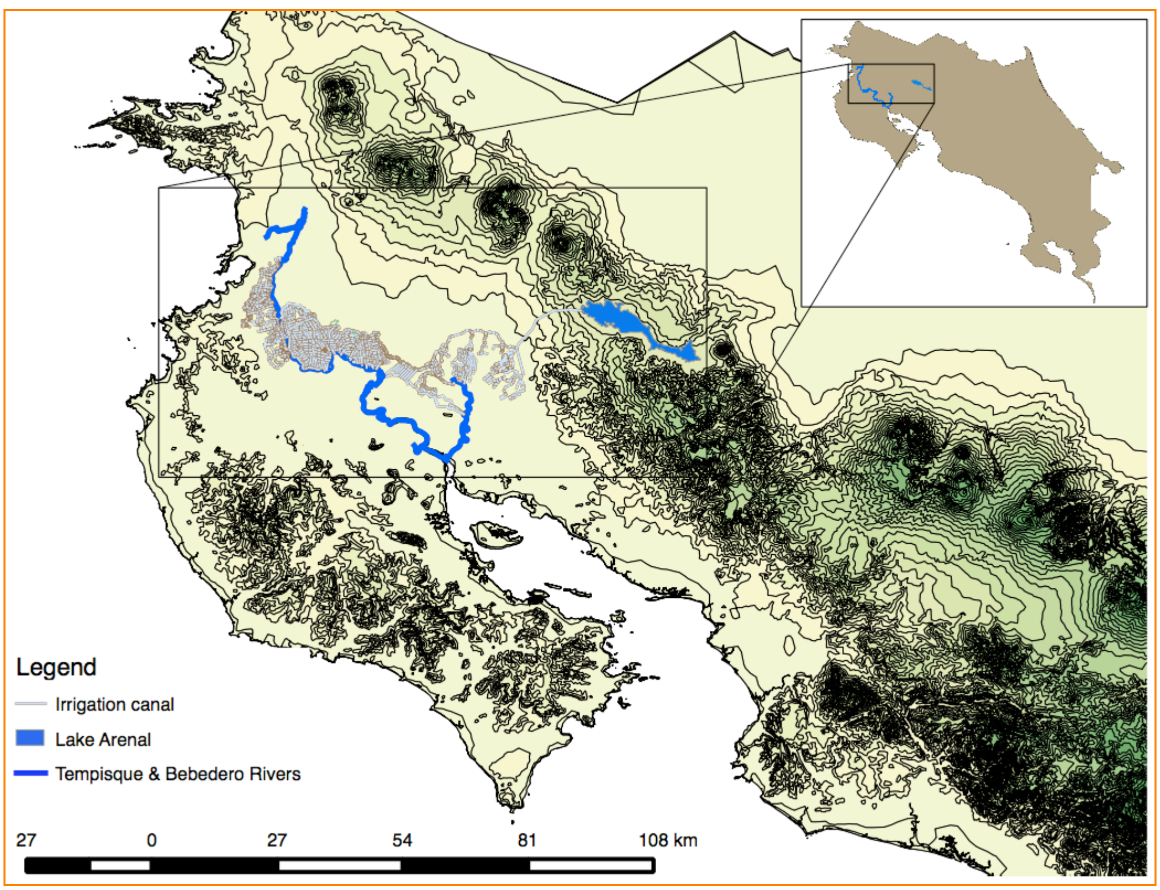


Figure 1.1 – Arenal-Tempisque Irrigation District (shown in bordered region) within the Tempisque River Basin in Guanacaste, Costa Rica; this map shows topography, PRAT canal infrastructure, Lake Arenal, and the Tempisque and Bebedero Rivers.

The risks faced by smallholder farmers in the PRAT stem from the interactions between regional drought and threats of international trade liberalization. From 2005-2012, approximately 40% of rice consumed in Costa Rica was imported. The Costa Rican agency overseeing these imports sells the imports to rice mills (the same mills that smallholder farmers use). Along with these sales comes a transfer of economic rents (i.e., a return in excess of the resource owner's opportunity cost; Tollison, 1982); rice on the global market is less expensive for rice mills to buy compared with domestically produced rice because domestic production is less efficient and state mandated price supports exacerbate this price difference for buyers. Imported rice is allocated to these industrial mills based on production and acquisition of domestic rice. This has initiated a rapid consolidation of industrial rice mills in the PRAT, which grows 45% of the rice in Costa Rica. This in turn has displaced many smallholder farmers from the rice market because mills no longer need to buy rice from local smallholder farmers. The situation is expected to become worse as Dominican Republic-Central America-United States Free Trade Agreement (CAFTA-DR) increasingly requires Costa Rica to diminish their import tariffs on rice, and ultimately to abolish them by 2025. As smallholder farmers are displaced from the rice-production supply chain, they either leave farming or switch to sugarcane, which is much less lucrative.

The Central American Bank of Economic Integration loaned approximately $20 million to the Costa Rican government in 2014 to expand the PRAT by 8,000 ha. The government claims that this irrigation expansion will benefit the region in three ways. First, it will increase the competitiveness of Costa Rican agriculture. It will increase agricultural innovation and development. Finally, the expansion will promote the livelihoods of smallholder farmers outside the PRAT who rely on rain-fed crops in this increasingly arid region because they will be provided with steady supplies of irrigation water. However, both water managers and smallholder farmers increasingly worry that the expansion will further over-allocate scarce water and exacerbate the conflicts and multiple risks faced by smallholder rice farmers in the PRAT.

2. Research questions

This study was designed to answer four questions in the context of this case. Each research question may stand alone and I provide unique answers for each. Each question was answered to gain increased insight into the barriers and limits on smallholder agriculture in Northwest Costa Rica. Taken as a whole, the answers to these questions provide insights into the sustainability of Central American smallholder agriculture in the context of global change processes. My questions are:

1. How did we get here? (What constrains farmer efforts in adaptation to drought? Why were the constraints imposed, and how do the constraints impact vulnerability among farmers?)
2. Why are smallholder farmers, targeted by an industrial-based rural development program designed to spread global change risks evenly among all farmers,

negatively impacted by these risks while other more powerful farmers, presented with the same risks, profit?

3. How do socio-economic determinants of adaptive capacity among smallholder farmers in Northwest Costa Rica determine their ability to avoid adaptation limits in the face of the impacts of multiple global change risks?
4. What are adaptation limits in smallholder rice farming in the region? How do farmers perceive adaptation limits given plausible impacts of future global change risks?

3. Research approach

My approach to this study was equal parts participatory rural appraisal, case study analysis, and interview and survey research. In the study of complex, or 'wicked' problems such as those that exist in the PRAT, the scope and aim of research must be continuously revised as the researcher builds an understanding of the processes and actors within the context of these problems. The goal of my research approach was to critically explore the processes and drivers of change in smallholder agriculture in Northwest Costa Rica that were obscured, either deliberately by those who could benefit from the obscurity, or inadvertently behind a complex and complicated tangle of truths and contexts. I used this style of hypothesis-based inquiry to provide an analysis of these processes in such a way as to offer potential next-steps toward achieving a fairer distribution of risks and rewards from global changes.

The theoretical foundations of my study are in human dimensions of global change, political economics, and hydrological engineering. I began this study with a problem-based political economy assessment of smallholder rice farming in Northwest Costa Rica to expose the multiple risks and drivers of those risks faced by farmers in the region. I explained how these risks developed in such a way as to redistribute vulnerability to global change risks across Costa Rican agriculture. Then, I proposed a theoretical concept that I used to perceive and understand processes of risk redistribution in industrial-based agrarian development programs, which includes the PRAT. I used quantitative methods to pinpoint the impacts of global change risks that are undermining the livelihoods of smallholder rice farmers, and I viewed my case study through my newly proposed perspective.

In the second half of this study I relied on household-level data, collected through surveys and interviews, to determine why differences exist in smallholder rice-farm vulnerability to multiple interacting risks. I also determined how farmers perceived limits in their abilities to adapt to these risks. I present the results of my surveys and interviews and I discuss my findings using both quantitative and qualitative methods.

4. Dissertation organization

This dissertation is organized into chapters based on my four research questions. Each chapter is designed to stand-alone, but each builds on the analysis presented in the other three chapters. In **CHAPTER 2**, I argue that we cannot assume that the same hindrances to successful rural development programs, including inequity, power differentials, and exclusivity, will not inhibit climate change adaptation programs in less-developed countries. I explore the relationship between the political pressures on trade liberalization and local climate change impacts in the Arenal-Tempisque Irrigation

Project in Northwest Costa Rica. I use this case study to elucidate both the existence and the complexity of a national political economy, which I show must be addressed in local climate change adaptation plans if Costa Rica is to address the development concerns of the most vulnerable in the region. In this chapter I argue that Costa Rican rice politics, not drought, poverty, or failed public policy, created inadequate water access for smallholder farmers throughout the irrigation system. I use a problem-processes approach to political economy assessment to investigate the political progresses across scales by which some groups of farmers became vulnerable to water scarcity. I explain, "How did we get here?" by analyzing the changes in rice-market and water allocation institutions that have shaped farmers' vulnerabilities. I discuss the current problems in the context of these changes and describe the political maneuvers that have reformed and reinforced the distribution of risks, wealth and power.

In **CHAPTER 3**, I argue that the rural poor are increasingly subjected to risks from the impacts of climate change and globalization. As industrial-based rural development programs increase in scope, scale, and application, made possible by increases in agricultural investment and trade liberalization, new risks to the rural poor may emerge from the adaptations of more powerful farmers. In this chapter, I describe a new type of idiosyncratic risk and advance its development by applying political economic theory to a framework based in the human dimensions of global change. I then provide an initial example of its application to the agricultural irrigation system in Guanacaste Province, Costa Rica. With this case study I ask: Why are smallholder farmers, targeted by an industrial-based rural development program designed to spread risks evenly among all farmers, negatively impacted by risks from global changes while other more powerful farmers, presented with the same risks, profit? I use statistical regression modeling to pinpoint and quantify the impacts that are driving smallholder farmer livelihood losses. I demonstrate how the adaptations of some farmers produced new risks for others, and how this ultimately prevented the rural development program from meeting its goals of increased living standards and equitably distributed resources, benefits, and risks. I end by reflecting on my case study and on the theoretical underpinnings of idiosyncratic risks to draw conclusions about the different ways these risks may emerge in industrial-based rural development programs.

In **CHAPTER 4**, I build on research on the effects of multiple, interacting impacts of global change risks on rural livelihoods in lesser-developed countries and seek to understand socio-economic determinants of adaptation limits. I ask: How do socio-economic determinants of adaptive capacity among smallholder farmers in Northwest Costa Rica determine their ability to avoid adaptation limits in the face of the impacts of multiple global change risks? I compare my findings to theoretical determinants of adaptive capacity. My data were based on workshop proceedings, focus groups, and survey responses from 94 smallholder rice-farming households within the PRAT. I analyzed my survey responses using logistic regression models to determine which socio-economic variables may be used to determine farmer abandonment of valued livelihood goals, which I define as an adaptation limit. My analysis showed that farm size, cattle ownership, and the diversification of household income were determinants of farmer abilities to successfully adapt or cross of adaptation limits. I also show that determinants of successful adaptation to one type of global change risk may make farmers more vulnerable to other types, creating a "catch-22" among vulnerable farmers adapting to multiple global change risks. I discuss the significance of these results in the context of solutions in the PRAT and broader research on the general determinants of vulnerability among smallholder farmers.

In **CHAPTER 5**, I argue that the abilities of rural households to avoid adaptation limits in the face of impacts are largely dependent on their valued goals and capacities to adapt to changes and transform their livelihoods. I argue that adaptation-limit research is crucial to sustainable rural development, and a focus on adaptation limits may allow researchers to better understand limits and support successful adaptation, before and after adaptation limits. I found the forced abandonment of livelihood security of well-being, and of the unique "*parcelaro*" identities of rice farmers in this region define adaptation limits in this context. I also found that farmers may revise their attitudes about what is a valued livelihood goal, or they may greatly change their behavior and perception to avoid intolerable risks, which modifies limits to adaptation. This is a key insight into the nature of adaptations to risks, as it speaks to the fluidity limits to adaptation. However, I argue that much suffering and hardship may accompany these transitions, and this cannot be discounted from adaptation-limit research.

Finally, in **CHAPTER 6** I conclude this study with a short discussion of the future of smallholder agriculture in Costa Rica in the context of changes in climate, international trade, and domestic politics. I argue that the evaluation of smallholder agriculture in Northwest Costa Rica must incorporate regional and national level politics, as well as rural development goals.

CHAPTER 2

POLITICAL ECONOMIC BARRIERS TO CLIMATE CHANGE ADAPTATIONS: A STUDY OF AGRARIAN RURAL DEVELOPMENT IN NORTHWEST COSTA RICA

1. Introduction

Rural development has slowly emerged as a new theme of research in the global change community (Dow, Berkhout, & Preston, 2013; World Bank, 2013). At the same time, recent research by this community has argued that barriers to the implementation of adaptation plans have not been adequately addressed (O'Brien & Wolf, 2010; Pelling, 2011). Much of the global change research on rural development has focused on mainstreaming adaptation (Huq & Reid, 2004; Klein et al., 2007; Sietz, Boschütz, & Klein, 2011), but much can be gained by focusing a critical lens on barriers to the implementation of climate change adaptation plans in rural development settings. The need to incorporate global changes into rural development plans necessitates that adaptation researchers confront many longstanding political barriers to development including inequity, power differentials, and exclusivity. Barriers to climate change adaptations are intertwined with institutions at different decision-making scales (Adger, Paavola, Huq, & Mace, 2006). To address these barriers, we must ask questions about who is allowed to make decisions about how a development program will respond to the impacts of climate changes, how are these decisions made, and how do the outcomes of these decisions affect the distribution of risks?

Research linking rural development with global change adaptation has shown that the concept of vulnerability is a common theoretical bond across the disciplines (Lemos et al., 2007). To date, much of this research has not addressed how political economic relations may create barriers to the success of these adaptation plans (Milman & Arsano, 2013). I define adaptations as responses to observed or expected global change risks—their effects and impacts—in order to alleviate adverse impacts of change or take advantage of new opportunities (Adger, Arnell, & Tompkins, 2005; IPCC, 2001). For the purpose of this study, I define vulnerability as the degree to which any group or community can be adversely impacted by the consequences, or the potential consequences of risks (Eriksen & O'Brien, 2007; Eriksen et al., 2011). Large questions remain regarding the ability of any adaptation plan to address the needs of vulnerable groups in the context of socio-political relations. We should assume that the same political economic barriers to the success of rural development projects would present themselves in climate change adaptation programs.

The goal of this paper is to explore and elucidate the extent to and processes by which economic politics may be responsible for climate change impacts at the local level within a rural development project in semi-arid northwestern Costa Rica that has been heavily impacted by trade liberalization, neoliberal politics, and drought. Relying on the concepts of vulnerability, I focus on local outcomes in this case to ask: What constrains farmer efforts in adaptation to drought? Why were the constraints imposed, and how do the constraints impact vulnerability among farmers?

To answer my research questions, I use a problem-driven political economy (PE) assessment that includes not only consideration of the current problems and their institutional foundations, but also examination of the drivers of the problems and an analysis of their solutions. Using this approach, I explain, "How did we get here?" by analyzing the institutional legacies that have shaped the distribution of vulnerability to global change processes among farmers. I discuss the current distribution of vulnerability within rural development in northwestern Costa Rica in the context of my historical analysis. I describe how those with the will and political power to do so reformed Costa Rica's political economic institutions, and how this process reformed and reinforced the distribution of climate change risk and political power in Northwest Costa Rican agriculture.

I build from of the definition provided by Moe (2005), and define of political power as the ability of any one player to change the development program context for other users. I view this process as a reflection of power. Water, land, agro-inputs, and market access are often scarce resources, and are often controlled by select groups at key points in agrarian development programs. As risks of scarcity increase—and these are often driven by trade-liberalization, agro-investments, or climate change—farmers controlling limited resources may adapt within the confines of their capacity to do so. This can limit resource access to other farmers and leave them more sensitive or exposed to global change risks.

2. Research site and design

2.1 Research site

The Arenal-Tempisque Irrigation Project (*Projecto de Riego del Arenal-Tempisque*, PRAT) in Guanacaste, Costa Rica provides up to 5,616,000 m^3/day of water to farmers in the Tempisque River Basin from Lake Arenal in the east. Water provision occurs through a series of irrigation canals and aqueducts. The irrigation infrastructure, in relation to the Tempisque River Basin is shown in Figure 2.1. In 1973, the Sandillal-Tempisque-Arenal Hydroelectric Complex was constructed to provide energy to the growing population of San Jose. Discharge from the hydroelectric plant allowed the PRAT to become a reality in 1980, when the Inter-American Development Bank (IADB) extended a loan of US$15.1 million to the Costa Rican government. Initially, the PRAT covered 6006 hectares of the Tempisque River Basin. Today, the PRAT irrigates approximately 28,000 ha, of which 10,000 ha were included in 2006. Water exits the system through evapotranspiration or it drains into Palo Verde National Park, and finally into the Gulf of Nicoya in the south.

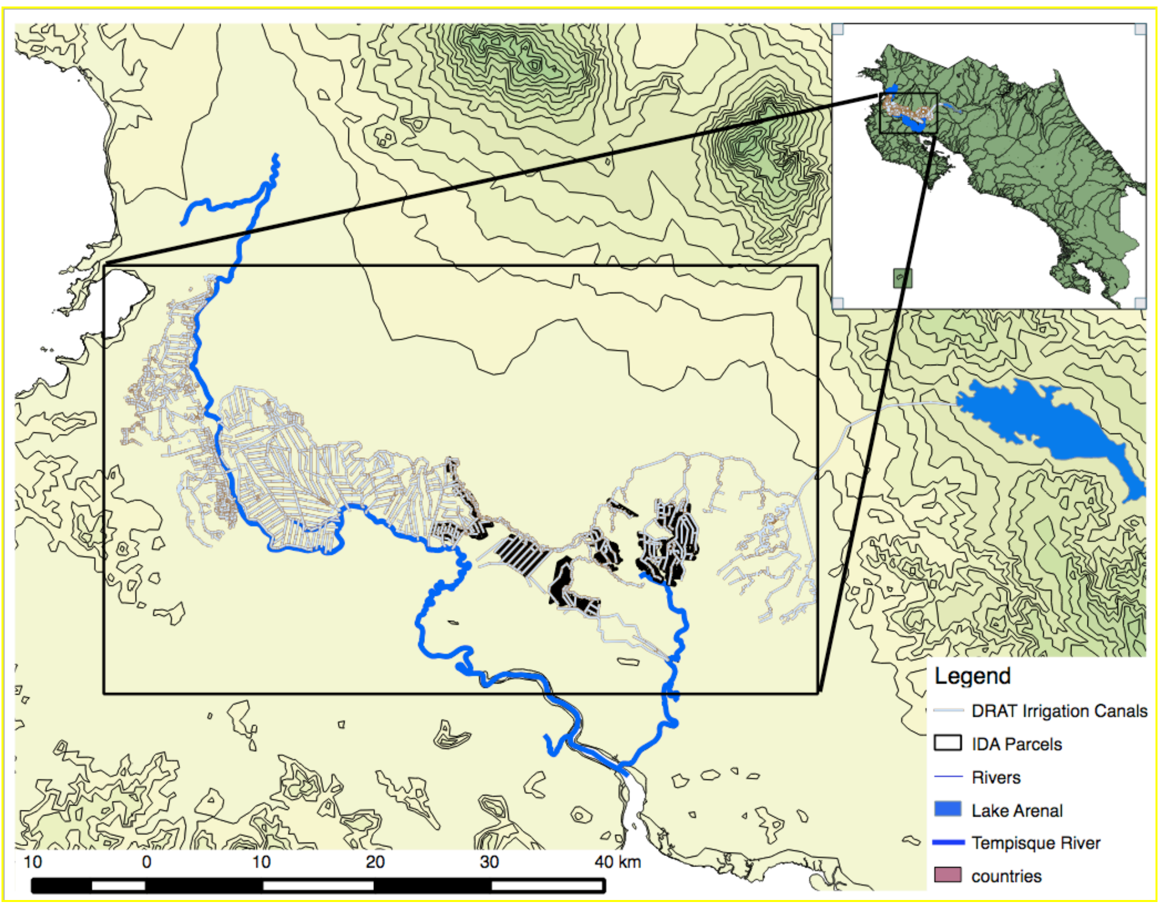


Figure 2.1 – Arenal-Tempisque Irrigation District (DRAT), Tempisque River Basin, Guanacaste, Costa Rica topography, canal infrastructure, and water source

The PRAT is the largest irrigation-based rural development program in Central America. As stated by the Costa Rican government, the specific goals of the project are (Edelman, 1992): (1) to utilize the waters discharged by the hydroelectric plants supplied by Lake Arenal; (2) to improve living conditions in the semi-arid Tempisque River Basin by generating agro-employment, redistributing income, and changing cropping systems; (3) to increase agricultural production and productivity; (4) to promote integrated regional development with complementary smallholder and agro-industrial sectors; and (5) to contribute to the improvement of the country's economic situation by exporting agricultural products. The Inter-American Development bank, which funded the project at an estimated US$67 million, states that 1125 farms benefit from the project, generating income of approximately US$163 million annually. The Agricultural Development Institute (*Instituto de Desarrollo Agrario*, IDA) transferred at little or no cost, 689 of those farms, totaling just less than 5,300, to smallholder farmers through the PRAT's agrarian reform initiatives. The configuration of smallholder farmers parcels within the larger irrigation system is shown in Figure 2.2. The remaining 22,700 hectares were brought under irrigation through a series of public-private agreements requiring lands to be used "effectively" in exchange for subsidized water.

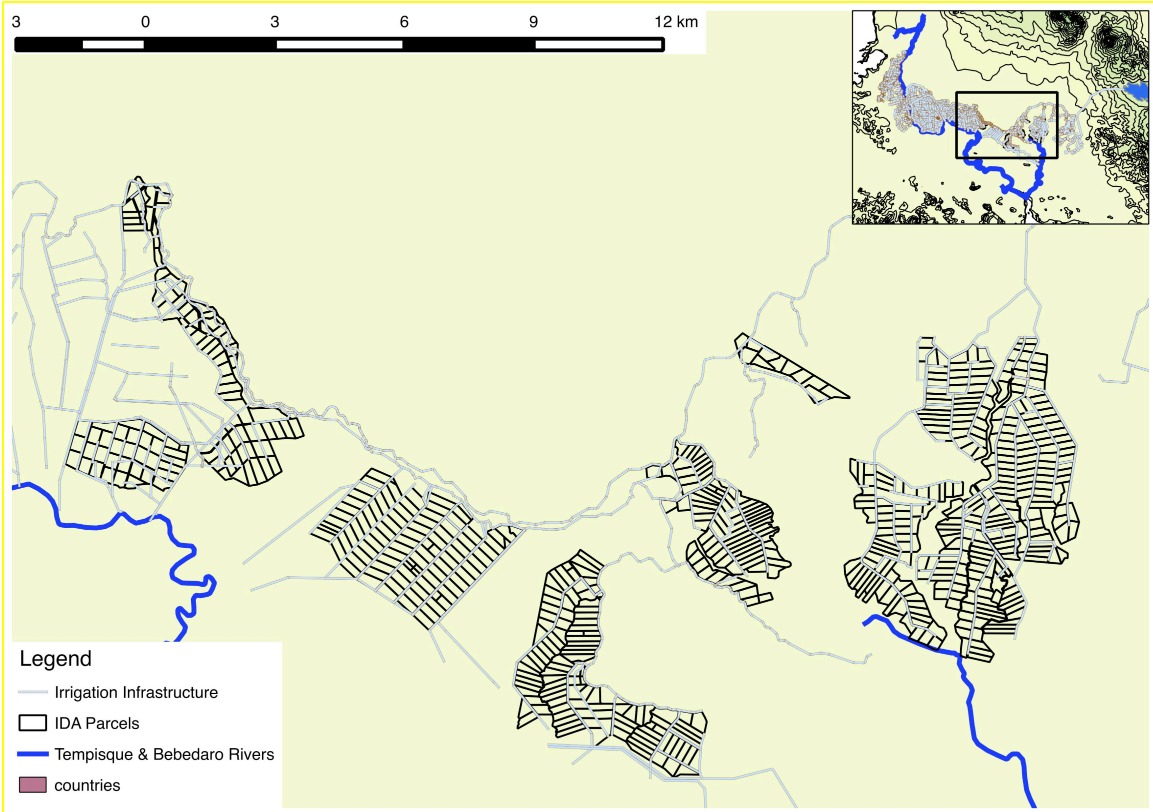


Figure 2.2 – IDA Parcels in the DRAT; parcels number 689 and account for approximately 25% of the total irrigated hectares shown in Figure 2.1

The idea of the PRAT was to provide smallholder farmers with plots of land, and to provide them with governmental extension services. The PRAT was to supply farmers with irrigation water during the dry season (November-March) to allow them to obtain higher crop yields. Market access for rice (Costa Rica's most heavily utilized grain in both 1980 and today) was to be provided to smallholder farmers by the government. Agro-industries funded in part and regulated by the state were to provide milling and refining capacity for the smallholder farmers. While the original goals of the PRAT never changed, the government's capacity to see them through to fruition did. The Latin

American debt crisis, beginning in 1982 brought a restructuring of Costa Rica's political economy. Costa Rica's government abandoned many of their public-private partnerships in the PRAT in order to meet the economic restructuring demands of the International Monetary Fund, World Bank, U.S.AID and the Inter-American Development Bank in return for financial support.

As of 2012, one successful rice harvest on a 10-hectare farm brings approximately US$33,000. Over 75% of their gross income covers input and milling costs, which provides smallholder farmers with a stable livelihood above Costa Rica's average gross national income of US$8,820 (World Bank, 2012). Ten-hectare smallholder farms in the PRAT average two harvests per year to gross just over US$16,000 (CONARROZ, 2012). When the same farmer is unable to sell a harvest, they lose US$2,679 per hectare (ibid). The inability to sell a 10-hectare rice harvest leaves farmers with a debt of over US$26,000 per harvest. In comparison, the production of sugarcane on the same 10-hectare parcel would pay, on average, US$3000 per year. This is one-fifth what they would gain through successful rice production. However, 40% of smallholder farmers within the PRAT have transferred their crop production from rice to sugarcane over the last six years, thereby undermining the Costa Rican government's primary development goals as listed above.

The transition of smallholder rice farms to sugarcane production was driven by two interrelated factors: (1) foreign and domestically owned, large-scale industrialized rice farm adaptations to trade liberalization, and (2) smallholder farmers' adaptations to irrigation water scarcity during rice planting. Rice, being a very water-intensive crop, has become more difficult to produce in the region. As drought increasingly affects the region, industrialized farms' adaptations to international trade liberalization have changed Costa Rica's rice production institutions. The combination of these two processes has driven livelihood losses among smallholder farmers in the Tempisque River Basin. These recent changes in the PRAT are good for some, but bad for the most vulnerable smallholder rice farmers.

2.1.1 Defining sustainability problems in the Arenal-Tempisque Irrigation Project

Different groups of farmers, policy-makers, and researchers perceive changes in the Tempisque River Basin differently. Some argue the future of farming in the PRAT should be efficient, industrial farms that export high value crops. Others argue that the State's rural development goals should be valued more highly than increased production efficiency. It is the difference in these perspectives that has made the search for solutions to agrarian development problems in the region difficult.

In a series of two interdisciplinary workshops focused on water sustainability in the Tempisque River Basin, researchers and local stakeholders were asked to define and map drivers and outcomes of sustainability challenges. The first workshop, entitled Interdisciplinary workgroup on water sustainability in the Tempisque Basin, NW Costa Rica Workshop #1, was held on December 2, 2011 at the University of Florida, Gainesville, FL. Attendees included 29 researchers and policy-makers from the University of Florida, Arizona State University, the Organization for Tropical Studies (OTS), NASA, Texas A&M, the Technical University of Costa Rica (ITCR), and the Costa Rican government. Participants worked to define sustainability problems and understand knowledge gaps around sustainability in the Tempisque River Basin.

Participants developed many drivers and types of sustainability problems in the Basin; those most relevant to agrarian development included (1) the neoliberal model that replaced the historical communal model, introduced through the free trade agreement CAFTA-DR in 2004/2009, greatly impacts smallholder farmers rice-market access, water extraction, allocation, use, treatment, etc.; and (2) the central government provides little enforcement of laws around water extraction, allocation, use, treatment, etc. in the Tempisque Basin. The institutional and stakeholder map used to structure this study was drafted in this workshop, based on these findings, and was further revised in workshop #2.

Workshop #2, entitled Interdisciplinary workgroup on water sustainability in the Tempisque Basin, NW Costa Rica Workshop #2, was held on April 24-27, 2012 at the OTS Palo Verde Biological Field Station, Guanacaste, Costa Rica. Participants included 20 collaborators from the four participating US universities and organizations and 5 Costa Rican collaborators from the University of Costa Rica, ITCR, MarViva, Texas A&M's Soltis Center, and *ProDesarrollo Internacional*. In this second workshop, causal linkages between sectors in the institutional and stakeholder map were further defined and clarified. This map defined the boundaries of my PE assessment of changes in smallholder farmer livelihoods in the PRAT (Figure 2.3).

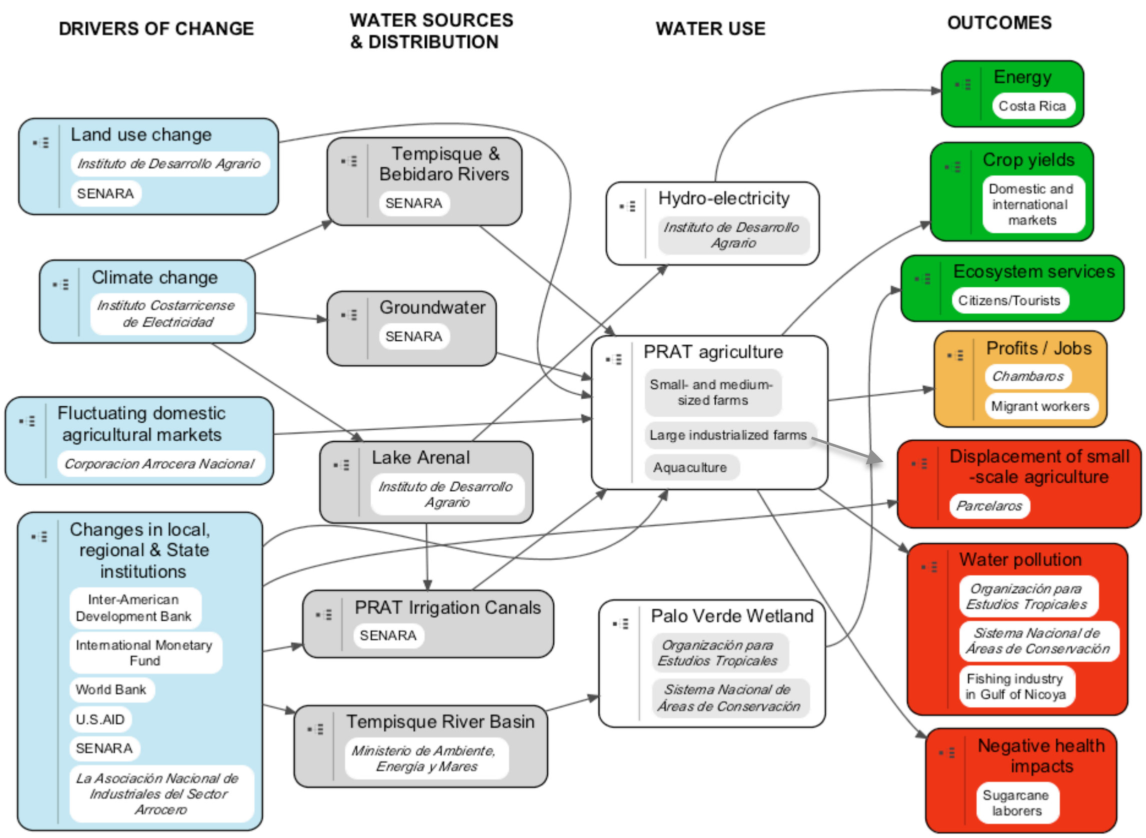


Figure 2.3 – Institutional and stakeholder map for the Tempisque River Basin. Actors and decision makers are depicted within each component. Arrows represent causal relationships. Outcomes are show from generally good, depicted in green, to bad, depicted in red. The map was organized around drivers of water use change, and it distinguishes the actors, their interactions, and their outputs, as defined by Kuzdas et al. (2014). Land use change is considered a driver because decisions about agriculture in the PRAT are made by policy-makers in San Jose'. This map was modified from Murcia et al. (2012) to include additional actors.

2.2 Methodology

My methodology was comprised of two components. I applied an (1) *explanation building* case study analysis (Yin, 2014, p. 147) within a (2) problem-driven PE assessment (Fritz, Kaiser, & Levy, 2009; Social Development Department, 2008). My PE assessment consisted of three steps:

1. I structured a case study and defined the social-ecohydrological components relevant to changes in PRAT smallholder agriculture using the institutional and stakeholder map (Figure 2.3);
2. Using this map as a guide, I explored the development and history of the underlying political economic drivers, including stakeholders, economic rent distributions, institutional inertias, and outcomes. I structured this third step by combining spatial and temporal scales, beginning first with an historical analysis at the global and country scales, and then moving to the regional-scale and finally to local-outcomes (as described by Fritz et al., 2009). I began by investigating the relevant global changes, country-scale institutions, and stakeholders to understand the main drivers of the political economy around smallholder farmer livelihood losses. I then directed my focus to a regional analysis of my case, thereby linking country- and regional-scale actors and institutions.
3. As my analysis converged on precise outcomes of livelihood losses among smallholder farmers, I identified drivers of both reforms to, and reinforcements of, the distribution of vulnerability, wealth and power in rice production.

2.3 *Data collection and analysis*

I relied on a combination of evidence including a literature review, a national archival review, interviews and focus groups with key stakeholders (e.g. governmental officials, farmers and local researchers), hydrologic and climate data, socio-economic census data, and direct observation (Table 2.1). Evidence was initially collected based on themes and variables depicted in my institutional and stakeholder map, and then I continued collecting evidence until multiple sources corroborated like findings. Using this method of triangulation, described by Yin (2014, p. 120), I ensured that each finding was supported by more than one source.

Table 2.1 – Evidence collected for case study analysis

Variable	**Justification**	**Type/ Units**	**Sources**
Socio-economic, agricultural and census data	Provides trends about changes in livelihood status	Varies	INEC (The National Statistics and Census Institute) www.inec.go.cr
GIS data for the PRAT and surrounding region	Provides agricultural land-use and hydrologic data	Spatial	Provided by OTS and SENARA. Additionally, OTS provided access to

			the 2008 Digital Atlas of Costa Rica
PRAT water allocation policy	Provides details about the role of water in livelihood outcomes	Description	5 semi-structured interviews with PRAT water and agricultural managers**; national archive records
Description of rural development history and goals	Provides an indicator for the success of the PRAT	Description	5 semi-structured interviews with PRAT water and agricultural managers**; national archive records
Average irrigation water deficit during rice planting	Represents climate change risk and water policy efficacy	Cubic meters/sec	SENARA database access (SENARA, 2012)
Yearly total rainfall in Tempisque River Basin	Represents climate change risk	Millimeters /Year	*Instituto Meteoroló gico Nacional* database access

			/Organization for Tropical Studies database access (IMN, 2006; OTS, 2014)
Total rice planted in Costa Rica from 1993 – 2012	Indicates changes in political protection from imports, and national demand	Hectares	CONARROZ database access (CONARROZ, 2006 – 2013)
Total demand to buy producers rice at Guanacasteca rice mills	Indicates the existence of rice market in the Tempisque River Basin; is function of rice consumption, total rice production, and total rice imported into Costa Rica	Metric tonnes	CONARROZ database access (CONARROZ, 2006 – 2013)
Average price paid to farmer for harvest from one hectare of rice	Indicates farmers' incentive to grow rice	U.S. dollars	CONARROZ database access (CONARROZ, 2006 – 2013)
Average price paid to	Indicates farmers'	U.S. dollars	LAICA database

farmer for harvest from one hectare of sugarcane	incentive to grow sugarcane		access (LAICA, 2010, 2013)
Number of rice mills in Guanacaste	Indicates vertical integration and consolidation of large rice farmers	Amount	Arroyo, Lucke, & Riveara, 2013, & CONARROZ database access (CONARROZ, 2006 – 2013)
Description of farmers' responses to reduced irrigation allocations	Provides understanding of LSCF responses to climate risks	Description	8 unstructured interviews with LSCF employees
Description of LSCF responses to changes in national rice politics	Provides understanding of LSCF responses to globalization risks	Description	8 unstructured interviews with LSCF employees; national archive records
Description of responses to changes in national sugarcane politics	Provides understanding of LSCF responses to globalization risks	Description	8 unstructured interviews with LSCF employees; national archive records

Description of smallholder farmer responses to decreased irrigation	Provides details about responses to water-related impacts	Description	5 unstructured interviews with smallholder farmers***
Description of smallholder farmer responses to rice production changes	Provides details about responses to changes in rice politics	Description	5 unstructured interviews with smallholder farmers***
Smallholder farmers' rice yield in PRAT from 1993 – 2012	Function of total area planted with rice by smallholder farmers and their yearly average yield per hectare	Metric tonnes	Arroyo, Lucke, & Riveara, 2013, & CONARROZ database access (CONARROZ, 2006 – 2013)

*National archive records include Ley 6877 de creación del SENARA: Artículo 15; Decreto 15321-MAG: Artículo 1. Creación del Distrito Arenal; Ley 7096 Contrato Préstamo II Etapa: Artículo 2° y 3°; Ley 8685 de Aprobación del Contrato de Préstamo entre el Gobierno de Costa Rica y el Banco Centroamericano de Integración Económica (BCIE), Contrato de Préstamo 1709; CÓDIGO DE REFERENCIA: CR-AN-AH-CODESA-000001-000528, Corporación Costarricense de Desarrollo.

** Institutions represented in interviews included Instituto de Desarrollo Rural (INDER), Servicio Nacional de Aguas Subterraneas, Riego y Avenamiento (SENARA), Ministerio de Agricultura y Ganadería, (MAG), Instituto Tecnológico de Costa Rica (ITCR), and the

Municipalidad de Cañas, Guanacaste, Costa Rica. Each interview lasted from 1.5 to four hours in length. Interviews were held at the offices of interviewees during January and February 2013.

3. The Arenal-Tempisque Irrigation Project, "How did we get here?"

3.1 Establishment of Costa Rica's neo-liberal agrarian development model, 1974 to 1992

Costa Rica's free-market policies of the 1980s were the result of both neoliberal measures taken by the President Monge Álvarez administration (1982-1986), that were driven by the country's economic collapse in 1980-1982, and by outside pressures calling for increased liberalization of trade and foreign investment with the U.S. and Europe. While the interplay among geopolitics, globalizing capital markets, and the lending terms of development banks produced Costa Rica's free-market policies of today (Marois, 2005), the catalyst for this change began in 1981 when Costa Rica suspended payment on its international debts. This suspension coincided with the onset of the Latin American debt crisis. Given the severity of Costa Rica's depressed economy in 1982, the IMF, the World Bank, USAID, and the Inter-American Development Bank were the only organizations that could negotiate between the Costa Rican government and the private banks to restructure debt (Honey, 1994). They were also the only organizations willing to lend money to support existing heath care and education governance systems as incomes dropped, economic growth stagnated, unemployment rose, and inflation reduced the buying power of the middle classes across the whole of Central and South America during this time (Bernal & Cristina, 1991).

The countries of Central America faced a larger disadvantage in renegotiating their debts, compared with South American countries, because economies were less diversified and repayment obligations were more highly scrutinized by the IMF and the World Bank. Thus, Costa Rica and other Central American countries were forced to agree to cross-conditionality agreements with the World Bank (Edelman, 1999). In these agreements, Costa Rica was required to fulfill IMF and USAID requirements in order to borrow money from the Bank. These requirements focused on reductions in government services and increased trade liberalization. This process of externally driven debt restructuring began Costa Rica's transition to free-market politics (ibid). While Costa Rica shared many similarities with Nicaragua, Panama, and its other neighbors in terms of the free-market demands placed on them during their debt restructuring, Costa Rica was much more heavily influenced by the U.S. geopolitical policy for the region. The U.S. used Costa Rica as an example of neoliberal economic success in contrast to the Sandinista government of Nicaragua. In return, throughout the early 1980s during Costa Rica's debt restructurings, the country received increased support from USAID relative to other Central American countries. USAID provided large grants and loans to Costa Rica for debt relief and policy reform (Honey, 1994).

Throughout the 1980s, USAID's investment in Costa Rica reflected the U.S.'s perceived importance of political stability in in Costa Rica (Edelman, 1999). Between 1983 and 1985, USAID gave US$592 million to Costa Rica, equal to roughly 35.7 % of Costa Rica's entire national budget (Honey, 1994; Marois, 2005). With this investment came the demand for an extensive restructuring of the country's 'nonproductive' social welfare spending (Edelman, 1999). The strings attached to the USAID money included an expanded role for private banks, the privatization of state-owned agricultural companies, and the creation of new private organizations that intentionally duplicated the functions of public-sector institutions to showcase privatization of government services. The ultimate goal appeared to be validation of a conservative vision of 'civil society' (Edelman & Seligson, 1994). In the context of agriculture, the most controversial of these USAID 'parallel state' institutions was a funded private agricultural school with the English acronym EARTH (*Escuela de la Agricultura de la Region Tropical Humeda*), which duplicated many of the programs already provided by the Costa Rican university system, as well as other new USAID-supported institutions that competed with underfunded programs in the Ministries of Agriculture and Livestock (Edelman, 1992).

IMF loans and USAID funds were used to make payments on Costa Rica's international debt (Honey, 1994). In contrast, the IDB and World Bank loans (see Table 2.2 for a summary of loaned amounts) were used for large agricultural and energy-related infrastructure projects. As with so many of these projects, the primary goal was to harness or harvest natural resources and increase farmer competitiveness through access to larger markets (Marois, 2005). By accepting these loans the Costa Rican government had to agree to a drastic liberalization of its agrarian economy. For example, the World Bank Structural Adjustment Loan I program of 1985, an $80 million loan, required Costa Rica to phase out subsidies for maize and beans. These measures were intended to match domestic food prices with international agricultural markets, thus improving efficiency, and to discourage food production for household use, thus freeing land and capital for agricultural export activities (Edelman, 1999).

Table 2.2 - Costa-Rican Foreign Aid, 1980–90 ($US millions) (Honey, 1994)

	80	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
USAID	14	13	50	212	168	207	157	181	102	115	75
WB	30	29	0	25	0	84	0	26	100	95	4
IMF	60	330	100	0	0	52	0	66	0	53	0

The World Bank also required a reorientation of agricultural extension programs by the Ministry of Agriculture and Livestock (*Ministerio de Agricultura y Ganadería*, MAG) away from food crops for domestic consumption and toward the nontraditional export crops such as ornamental plants, coconut oil, aquaculture, citrus, nuts, mangos, and melons. These new agricultural exports expected to take advantage of the newly formed U.S. Caribbean Basin Initiative, designed to provide access to the U.S. market. The World Bank Structural Adjustment Loan II, signed in 1988 and paid through 1992, was a US$200 million loan agreement with the World Bank that continued the reallocation of state-owned agricultural resources to the private sector and their rededication to agricultural export activities (Honey, 1994). By accepting the loan, the Costa Rican government agreed to reduce domestic prices for many basic grains to match international market prices (Picciotto, Ingram, Ramirez, & Lamdany, 2000), but to keep subsidies for the nontraditional export crops. This agreement opened the domestic agricultural market to grain imports from across the globe, thus flooding the domestic market with cheap grains and undermining smallholder producers across the country. However, tariff protections for rice remained in place.

3.1.1 Agrarian development in Guanacaste Province: water, electricity, and neo-liberal politics

To explain the current characteristics of the Arenal-Tempisque Irrigation Project, it is necessary to consider the legacies of Costa Rica's neo-liberal economic restructuring of the 1980s and 1990s. The project was designed around the concept of integrated rural development, and was ostensibly focused on the modernization and industrialization of smallholder farmers in the Province of Guanacaste. However, the development path changed course during Costa Rica's neoliberal shift, resulting in a new direction for irrigated agriculture in Northwest Costa Rica. As agricultural land use doubled across Costa Rica, beginning in 1960 and continuing through 1983 (Carr, Barbieri, Pan, & Iravani, 2006), the province of Guanacaste remained largely unchanged. Guanacaste was shielded from the political shifts occurring across Costa Rica by the region's semi-arid climate and by its location remote from the capital, San Jose. While Guanacaste, and specifically the Tempisque River Basin were rich in arable land, with large expanses of flat, fertile alluvial soils, agricultural development was limited because of the relatively dry climate. Furthermore, the province was devoid of key infrastructure—many of the roads in the region were only passable in the dry season, further complicating development challenges.

3.2 Effects of neo-liberal policies on the design and development of the Arenal-Tempisque Irrigation Project, 1974 to 1992

3.2.1 Design of the Arenal-Tempisque Irrigation Project

In 1974, the Inter-American Development Bank extended a US$50.5 million loan to Costa Rica to build a hydro-electric generating facility on the Arenal River, on the Atlantic slope, creating Lake Arenal, at 530 meters above sea level, with an area of 75 square kilometers, and a capacity of 1.5 billion cubic meters (IICA, 1993). The facility was to provide electricity to San Jose' during periods of peak demand, from March to June of each year (SENARA, 2013). In an effort to manage this flow, and coinciding with the publication of the administration's National Agribusiness Development Plan (*Plan Nacional de Desarrollo de los Agronegocios*, PNDA) in 1978, President Oduber Quirós's administration (1974-1978) developed the Arenal-Tempisque Irrigation Project Master Plan (1978). They coordinated with engineers from the U.S. Department of the Interior to design a 33-by-5 kilometer irrigation system along the Tempisque River (Jimenez, 1996).

The PNDA was designed to promote 'agribusiness' among smallholder farmers across the country. It was touted as the solution to problems of livelihood stagnation throughout the Tempisque River Basin (Villalta, 1994). The plan was developed to move smallholder and subsistence farmers from poverty by providing them with irrigation infrastructure and through increased market access. President Oduber Quirós's administration (1974-1978) assumed irrigation water from Lake Arenal would enable farmers in Guanacaste to increase output, transforming summer seasonal agriculture into a continuous activity. The Arenal-Tempisque Irrigation Project Master Plan was the mechanism through which the Costa Rican government planned to achieve the goals of the PNDA. These goals were two fold: (1) to increase the availability of a regular supply of raw materials for agriculture including, water, land, and agro-inputs, and (2) to reorganization the marketing system for agriculture in Costa Rica by providing smallholder farmers direct access to agricultural markets (IICA, 1993). Not surprisingly, the goals outlined in the Arenal-Tempisque Irrigation Project Master Plan aligned closely with those of the PNDA (in order of descending priorities): (1) to take maximum advantage of the waters discharged by the Lake Arenal hydroelectric dam; (2) to improve living conditions in the region by generating employment, redistributing income, and changing cropping systems; (3) to increase agricultural and livestock production and productivity; (4) to promote integrated regional development with complementary agricultural and industrial sectors and an expanded service sector; and (5) to contribute to the improvement of the country's economic situation by exporting fresh and processed agricultural products (Edelman, 1992).

In 1978, President Carazo Odio was elected into the presidency (1978-1982). Carazo Odio continued Oduber Quirós's legacy and he began designing the legislative framework for the PRAT using the goals defined in both the Arenal-Tempisque Irrigation Project Master Plan and the PNDA. Carazo Odio created a special Department of Irrigation and Drainage with an executive decree in 1979 to provide an institutional basis for planning and building necessary the infrastructure throughout the Tempisque River Basin. However, the newly formed department did not have the power to manage the land acquisition issues needed to meet Carazo Odio's rural development goals, which were based on a redistribution of land and income from large landowners to poor families.

Without the support of the legislature, Carazo Odio was unable to pass a land redistribution policy.

President Luis Monge Álvarez (1982-1986) took office on May 8th, 1982 as a member of the National Liberation Party (*Partido Liberación Nacional*, PLN). The more progressive PLN was able to generate the support necessary to pass two agrarian reform bills in 1982 and 1983. The Agrarian Development Institute (*Instituto de Desarrollo Agrario*, IDA, in 2011 the Institute's name was changed to the *Instituto de Desarrollo Rural*, INDER) was created in 1982, and the National Subterranean Waters, Irrigation, and Drainage Service (*Servicio Nacional de Aguas Subterraneas, Riego y Avenamiento*, SENARA) was created in 1983, replacing the Department of Irrigation and Drainage. These new agencies were given legal authority to dictate land use objectives.

Costa Rica began the largest rural development program in its history with the creation of IDA and SENARA, but the changing political climate in San Jose that coincided with the debt restructuring by the IMF gave private land owner lobbyists enough influence to strike one key element from the legislation. All wording in the legislation that would have made it illegal for any one landholder to own more than 100 hectares within the new irrigation system was struck from the law (Edelman, 1992). This allowed large landholders to retain large tracts of land that would now be irrigated by the government. While Monge Álvarez ultimately signed the bill into law, the administration considered the failure to establish legal limits on land ownership concentration in the district a defeat. He worried that private land speculation would undermine their development program and further separate the 'haves from the have-nots.' However, though the IDA's ability to redistribute irrigated lands from large landholders to smallholder farmers was hampered, a slow redistribution of land did unexpectedly occur in the PRAT throughout the mid to late 1980s. This was due to the newly gained power of SENARA's water managers to dictate land-use, as stipulated by the legislation that created the organization in 1983 (Edelman, 1992).

No cap was placed on the size of irrigated land holdings in the PRAT, but the new regulation did provide the following land use requirement: all lands receiving irrigation water from Lake Arenal must be used efficiently for irrigated agriculture. Congress, through SENARA's enforcement, legislated that large landholders must, if provided water, use the land efficiently. This clause, overlooked by private lobbyists during the passing of the development legislation, transferred much of the power for rural development to the PRAT's water managers. As a result, the government was able to use SENARA to meet the goals of their reform program. Throughout the 1980s SENARA ferociously enforced the efficient land use stipulation across the PRAT, and as large landholders realized they did not have the capacity to utilize irrigation water efficiently, they sold their lands to IDA. IDA then distributed the acquired lands to smallholder farmers as part of the country's rural development program (Edelman, 1992). At the time, large landowners did not have the capacity to bring large tracts of land into production with or without irrigation because transportation infrastructure within Guanacaste was still the limitation. They had very restricted access to large-scale planting and harvesting equipment, and the agricultural labor market had not yet developed. By the end of the 1980s, smallholder farmers had become the most efficient producers in the region, producing more rice per hectare than any other agricultural region in the country.

3.2.2 Development of the Arenal-Tempisque Irrigation Project in the context of Costa Rica's economic restructuring

IDA and SENARA were designed and passed into law as a means to redistribute and provide agricultural resources including land, water, and agro-inputs to the smallholder farmers throughout the Tempisque River Basin, but this would only address half of the National Agribusiness Development Plan (see above). If smallholder farmers were to be able to base their livelihoods on agriculture, reorganization the agro-marketing system would be needed to provide smallholder farmers with access to agricultural markets. Of the three administrations responsible for the design and early development of the PRAT (Oduber Quirós 1974-1978, Carazo Odio 1978-1982, and Monge Álvarez 1982-1986), President Carazo Odio did the most to reorganize Costa Rica's agricultural market system to promote smallholder agriculture. He co-opted a pre-existing federal program called the Costa Rican Development Corporation, S.A. (*Corporación Costarricense de Desarrollo*, CODESA), and reoriented it to promote the goals of the National Agribusiness Development Plan, as was typical of integrated rural development planning of this era throughout Latin America. CODESA was originally a state development agency established by Act No. 5122 in 1972 to promote the economic development of the country. CODESA was originally designed to develop and implement programs and projects of economic development on regional and national scales (Alvarado-Quesada, 2012). Carazo Odio began establishing agricultural subsidiaries of CODESA. These subsidiaries included processing plants and agro-resource facilities within the boundaries of the PRAT that provided assistance to smallholder farmers and operated as buyers and sellers of farmers' rice and agro-inputs.

In 1984 and 1985, CODESA underwent drastic changes due to the IMF/World Bank/USAID restructuring program. These changes undermined much of Carazo Odio's efforts regarding CODESA, and farmers in the PRAT ultimately received little government support from the CODESA subsidiaries. The Monge Álvarez administration was obligated to reduce funding to and sell off CODESA assets that had been established by Carazo Odio four years prior, as a condition of the restructuring. On January 18, 1985, a Memorandum of Understanding between the Monge Álvarez administration and USAID was signed as a condition of increasing USAID support, which required Monge Álvarez to privatize CODESA. By Executive Decree No. 16520-P-MCE, on February 25, 1985, Monge Álvarez created the National Commission for Restructuring CODESA that began the sale of CODESA and its subsidiaries to private investors. By the early-1990s, all rice mills located in Guanacaste were privately owned. In this new economic environment smallholder farmers' were required to rely solely on private mills to access markets.

Limited technology, agricultural extension services, and credit access coupled with limited options for market access prohibited smallholder farmers from reconfiguring their farms to produce the nontraditional export crops promoted by USAID throughout the 1980s. Sugarcane, the most widely produced crop in the PRAT as of 2013, was not yet commonly produced, and Guanacaste farmers could not compete in the regional fruit and vegetable market with farmers in the more fruit-friendly climates of Tilaran, Arenal, and further south toward the Central Basin. For these reasons, smallholder farmers continued to rely on the production of rice for both household consumption and livelihood preservation. Throughout the 1980s into the early 1990s, as IDA acquired land

and established new smallholder parcels, new farmers overwhelmingly relied on rice production, as shown Figure 2.4.

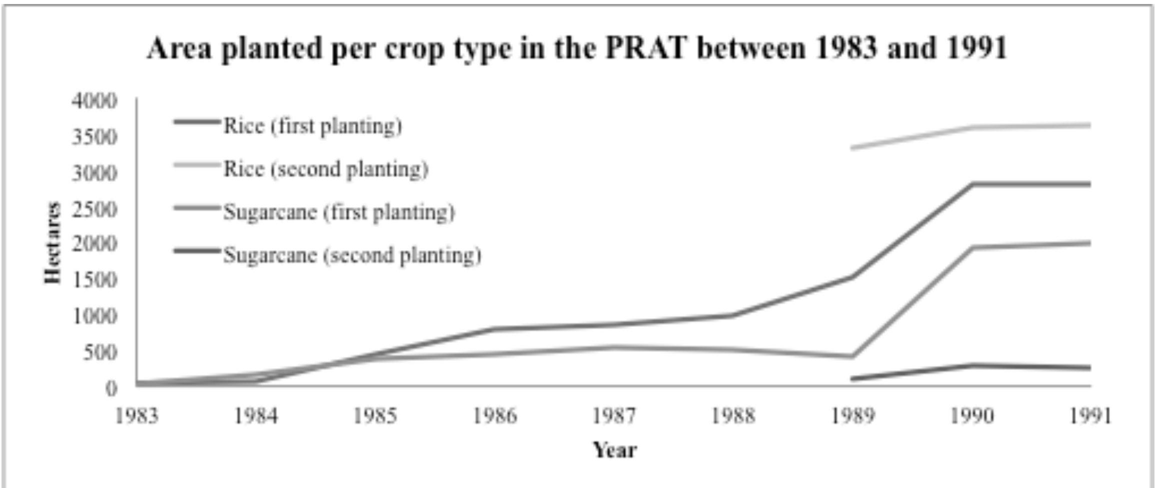


Figure 2.4 – Rice and sugarcane production in the PRAT from 1983 to 1991; in 1989 farmers started producing two crops per year using irrigation water (SENARA; 1989; 1990; 1992; IICA, 1992).

3.3 Smallholder rice farming in the Arenal-Tempisque Irrigation Project, 1992 to 2002

Throughout the remainder of the 1990s until 2002, smallholder farmers were generally able to sustain their livelihoods through the utilization of SENARA's irrigation water. They were able to sell their rice harvests to many of the larger private mills throughout Guanacaste. Rice did not bring the high profits received by fruit and vegetable farmers in the Central Basin, but smallholder farmers in the Tempisque River Basin were able to find buyers because most of the newly privatized mills were not vertically integrated (i.e. amassed control over each step in the supply chain including the production, processing, and sales of agricultural products), and most of the rice consumed in Costa Rica was produced domestically. At the turn of the century, almost all *parcelaros* (i.e. smallholder farmers who were given land or who were sold land at discounted rates by the IDA) in the PRAT grew rice (Arriagada, Sills, Pattanayak, Cubbage, & González, 2010).

The substantial reliance on rice production by smallholder farmers in the PRAT was the product of limited extension services for other crops, limited market access for anything except rice and sugarcane, and a historical precedence for growing rice. Fortunately, rice was still wielding a high price on the domestic market throughout the 1990s; IDA and SENARA made rice production a priority during this time for this reason, and they financed extension projects for farmers to support farmer rice producing goals throughout the 1990s. In some IDA sectors (i.e. each continuous tract of land purchased by IDA from large landholder was considered a different sector, there are currently seven sectors as shown in Figure 2.2), such as Bagatzi, rice production was almost necessary. Rice production on small plots requires collective action between farmers to be profitable. In Bagatzi, where rice was cultivated on adjacent 10 hectare plots, *parcelaros* intricately coordinated planting, harvesting, watering, and fumigation schedules. No one *parcelaro* could afford areal fumigation, so all-96 parcels in the Bagatzi reform project coordinated.

During the 1990s, larger landholders, able to maintain their holdings throughout the 1980s, began industrializing rice production on their farms, which were between 50 and 500 ha in size. Industrialized rice farms also established additional *arrozarias* (i.e. industrialized rice mills) that purchased rice from other farmers, thereby diversifying market access for smallholder farmers. The increasing rice production throughout the PRAT both by small- and large-sized farms hinged on the provision of irrigation water by SENARA, and this reliance made the region's agricultural sector particularly vulnerable to changes in water availability and rice commodity policies.

3.4 Effects of trade liberalization and climate change on the Arenal-Tempisque Irrigation Project, 2002 to 2013

3.4.1 Large rice producers' response to threats of trade liberalization

In 2002, the rice market in Costa Rica changed. As the third largest rice consumer per capita across the globe (IRRI, 2013), rice was at the center of legislative politics as debate began on the ratification of the Dominican Republic – Central America Free Trade Agreement (CAFTA-DR), designed to create a free trade area among the USA, Central America and Caribbean countries. While Costa Rica did not ratify the treaty until 2009, it drew attention to vulnerable sectors of the Costa Rican economy (Frajman, 2012). When talks of CAFTA-DR first began in the early 2000s, both large rice producers and *arrozarias* lobbied policymakers in San Jose, claiming that Costa Rica should keep its tariff protection for direct rice imports intact, thereby supporting domestic producers (Monge-González, Rivera, & Rosales-Tijerino, 2010).

The Costa Rican National Association of Rice Millers (*La Asociación Nacional de Industriales del Sector Arrocero de Costa Rica*, ANINSA) and the National Chamber of Rice Producers (*Cámara Nacional de Productores de Arroz*) funded the lobbying effort, and they proposed a set of improvements to the Rice Office (Law 7014). They claimed changes to Costa Rican rice policies were necessary to protect rice producers, millers, and consumers from volatile international rice markets. Their proposed changes included a rice-price fixing scheme to ensure profitability for domestic rice producers; they proposed a transfer of decision-making power on rice industry policies to a board of private producers and rice mills. They also lobbied to change the Rice Office's legal status from a government organization to a publicly funded, non-governmental organization. Realizing that rice production in Costa Rica was not able to meet the increasing domestic consumption demands, ANINSA also argued that the new rice office should be granted the sole right to import rice from the international market into Costa Rica with zero tariffs to supplement domestic production as needed.

The debate on the proposed changes to the Rice Office took more than two years. On May 23, 2002, the lobbying effort prevailed, and Law 8285 was passed by the legislature, creating the National Rice Corporation (*Corporacion Arrocera Nacional*, CONARROZ). The main opposition to the creation of CONARROZ came from lawmakers opposed to granting CONARROZ exclusive rights to import rice with no tariff, which they claimed contradicted the principle of free competition and would negatively affect consumer welfare (Monge-González et al., 2010). The objective of CONARROZ was to manage a hedge fund created by the government to stimulate the price margins of Costa Rican rice producers and enhance their competitiveness by protecting rice producers from competition. It was supposed to protect domestic producers from fluctuations in international rice prices and to improve their yearly rice yields through extension services. Legislators, through the passing of Law 8285, provided CONARROZ, which was managed in its entirety by large producers and mills owners, two key decision-making rights within the rice sector (ibid): (1) decision-making authority for the type and application of publicly funded agricultural extension services was granted to CONARROZ's board of rice producers and rice mills, and (2) monopolistic rights were granted to the board to import paddy rice with no tariffs (Article 40 of Law 8285). The passage of CONARROZ constituted the privatization of public benefits, from a heavy public subsidy and investment in rural development with the assumption of a poverty alleviation to one in which the primary beneficiaries were private producers and mills with commercial identities. This represented a shift in the role of the state in agrarian rural development policy.

The passage of CONARROZ also initiated Costa Rica's rice-price fixing scheme. Even though Law 8285 was passed to protect domestic producers from fluctuations in international prices, rice imports from the international market have increased over the last decade. This increase is the logical result of lower international prices and higher domestic-fixed prices, given the import incentive dictated in Article 40 of Law 8285:

> *CHAPTER VI, Article 40: The charge of importing paddy rice falls to the Rice Corporation (CONARROZ). For the purpose of marketing imported rice in the country, priority will be given to processing plants in proportion to domestically acquired rice.* (translated by authors, for original wording see National Archives, 2002).

As stipulated, CONARROZ must sell rice imports to rice mills, and with this sale comes a transfer of economic rents, which are the price differences between rice bought on the domestic market and rice bought by the mills from the international market through CONARROZ. Rice on the world market is consistently less expensive than domestically produced rice. This is due to (1) the high fixed prices of domestically produced rice, and (2) the production efficiency of rice produced in the USA, China, and Thailand, which averages 7 metric tonnes per hectare, compared with Costa Rica's average production of 4 metric tonnes per hectare (Arroyo, Lucke, & Riveara, 2013). Two years after the Law 8285 went into effect, in 2004 the economic rent transferred to rice mills through CONARROZ was US$6.7 million (Polo-Cheva et al., 2006). The rents won by CONARROZ and transferred to industrial producers and mills reached US$104 million in 2012 (Barquero, 2013).

Article 40 also stipulates that tariff-free rice imports be distributed to "*processing plants in proportion to domestically acquired rice*." This clause was included in Law 8285 in an attempt to ensure that imported rice is processed and sold as efficiently as possible. In actuality, what this clause did was create an incentive for agro-industrial consolidation and vertical integration (i.e., the combination in one agro-business of two or more stages of production). Because tariff-free rice is allocated based on acquisition of domestic rice (regardless of producer size) and milling capacity, economic rents from imported rice are also transferred based on domestic rice acquisition and milling capacity. Industrial mills were incentivized to begin producing rice, because they could gain increased rents from imported rice without paying the high fixed rice prices for smallholder yields. This successful rent seeking by the National Chamber of Rice Producers and ANINSA, which today represents 11 of Costa Rica's 15 rice mills, began the gradual displacement of smallholder farmers from the rice market. This trend was most significant in the Tempisque River Basin, which produces 45% of the country's rice

(CONARROZ, 2012). Large mills throughout the basin drastically consolidated to gain the rents from CONARROZ imports and avoid paying high prices for smallholder yields. In 2002, there were 11 agribusinesses with milling capacity operating in the Basin, but by 2012 there were only 5 (Figure 2.5 depicts this trend).

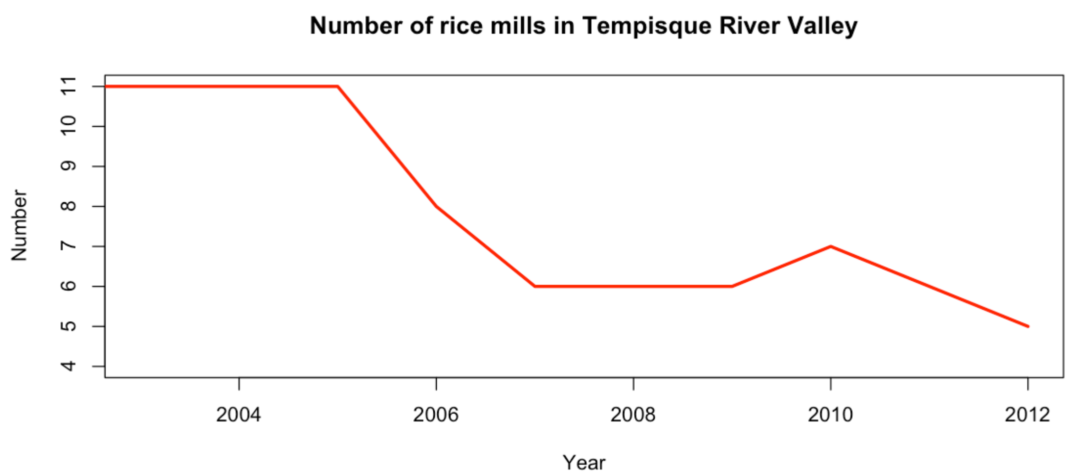


Figure 2.5 – Rice mills in the Tempisque River Basin from 2003 to 2012 (CONARROZ, 2006, 2007, 2008, 2009, 2010, 2011, 2012)

With this concentration came a drastic vertical integration of rice production in the Tempisque River Basin. Mills increased their private land holdings and direct production using rents from imported rice, allowed within the PRAT because no limitation on land holdings was stipulated in the passing of the Agrarian Development Institute (*Instituto de Desarrollo Agrario*, IDA) legislation in 1983. Mills can produce rice more cheaply because they are able avoid the high-fixed prices that must be paid to purchase smallholder harvests. Also, mills are able to avoid the high transactions costs associated with purchasing rice from smallholders through vertical integration in the rice market. This process has greatly impacted smallholder rice farmers in the PRAT who rely on private mills for market access. Because mills are now relying on imported rice and increasingly producing their own harvests, they eliminated many of their production contracts with smallholder farmers, which effectively means that these farmers cannot sell their crop.

As of 2013, most smallholder farmers are unable to gain rice contracts, which would ensure the successful sale of their harvests. The lack of contracts among smallholder farmers increases their business risks because they have no guarantees that their harvests will be purchased. The consolidation of agribusinesses that purchase imported rice from CONARROZ and supplement this supply with their own domestic harvests has changed rice production for smallholder farmers in the PRAT. Some smallholder farmers are still able to find buyers for their rice harvests, but these *arrozarias* will only purchase others' harvests if imports and industrially produced supplies do not meet demand.

Between 2007 and 2012, the total hectares planted with rice across the entirety of Costa Rica increased by 40% because large producers switched from sugarcane to rice as a result of increasing fixed domestic rice prices (Stange & Gonzalez, 2013; Figure 2.6). However, traditionally stable rice production among smallholder farmers in the PRAT followed an entirely opposite trend. While producers across the entirety of Costa Rica switched 40% of their arable land from sugarcane and other crops to rice production, smallholder farms switched approximately 30% of their planted land from rice to sugarcane production (Figure 2.6).

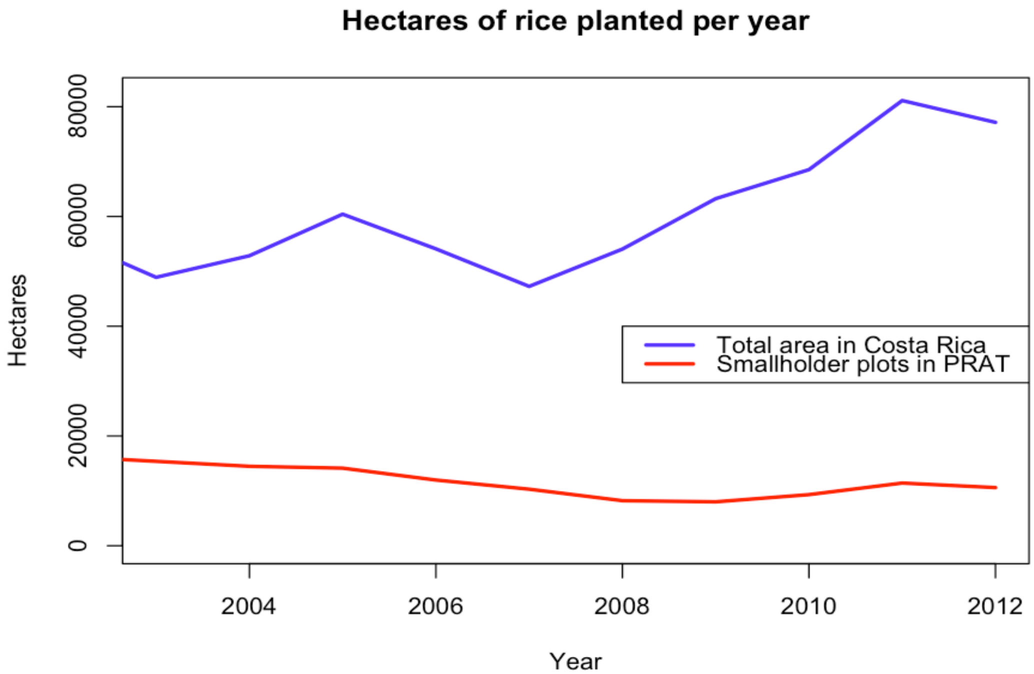


Figure 2.6 – Total rice planted in Costa Rica (CONARROZ, 2007, 2008, 2009, 2010, 2011, 2012) and rice production among smallholder farmers in the PRAT (Arroyo et al., 2013; CONARROZ, 2007, 2008, 2009, 2010, 2011, 2012); this planted area data is the summed total of up to three rice harvests per year per farm; smallholders in the PRAT typically grow two crops per year, and some grow three, and this is reflected in this figure.

Three sugarcane mills operate within the boarders of the PRAT, and together they control approximately 65% of Costa Rica's sugar milling capacity (LAICA, 2013). The companies that own and operate these three mills are also vertically integrated, and they own approximately 25% of the 28,000 irrigated hectares in the PRAT; in 2012, the area planted with sugarcane in the PRAT was estimated by SENARA to be nearly 53% of that area.

It is increasingly difficult for smallholder farmers to secure contracts with rice mills due to the mills' vertical integrations, but many try to continue to plant rice without securing a contract, and then they search for dwindling demand at regional mills. This has led to increased competition to sell rice among smallholder farmers. Some have switched to fast growing rice varieties in order to harvest before mills stop buying rice for the season. Mills only purchase smallholder rice harvests to supplement their expanding production. They purchase "non-contract" rice on a "first-come-first-served" basis, and then they stop purchasing for the season. Many smallholder farmers have been unable to sell their harvests and therefore many have assumed debts since 2002 due to their inability to sell their harvests. These debts are being purchased by the three sugarcane mills in return for full land-management contracts in an effort to increase hectares planted with sugarcane to meet domestic processing capacities. The sugarcane mills then manage and farm smallholders' plots, and smallholder landowners receive a flat fee per hectare depending on their debt, but on average they receive approximately 150,000 *colones* ($300 US) per hectare per year. One successful rice harvest on a 10-hectare farm brings approximately US$33,000 as of 2012 (CONARROZ, 2012). Over 75% of their gross income covers input and milling costs, which provides smallholder farmers with a stable livelihood above Costa Rica's average gross national income of US$8,820 (World Bank, 2012). Ten-hectare smallholder farms in the PRAT average two harvests per year to profit just over US$16,000 (CONARROZ, 2012). When the same farmer is unable to sell a harvest, they lose US$2,679 per hectare (ibid). The inability to sell a 10-hectare rice harvest leaves farmers with a debt of over US$26,000 per harvest. In comparison, the production of sugarcane on the same 10-hectare parcel would pay, on average, US$3000 per year. This is one-fifth what they would gain through successful rice production.

3.4.2 Effects of increasing regional drought on the Arenal-Tempisque Irrigation Project

Water availability has always been a barrier to agriculture in the Tempisque River Basin due to the region's semi-arid climate, but recent scarcity has not been the product of fluctuating rainfall. SENARA's allocation scheme, based on equality (i.e. every hectare receives an equal allocation regardless of ownership), was designed in 2006 after the fourth expansion of the PRAT brought water demand within reach of water supply. At the same time, the region began suffering from one of the worst droughts in recorded history.

The Tempisque River Basin operated under drought conditions in six of the eight years between 2006 and 2014. In 2007 Intergovernmental Panel on Climate Change reported strong consensus among climate models that temperature will increase and precipitation will continue to decrease in much of Pacific Central America over the next four decades (Magrin et al., 2007). Downscaled regional climate models for Northwest Costa Rica predict higher temperatures and water deficits (i.e. yearly evapotranspiration will be greater than yearly precipitation) in the region within the next two decades (Anderson, Flores, Perez, Carrillo, & Sempris, 2008). Wet season precipitation is expected to decrease as much as 27%, creating soil-moisture deficits and reducing the amount of surface water available for irrigation. Dry season river flow is also expected to decrease due to reduced cloud cover on mountain ridges (Karmalkar, Bradley, & Diaz, 2008). This trend towards increasing aridity is already evident in the Tempisque River Basin, as the average annual rainfall in the Tempisque River Basin has decreased by approximately 100 mm since 1950 (Figure 2.7). This increasing aridity has started to impact agriculture and water availability (Poveda et al., 2006; Waylen et al., 1996).

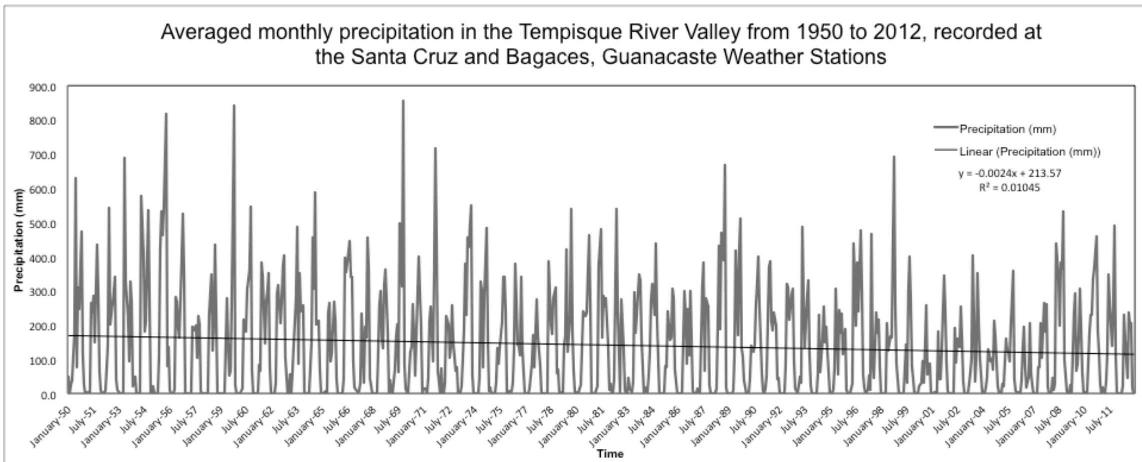


Figure 2.7 – Monthly precipitation trend in the Tempisque River Basin from 1950 to 2012, recorded at the Santa Cruz and Bagaces, Guanacaste weather stations and averaged between the two; regression line slope = -0.0024.

In September 2006, for the first time, the PRAT operated under conditions of water scarcity. Reductions in rainfall increased irrigation demand in the PRAT, but the low water volume in Lake Arenal dictated that SENARA could not meet farmers' demands for water. This decreased water availability to farmers was been driven by the fact that San Jose's rainy-season electricity demand took precedent over Guanacaste's dry season irrigation demand (see prioritized goals for the system above). While there was enough water in Lake Arenal to meet farmers' demands, the increasing drought led the hydroelectric facility managers to hold back water for hydroelectric production to ensure San Jose's electricity demands could be met, rather than turning it over to SENARA for allocation to farmers. The Arenal-Tempisque Irrigation Project Master Plan of 1978 authorized this water-right prioritization. Both farmers and the water manager were forced to adapt quickly. SENARA devised a plan to irrigate by sector to provide farmers with enough water to plant and harvest and suffer yield decline. The theory was that rice only requires a "flooding" during planting; it does not need a consistent influx of water. While SENARA was not able to provide this initial flooding to all rice farmers across the PRAT at once in early December, it was able to provide individual sectors with the water necessary to flood farmers' fields, and all sectors would receive their full planting allocation of water between December and January. SENARA informed farmers that irrigation would be provided in 'shifts' by sector. SENARA then alternated irrigation between sectors on a 14-day cycle until planting was completed.

Since 2006, water shortages throughout the PRAT have worsened (Figure 2.8), and supplies cannot fulfill the demand during the high water demand months of December and January, during which time both rice and sugarcane are planted. Both crops must be planted near the start of the dry season so they can be harvested prior to the beginning of the next rainy season. Many smallholder rice farmers have had to wait over a month to plant, which then pushes their harvest dates back. Because few smallholder farmers have sales contracts with *arrozarias*, a later harvest date reduces the probability that they will find remaining capacity at any one of the five remaining *arrozarias*. Larger farms and smallholder farmers near rivers overwhelmingly adapt to this situation by relying on illegal wells and illegally pumping from the numerous rivers that exist throughout the region. Many smallholder farmers have resorted to building illegal dams in canals downstream from their farm to increase the water level in the canal at the entrance gate to their fields; they then break the locks on their entrance gates to gain access to the water. This practice has incited conflict and violence among farmers as those further downstream lose their access to water. Dozens of related conflicts have been reported throughout the system over the last eight years. Many smallholder farmers have been forced to abandon their rice fields because there simply is not enough water left in the irrigation canals, and many others have been unable to sell their harvests because they harvest too late to find buyers for their crop.

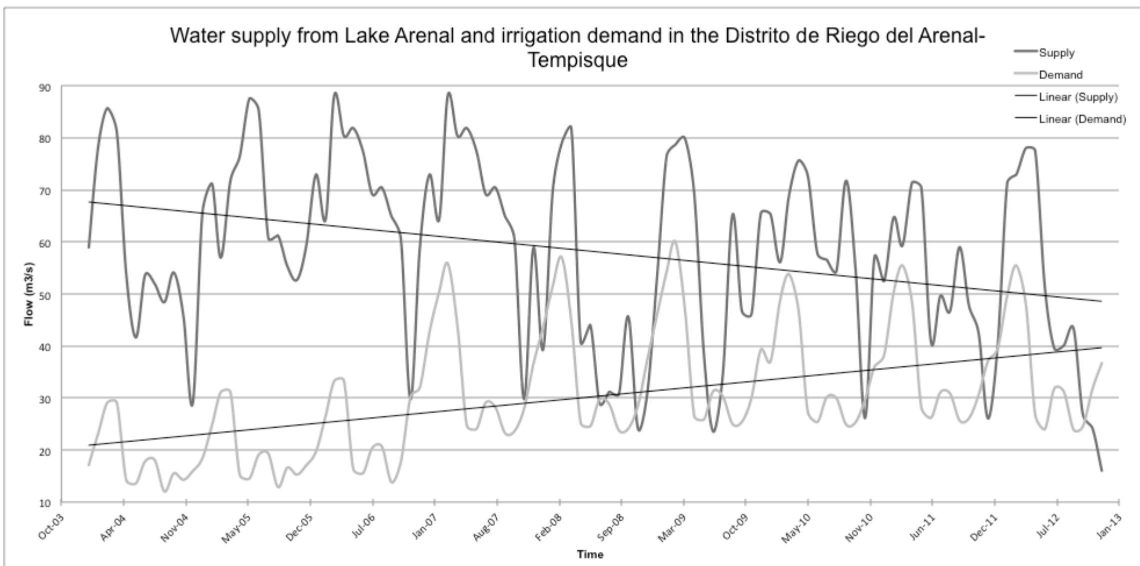


Figure 2.8 – Water supply and water demand in the PRAT (data provided by SENARA)

Unprecedented drought during the 2012 rainy season caused the PRAT to experience its largest irrigation water deficit to date because there was insufficient water being discharged from Lake Arenal to meet irrigation demands. From September 2012 to

February of 2013, SENARA spent over one million *colones* (approximately US$2000) per month replacing locks that farmers broke to gain access to water. In December of 2012, this water scarcity conflict in the PRAT reached a boiling point when farmers began threatening SENARA employees. One farmer was charged with attempted murder for his alleged assault of a SENARA *canalaro* (i.e., SENARA employee responsible for managing irrigation infrastructure) who was shutting a sluice gate after the farmer had received his reduced allocation of water. The farmer confronted the SENARA employee, rolled his bike into the irrigation canal, and then attempted to run him down with his farm truck. Needless to say these events have strained the relationship between SENARA and smallholder farmers. SENARA requires irrigation payments from farmers to maintain infrastructure. These payments average US$100 per year for smallholder farmers. For a typical smallholder farmer, they account for 2.5% of rice production costs, and they are highly subsidized. By contrast, the annual cost of unsubsidized irrigation water from Lake Arenal has been estimated to be approximately US$400 per irrigated hectare (Umaña, 2011). However, 65% of farmers owning less than 10 hectares of irrigated land submitted requests to defer their payments in 2013 due to strained relationships between farmers and water managers. This increase in deferments has forced SENARA to postpone infrastructure repairs, further stressing the entire system.

4. Adaptations in the PRAT to global changes: reforms to, and reinforcements of the distribution of risk, wealth, and power

The IMF, World Bank and USAID economic restructuring demands greatly changed Costa Rica's socio-economic development model that created and legitimized

IDA/SENARA, and they have effectively dictated the PRAT's development trajectory since. The restructuring impacted the PRAT in three primary ways. First, the liquidation of CODESA made smallholder farmers dependent on private rice mills for market access. Second, the creation of private agricultural extension services that replaced state agricultural agencies constrained smallholder farmer production options throughout the 1980s and 1990s, requiring them to rely on rice or leave farming. And third, the lack of land size restrictions in the PRAT allowed vertical integration by private farms and mills and enabled a competitive advantage for some farmers by removing resource access protections for many smallholder farmers; this ultimately excluded many smallholder farmers from lucrative agricultural supply chains. As the national political economy changed, so did the PRAT's development path. The shift to a neoliberal development model eliminated the potential for meaningful wealth redistribution across the PRAT. The initial agrarian development goals of wealth, land, and water redistribution were never realized due to the inability of the State to prioritize rural development over agricultural efficiency. IDA and SENARA continued to work toward the original goals of the project, but within the changed institutional structure, what has resulted is a resettlement program that has redistributed land to the rural poor without providing them with the capacity to use that land for their own good or to respond to changing climate and crop markets, thereby making them vulnerable to these changes.

Costa Rica's economic restructuring also instilled an institutional structure that ultimately disproportionately burdened the most vulnerable farmers in the PRAT by redistributing the impacts of global change risks. Global changes, specifically trade liberalization, drove rice mills to adapt which limited smallholder farmers' market access.

Increasing drought in the Tempisque River Basin exacerbated smallholder farmers' vulnerability. President Oduber Quirós's vision of agriculture in the Tempisque River Basin brought livelihood security to 680 smallholder farmers and almost 2,500 farm hands (*chambaros*), but this, combined with the restructuring also created a dependence on government-supplied irrigation water and market access. As the economic restructuring stripped away state provisions in the PRAT, smallholder farmers and the larger agrarian economy were left dependent on larger, private farms. Smallholder farmers were left vulnerable to risks created by larger farms' adaptations to the impacts of global changes. These risks included the vertical integration of rice mills and industrial farms to gain increased access to economic rents, made possible through the passage of CONARROZ. This integration then, unintentionally, created water scarcity among smallholder farmers, driven by decreased rice-market access. The heavy reliance on rice production, industry for market provision, and irrigation water made smallholder farmers vulnerable to any changes in the rice market or in the regional climate. These vulnerabilities were exposed as the debate on CAFTA-DR began.

As CAFTA-DR began the debate on trade liberalism in Costa Rica, smallholder farmers, while very aware of the debate, were largely powerless to weigh in, due to their lack of influence on legislators in San Jose. Rice mills and large producers in the Tempisque River Basin were able to lobby legislatures through the efforts of ANINSA, and thereby adapt to increasing trade liberalization and secure their goals by changing the institutional structure. The institutions governing the rice market in Costa Rica were changed with the passage of CONARROZ, and smallholder farmers had no real voice in these changes. This political process gave rise to a new institution that was good for a small and select group of farmers and ultimately bad for others. Members of ANINSA exercised their political power to adapt to conditions of changing global trade. The 11 rice mills in the Tempisque River Basin in 2002 were made less vulnerable to an influx of cheaply produced rice onto the global market. They were simultaneously able to secure a larger share of the domestic production market, allowed because no limitations on land ownership existed in the PRAT as a result of the lobbying efforts of Guanacaste's private landowners during the passage of the IDA legislation in 1982. Beginning in 2003, a slow redistribution of wealth occurred across the PRAT as rice mills gained profits from imported rice and domestic production, and smallholder farmers competed for decreasing rice contracts and scarce water.

4.1 Political production of water scarcity for the most vulnerable

Water shortages primarily occur in the PRAT during the high water demand months of December and January, during which time both rice and sugarcane are planted. Both rice and sugarcane require large inputs of water during planting, and both crops must be planted near the start of the dry season so they can be harvested prior to the beginning of the next rainy season. The water-cycling program, developed by SENARA, was designed to spread farmer-planting dates across a series of 6 weeks, thereby allowing all farms to successfully plant and harvest prior to the beginning of the next rainy season, which usually begins in May of each year. While the water-cycling program could allow all smallholder farmers to plant their rice crops and harvest before the rains begin, farmers who are forced to wait to plant have more difficulty selling their harvests because their later harvest dates limit their ability to sell their harvests before mills stop buying smallholder rice harvests for the season. And, while it is possible for smallholder farmers to store their harvests, the debts accrued through the planting and harvesting process necessitate the timely sale of their harvests.

Delayed water allocations, in combination with limited access to the rice market during harvest, have caused water piracy among farmers throughout the PRAT. This has created water scarcity for some. Farmers upstream in the PRAT illegally modify irrigation infrastructure to gain early access to downstream-farmer water allocations. Many farmers furthest downstream plant rice but then lose their water access as a result of the actions of upstream farmers, and therefore many downstream farmers have been forced to abandon rice crops. Water scarcity and the subsequent conflict among smallholder farmers can be attributed to the adaptations of more powerful rice farmers to the threat of trade liberalization. Those farmers downstream in the PRAT without illegal access to alternative water sources lose both their crop harvests and their access to the market. This redistribution of wealth and global change risks has undermined the development goals of the PRAT.

4.2 Distribution of global change risks in the region

This case of smallholder rice production in the PRAT has similarities with many other agrarian development programs throughout Central and South America that were brought about and changed during the "lost decade." Eakin, Perales, Appendini, & Sweeney (2014) show that while the impact of neoliberalism and the North American Free Trade Agreement on smallholder production in Mexico has been widely conceived as negative, smallholder production continues twenty years after structural reforms. They argue that adaptability in Mexican maize farming has allowed it to persist, and for a reconsideration of the assumptions of development policies to focus on unrecognized potential within heterogeneous smallholder-systems. Eakin, Bausch, & Sweeney (2014) show that smallholder maize production in Sinaloa has restructured Mexico's white maize market, but they highlight the dangers of the emerging negative externalities associated with increased dependency on maize production. This is similar to the vulnerabilities produced through smallholder farm dependency on rice production in Northwest Costa Rica. Appendini (2014) shows that the transition a State-managed maize market to the 'free market' has been largely influenced by policy decisions that support private actors in the maize market, and as a result maize production is now concentrated in the hands of relatively few producers, similar to the Costa Rican rice market.

These examples show commonalities in agrarian development in the Latin American case. As the redistribution of risk among groups of farmers to global changes drives differences in exposure, sensitivity and resilience in responding to these changes, those smallholder farmers without a voice are disproportionately burdened. Global change risks are frequently concentrated on the most vulnerable (Kasperson, Kasperson, Turner II, Dow, & Meyer, 1995). And, the most vulnerable typically do not have the means to participate in local or regional adaptation decisions. A discussion of the redistribution of global change risks in the PRAT, in the context of rural development for poverty alleviation, must include the procedures that dictate how and by who decisions about how the redistribution of risks are made. This discussion must include the mechanisms by which some actors' can change the institutions that dictate this distribution of impacts. The threats of the ramifications of CAFTA-DR on the domestic rice trade drove vulnerable farmers with a means to dictate the distribution of the treaty's impacts by altering the State's institutions and thereby preserve their valued goals. Their alterations of the Costa Rica's rice markets were imposed on all farmers, even those who did not have a means to influence the debate. The adaptations by the more powerful, agro-industrial companies to international trade liberalization pressure imposed new institutions on other farmers. As drought began to limit water availability in the PRAT, this change in Costa Rica's rice policy created water scarcity for some farmers, ultimately forcing them to abandon their valued livelihood goals.

5. Conclusion

The key lesson from this case is that the ability to enact adaptation policies within complex development programs requires a deep understanding of the interrelations between climate and the political economy. I show that these vulnerabilities were produced even as SENARA allocated water equally to all farmers because global trade liberalization drove some farmers to change Costa Rica's rice policies, which drove competition among farmers vulnerable to these changes. Recent research on globe change adaptation argues that barriers to the implementation of adaptation plans have not been aptly addressed (O'Brien & Wolf, 2010; Pelling, 2011). I show that a political economic perspective can provide a valuable lens through which barriers to adaptation can be viewed. This perspective may allow researchers and development practitioners to understand the interrelations and feedbacks between global changes without which can lead to myopic development policies. Also, this perspective inherently focuses researchers on the barriers to the implementation of climate change adaptation plans in rural development because questions of development inherently lead to questions about vulnerability in rural settings. This concept of vulnerability necessitates that adaptation researchers confront many longstanding barriers to development including inequity, power differentials, inclusivity and sustainability. Vulnerability, through a political economic perspective, may also provide insight into the complexity of interacting risks faced by the rural poor.

There is growing recognition among global change researchers of the linkages between environmental change and economic activities (R. M. Leichenko, Brien, & Solecki, 2010; R. Leichenko & O'Brien, 2008; O'Brien & Leichenko, 2000). However, many feedbacks and synergies between these two processes are not well documented or understood. This case of the risks interactions of international trade liberalization and climate change in the context of the PRAT provides an example of the complexity that may exist in these feedbacks, and of the ways these feedbacks may redistribute risk over both space and time from politically and economically powerful actors to the most vulnerable. We have shown that adaptations reformed and reinforced the distribution of vulnerability in the PRAT. Farmers with the political ability to change Costa Rica's status quo in an attempt to avoid impacts of trade liberalization benefited greatly from new rice policies. Farmers who had no voice in these change were heavily impacted by the interaction of increasing drought and decreasing market access. And, even as we understand how these complex interactions between global changes redistribute vulnerability and power across the DRAT, major barriers exist that will be difficult to overcome by rural development practitioners. In many rural development programs across Central America, the authority to make sweeping changes is not granted to practitioners. While water policies could be altered to promote fairness in adaptation, those in charge of water distribution have little authority to alter agricultural extension or market policies.

CHAPTER 3

THE PRODUCTION OF IDIOSYNCRATIC RISKS IN INDUSTRIAL-BASED RURAL DEVELOPMENT PROGRAMS: LESSONS FROM GUANACASTE PROVINCE, COSTA RICA

1. Introduction

The politics of land and water allocation are changing across the developing world as international commodity markets increasingly influence household decisions, and as international agro-investors demand more arable land and increased access to water (Borras et al., 2011). These processes of agricultural globalization (i.e. the tightening of coordinated agro-supply chains that increasingly operate on a global scale; IFAD, 2006; Najam, Runnalls, & Halle, 2007; Reardon & Barrett, 2000) offer potentially increased affluence to investors, cost efficiencies and lower food prices to consumers, and more opportunities for rural development to countries. Recently, we have seen an increase in policymakers' and researchers' promotions of agro-industrialization projects as tools for rural development. On the heels of the "Lima Declaration" (UNIDO, 2013), the United Nations (UN) is increasingly supporting this development scheme. The "Lima Declaration: Towards inclusive and sustainable industrial development," was adopted and signed at the 15th Session of the United Nation Industrial Development Organization (UNIDO) General Conference in Lima, Peru, on 2 December 2013. Through the declaration, the UN tasks UNIDO to assist Member States towards achieving sustainable industrial development by expanding manufacturing and competitiveness in rural areas. Development banks and NGOs are also increasingly relying on industrial- and agribusiness-based development projects to meet their objectives, which are often established based on Millennium Development Goals (UN, 2013), because these projects appear to offer unparalleled opportunities for the development of previously marginal, often arid, agrarian lands.

A renewed interest in agricultural investments, or agro-investments, by multinational agro-businesses and foreign governments, spurred by the food crisis of 2007-2008 (Deininger & Byerlee, 2011), has created unparalleled opportunities for industrial-based rural development in regions where none had existed previously. Industrial-based rural development links agricultural supply chains between smallholder farmers to those of larger commercialized farms in order to increase production efficiency and access to markets. These projects also generally advance the use of agro-technologies with the aim of increasing the resilience of farmers to climate hazards such as droughts (for examples see IDB, 2011; World Bank, 2012, 2013b; 3ADI, 2010). The availability of new agro-technologies including more efficient irrigation schemes and drought-tolerant crop varieties has also contributed to investments in previously marginal agricultural production systems. These investments, most pronounced in Sub-Saharan Africa and Latin America, are driven by four factors (Deininger & Byerlee, 2011):

1. Global population and income growth has increased demand for food and other industrial raw materials.
2. Demand for biofuels has increased across the Americas and Europe.
3. Many multinational agro-corporations are continually shifting production of bulk commodities to land-abundant regions where land rights and labor are cheaper.

4. The 2007–08 boom in food prices uncovered vulnerabilities in many import-dependent countries, which spawned food acquisition programs and led to a "rediscovery" of the agricultural sector.

Industrialization is quickly becoming the new paradigm in rural agricultural development for these reasons. However, some local farmers and development researchers are questioning the utility of liberalizing institutions to expand internationally owned, industrialized agriculture as a means of bolstering smallholder farmer livelihoods. Some smallholder farmers (i.e. rural producers in developing countries who rely mainly on family labor to produce crops for market as their primary source of income; Morton, 2007) argue that this process actually produces new risks that threaten their livelihoods, natural environments, and quality of democracy (for examples see Bebbington, 2012). These worries have spawned spirited reactions from the rural poor throughout less-developed countries (LDC) (Edelman, 1999). In Costa Rica, smallholder farmers have recently reacted to these new risks by staging protests (El Nuevo Diario, 2014), occupying government buildings (Inside Costa Rica, 2012), and staging road blockades (A.M. Costa Rica, 2011).

Climate change further complicates the ability of development practitioners to provide livelihood security to smallholder farmers within industrializing development programs. Newly liberalized economic institutions, combined with often-lax enforcement, can allow opportunities for more politically or economically powerful farmers to adapt in order to gain access to dwindling resources. I define adaptations as responses to observed or expected global change risks—their effects and impacts—in order to alleviate adverse impacts of change or take advantage of new opportunities

(Adger, Arnell, & Tompkins, 2005; IPCC, 2001). There is evidence that this process may derail development programs (Byerlee, de Janvry, & Sadoulet, 2009; Deininger & Byerlee, 2011). And, while frequent arguments claim industrialization addresses agricultural market failures and inefficiencies (FAO, 2009), it is not sufficient to focus solely on economic costs and benefits. The removal of agricultural market failures through industrialization may not always improve production efficiency because doing so may change the local, regional, or national political equilibrium resulting in unintended power shifts that exacerbate other market failures (Acemoglu & Robinson, 2013). I argue that the political, economic and physical power wielded by some groups in agro-supply chains (and the subsequent actions they take) may make others more vulnerable to climate and market hazards as they adapt to gain access to scarce resources. As more powerful resource users adapt their production and livelihood strategies to manage climate- and market-based risks, new risks may emerge to other groups from the changed context. I define these new risks as a specific type of idiosyncratic risk.

Generally, risks are defined as the possibility of adverse consequences from events or activities with regard to something that people value (Kates, Hohennemser, & Kasperson, 1985), and they can be imposed from outside or taken on voluntarily in the pursuit of opportunities (World Bank, 2013b). For the purposes of this study, I focus on a particular type of idiosyncratic risks, defined as those that are endogenous to a system, and that are produced through the actions of others within the system in response to exogenous risks (for a more general definition of idiosyncratic risk see World Bank, 2013). Within industrial-based rural development programs, these idiosyncratic risks may emerge from the adaptations of farmers, who control key components of agricultural supply chains, to new, complex, and systemic risks produced from the interaction of market forces and climate changes; this is how the industrialization of development programs may exacerbate the exposure of the most vulnerable to idiosyncratic risks. We know little about how the responses of different groups to new complex risks from global changes may feedback to create new, endogenous, and unforeseen risks within agricultural supply chains for different groups of farmers. I argue that these idiosyncratic risks may force the most vulnerable to abandon their livelihood goals, resulting in the failure of the very programs that were put in place to enhance rural development.

In this paper, I posit that agricultural globalization presents opportunities for industrial-based rural development, but the sustainability of these programs depends on the ability of policymakers and smallholder farmers to manage idiosyncratic risks. The sustainability of these development programs is based on their ability to secure desirable social outcomes including inclusive agricultural growth in the face of global change risks. I present and justify the study of this new type of idiosyncratic risk, viewed through a political economic lens (Moe, 2005), and analyze its emergence in rural development programs. I argue that industrial-based rural development programs are uniquely prone to these types of idiosyncratic risks. Then, I analyze a case study from an industrial-based rural development program in the semi-arid tropics of Northwest Costa Rica using mixed methods to begin to understand the pathways through which idiosyncratic risks may emerge within industrial-based development programs as different groups of farmers respond to systemic risks. I end with a theoretical analysis of idiosyncratic risk pathways.

2. Political economic justification for the study of idiosyncratic risks in industrial-based rural development

While industrialization processes within any agrarian rural development program may be generally conceptualized as risks, practitioners, policymakers, and smallholder farmers often consider the opportunities they afford rural development as worthy of these risks. The expected consequences of industrialization, including rural development, are generally assumed to challenge some livelihood values of some rural people, but these tradeoffs are expected to be small, and these risks are implicitly or explicitly considered necessary in pursuit of opportunities. However, a threshold exists, across which opportunities for rural development through agro-industrialization are no longer worth assuming the adverse consequences. Agro-industrialization has been shown to increase inequity and exclusiveness between groups that limits its usefulness to rural development when development goals are not promoted and enforced by local institutions (FAO, 2009). Uneven market power in agricultural supply chains can allow economic rents to be captured by one or a few farmers in a region. This often leaves other farmers worse off. A collapse of the competitiveness of smallholder farmers is the traditional risk of agro-industrialization in rural development projects. Although agro-industries may provide a consistent channel for smallholder farmers to gain market access, the need to promote competitiveness typically favors larger farms that are better able to deliver large harvests more efficiently. To the extent that smallholder farmers are left out of supply chains, the equitable socio-economic benefits of agro-industries are reduced. However, development researchers and practitioners largely understand the strategies to overcome these risks in absence of systemic risks from global changes. A summary of these strategies is provided by FAO (2003).

The pace of agricultural globalization across LDCs has greatly increased over the last decade, which has coordinated supply-chains on a far larger scale and greatly changed the organization of local and regional agricultural markets (Byerlee, de Janvry, & Sadoulet, 2009). New technologies, more demanding markets, and the increasing frequency of climate extremes are creating new challenges for development practitioners and they may challenge the future success potential of the agro-industrial-based development model. The sustainability of smallholder farm competitiveness within industrial-based development programs may be compromised by increasingly restricted access to technological innovations, which are controlled by select farmers in agricultural supply chains. This limits their ability to compete in more demanding globalized markets. In arid and semi-arid regions, where much of the agricultural growth has occurred over the last five years, efforts taken to secure reliable water sources by new industrial farmers have often limited the access to water for small farms and escalated numbers of water conflicts (Miralles-Wilhelm, 2010). These new risks, which I contend can be classified as either systemic or idiosyncratic, may challenge the utility of industrial-based development programs in the future. Systemic risks are exogenous and are driven by climate change and globalization. Idiosyncratic risks are endogenously produced risks that are generated by the adaptations of others to exogenous risks of climate and market changes.

The concept of risk has three common elements: first, outcomes that negatively affect what people value; second, the probability of their occurrence; and third, a function for combining the two (Dow, Berkhout, & Preston, 2013). Conceptually, risk also provides a link between the concepts of rural development and global change adaptation. In this context, global change adaptations are actions taken by groups or individuals to secure valued attributes in the face of global change risks (Füssel, 2007). Global change adaptation and rural development are then ethical issues, aiming to protect and enhance what stakeholders value (i.e. profit, security, or livelihood). But, not all development-program stakeholder values align with the goals of rural development programs, and adaptations occur unevenly. As different groups of stakeholders respond to systemic risks, the trajectory of a rural development program may change. Farmers may decide to pursue alternative livelihoods outside of agriculture, or farmers may take actions to secure resources that limit the ability of their neighbors to secure resources. These types of adaptations may increase the vulnerability (i.e. the degree to which a group or community is impacted adversely by the consequences, or potential consequences, of risk; Eriksen & O'Brien, 2007; Eriksen et al., 2011) of some individuals or groups being affected by rural development programs.

As new systemic risks emerge, different groups adapt in different ways. Systemic risks play out as global changes impact the system, and thereby subject individual groups to impacts that produce their responses and outcomes. The outcomes of these impacts for each group depend on vulnerability to each risk, and whether and how a particular group can and does respond to systemic risks (Smit et al., 2001). These responses may create new idiosyncratic risks for some groups. Idiosyncratic risks develop as groups respond to systemic risks and create new risks for other groups. As the actions of one group may affect the outcomes of another group's adaptations, some may reach their adaptation limits—e.g. the point at which an objective that is valued by individuals or groups cannot be secured from risks by further adaptive actions (Dow et al., 2013). At this point, it may become more difficult for the development program to meet its goals. And, while no development programs ever "risk free," I argue industrial-based rural development programs are at greater risk of derailment from new, idiosyncratic risks because of the necessarily large disparity in economic and political power differentials among farmers, and those farmers with the power to alter development institutions often control key sectors of local agricultural supply chains upon which the most vulnerable rely. As politically and economically powerful farmers adapt to global changes, they alter development institutions for all other farmers, for better or worse.

2.1 Idiosyncratic risks: a political economic view of adaptations to systemic risks in the absence of 'no-regrets' approaches

Climate adaptations are typically recognized as necessary or useful actions on the part of exposed or vulnerable populations (Füssel, 2007). Much of the research into climate change adaptations traditionally viewed these actions as the successful end goal for those managing the effects of global change (see Carter, Parry, Harasawa, & Nishioka, 1994; Jones, 2001). This was often the case because vulnerable populations were often viewed in isolation from the adaptations of other groups to the same risks (Voß & Bornemann, 2011). A critical political economic perspective may better allow us to include the goals of rural development programs in our evaluations of climate adaptations, and to view individual adaptations as part of a larger social-ecohydrologic system. We must evaluate the effects of any given adaptation on other groups that rely on the same resources and markets because adaptations of one group may limit the ability of another group to adapt and pursue their goals. This process is likened to idea of ‘disproportionately burdening the most vulnerable’ in global change literature (Barnett & O’Neill, 2010), but it is not as straightforward as this idea of maladaptation, which implies a mistake in the adaptation process. This process may also be considered a type of externality within a development program with respect to individual livelihood losses, but it may be difficult to valuate because it may simultaneously represent a shift on the Pareto frontier (i.e., a state of resource allocation in which resource managers cannot make any one individual better off without making at least one individual worse off) or even a Pareto improvement in terms of crop-production efficiency. The production of this specific type of idiosyncratic risk occurs when trade-offs are inherent, and when more politically powerful groups are able to deliberately change the social-ecohydrologic status quo by imposing their interests on a broader population, thereby and making others more vulnerable to global changes.

This critical political economic perspective provides a useful lens through which to view the interconnectedness of farmer adaptations in rural development programs where collective action is difficult to achieve and meaningful ‘no-regrets’ adaptations are limited (see Heltberg, Siegel, & Jorgensen, 2009 for a definition of 'no-regrets' adaptations). Building from of the definition of political power provided by Moe (2005), the ability of any one player to change the development program context for other users through adaptive actions can be viewed as a reflection of power. Water, land, agro-inputs, and market access are often scarce within the region that a given program is trying to influence, and within industrial-based development programs these resources are often controlled by select groups (i.e., farmers, agro-input providers, resource providers, etc.) at key points in agricultural supply chains. As risks of scarcity increase—and these are often driven by trade-liberalization, agro-investments, or climate change—farmers controlling limited resources may adapt within the confines of their capacity to do so. This can limit resource access to other farmers and leave them more sensitive or exposed to global change risks. Some farmer adaptations may be considered Pareto improvements, which are benign in the context of a development program. Examples of these "no regret" approaches include switching to more drought resistant crop varieties, the adoption of new water saving agro-technologies, and the promotion of new collective actions to more efficiently allocate resources. These adaptive actions have been the focus of much adaptation research.

Here, I am interested in development programs that have few options for no-regrets approaches, and in which adaptive actions produce resource allocation trade-offs between farmers. In this way, adaptation may be viewed as a common pool resource. In these programs, formal institutions (i.e. anthropogenic constraints on resource access and use; North, 1990) designed by development practitioners and enforced by governments dictate the allocation of scarce resources based on the goals of the development program. However, the origin and sustainability of many of these formal institutions lies in politics (Bates, 1994), and their implementation is political, responding to informal norms and institutions (Dacin, Goodstein, & Scott, 2002). Furthermore, while the origin of many informal or collective action-based institutions may lie outside of politics, they may be interdependent with political institutions. Therefore the sustainability of rural development programs lies largely in politics. This idea stems from the underlying logics that: (1) institutions directly affect the outcomes of resource allocation (distribution and growth); (2) individuals realize this, and; (3) they attempt to change institutions to service their ends more effectively (Ensminger, 1992). Within this perspective, the capacity to adapt can be seen as a function of power to change the status quo, and this power is derived from two sources (Mueller, 1980, 2003; Wagner, 1969): (1) the asymmetric possession of information about climate and market uncertainties, and; (2) the availability of capital (i.e., a stock of resources created through human action by investing current income streams, thereby increasing future benefits from labor or raw materials; Scoones, 1999), cognitive capacities, and self efficacy to act upon the asymmetric possession of information.

In some cases, differential in uncertainty among actors about the future creates the potential to exercise power, and information, capital, and ability provide the capacity to do so. So, groups of farmers seek information about climate and market changes, and those with increased means are better able to act within the legal bounds of development policies to secure access to resources. Others may lack the information to understand and anticipate risks, or they may lack capital or ability and be unable to respond. In other cases, some actors may be able to leverage power over others, legitimately or illegitimately, even in the absence of uncertainty. In both cases, over time, as farmers with more power adapt to secure more resources, others are left with fewer resources and may be more vulnerable to the impacts of globalization and climate change risks. This may exacerbate vulnerabilities of the already vulnerable. Following this logic, adaptive actions often aim to alter institutions and unintentionally or intentionally impose constraints on stakeholders with less decision-making power, and these constraints provide the means for informed groups to extract larger transfers of rents and resources. In the context of the case here, these new institutions may provide seemingly productive outcomes in terms of overall crop yields and efficiency, but often at the expense of those groups that rural development programs were designed to benefit. These types of institutional changes that lead to an increase in inequality are shown to sometimes have counterproductive political implications (Acemoglu & Robinson, 2013), that may call into question the sustainability of the agricultural system in question.

3. Theoretical framework to structure political economic analysis of idiosyncratic risk

This specific type of idiosyncratic risk, depicted in Figure 3.1, builds on and integrates into a global change framework developed to consider how adaptations, driven by multiple exogenous risks, can create winners and losers (e.g. Leichenko, Brien, & Solecki, 2010; Leichenko & O'Brien, 2008; & O'Brien & Leichenko, 2000) in order to understand how the adaptations of some groups can increase vulnerability of others. This concept helps to structure critical analysis of the interactions among the adaptations of different groups within a single system. In the framework that includes the concept of idiosyncratic risk, exogenous systemic risks from climate change and globalization manifest as gradual or sudden impacts (either positive or negative) to the entire system. Systemic risks play out as global changes impact the system, and thereby subject individual groups to impacts that produce their responses and outcomes. Impacts affect different groups (e.g. communities, social networks, families, etc.) in different ways, resulting in different outcomes for each group. The outcomes of these impacts for each group depend on exposure and sensitivity to each impact, and whether and how a particular group can and does respond to systemic risks (Smit et al., 2001). These responses may create new idiosyncratic risks for some groups. These types of idiosyncratic risks develop as groups respond to systemic risks and create new risks for other groups.

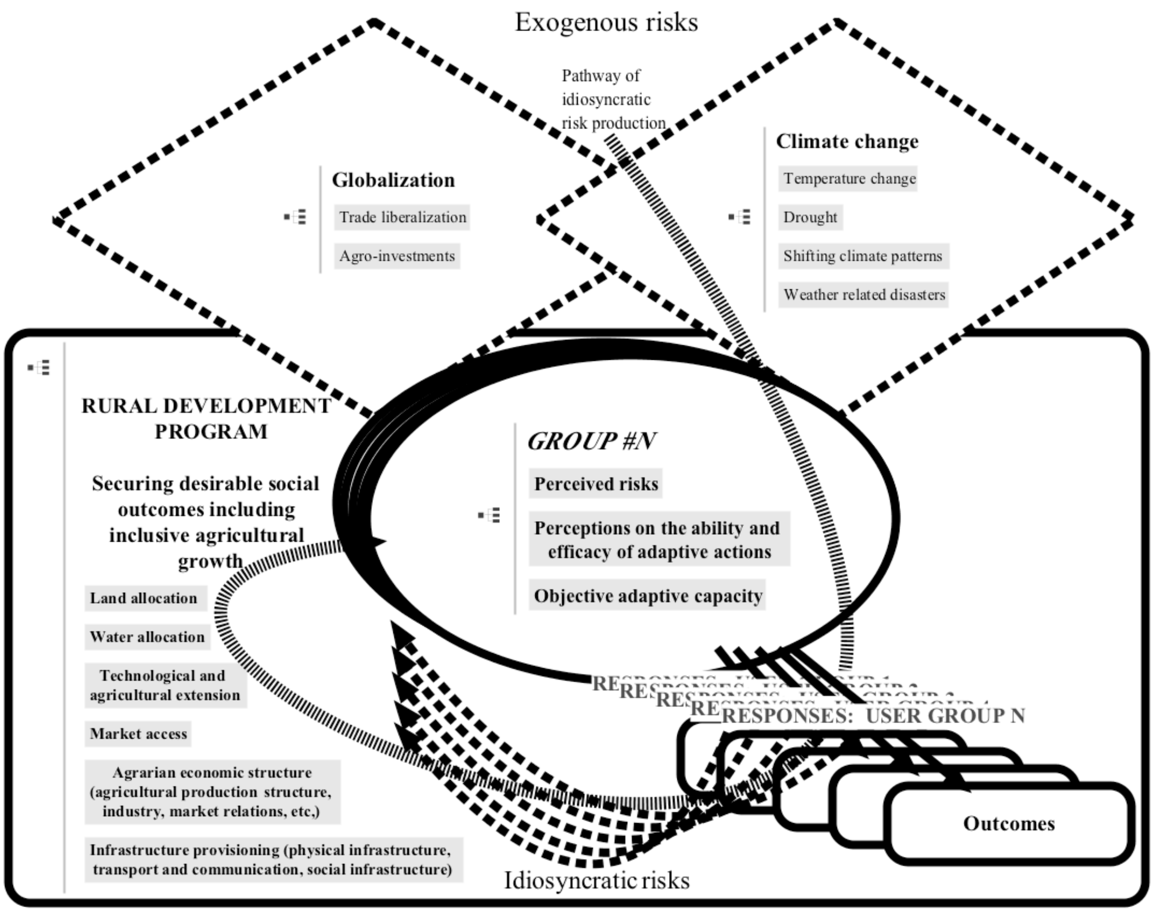


Figure 3.1 – Framework for understanding the of production of idiosyncratic risks in rural development programs and their related institutions including resources, technological extension, and infrastructure; rural development programs are conceptualized as articulated and maintained by regional, state, and international

governments, international development organizations, banks, NGOs, and public-private organizations with the aim to secure desirable social outcomes through inclusive agricultural growth. The production of idiosyncratic risks begins as exogenous risks from global change processes impact a development program, causing different groups to respond in different ways and potentially altering the physical or institutional environment for all actors. This may make other actors more vulnerable to risks.

In this framework, global change and globalization processes overlap, and they individually affect rural development, posing interacting, systemic risks. Akin to the Leichenko & O'Brien (2008) conceptualization, exposure represents the condition of being sensitive to impacts from systemic risks. For example, if global rice prices decrease, rice farmers will be sensitive to this impact (e.g., sudden change) but sugarcane farmers likely will not. Exposure is also influenced by group responses. Responses to impacts are the adaptations (or lack of adaptations) taken either in anticipation of or in response to impacts. Outcomes, in turn, are then dictated by (1) the rural development program, (2) groups' pursuit of valued goals, (3) the impacts from systemic risks, and (4) groups' capacities to perceive and respond to risks. However, groups' responses may feed back and potentially change the context (e.g., governing institutions) of the development program, which I conceptualize as idiosyncratic risk. This concept incorporates power structures and provides an additional pathway through which the impacts of risks may be critically seen to alter a contextual environment (see Leichenko & O'Brien's, 2008, "feedback double exposure" and "context double exposure" for additional types of feedback loops).

Next, I use the components, processes, and theoretical underpinnings depicted in this framework to structure and analyze idiosyncratic risks that have driven recent livelihood losses among smallholder farmers in an industrial-based rural development program in Northwest Costa Rica. With this case study I ask: Why are smallholder farmers, targeted by an industrial-based rural development program designed to spread risks evenly among all farmers, negatively impacted by risks from global changes while other more powerful farmers, presented with the same risks, profit? Then, I conclude by presenting the pathways through which idiosyncratic risks have emerged within Northwest Costa Rican agriculture.

4. Analysis of idiosyncratic risks in the Arenal-Tempisque Irrigation Project in Northwest Costa Rica

4.1 Case background

The Arenal-Tempisque Irrigation Project (*Projecto de Riego del Arenal-Tempisque*, PRAT) provides up to 5,616,000 m^3/day of water to farmers in the Tempisque River Basin from Lake Arenal in the east. Water is provided to users through a series of gravity-fed irrigation channels and aqueducts (Figure 3.2).

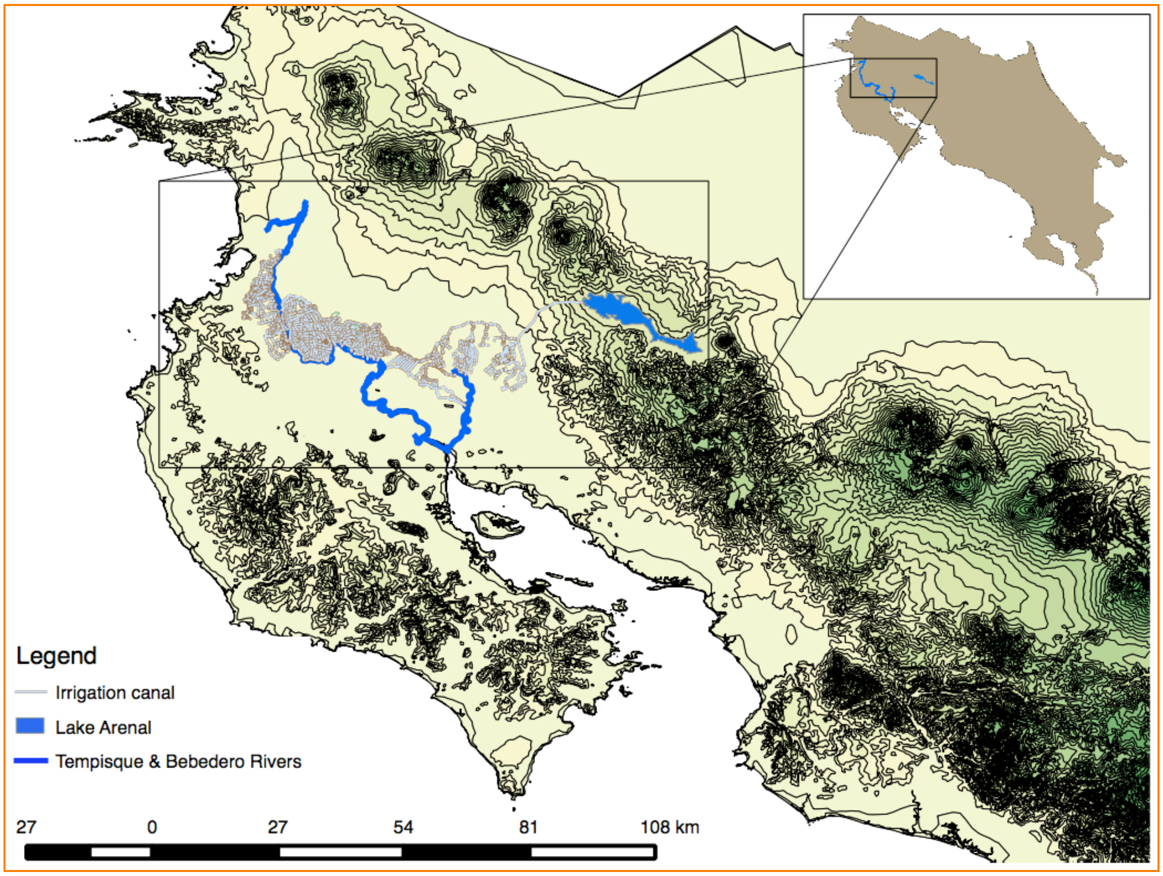


Figure 3.2 – Arenal-Tempisque Irrigation District (DRAT) topography, canal infrastructure, and Lake Arenal (irrigation water source)

The idea of irrigated agriculture in the semi-arid Tempisque River Basin dates back to the 1940s, but it did not become a reality until 1980, when the Inter-American Development Bank (IADB) extended a multi-million dollar loan to the Costa Rican government (Ballestero et al., 2007). Today, the PRAT irrigates approximately 28,000 ha. The PRAT is the largest irrigation-based rural development project in Central America. Over a 1,300 farms benefit from the project, generating over 20,000 jobs and income of approximately US$163 million annually (SENARA, 2013). The Agricultural Development Institute (*Instituto de Desarrollo Agrario*, IDA), Costa Rica's agrarian reform agency, provided 689 farms, averaging 7.2 ha each and totaling just less than 5,300 hectares (shown in Figure 3.3), to smallholder farmers through agrarian reform initiatives. The remaining 22,700 hectares in the PRAT were brought under irrigation through a series of public-private agreements requiring lands to be used "effectively" in exchange for irrigated water.

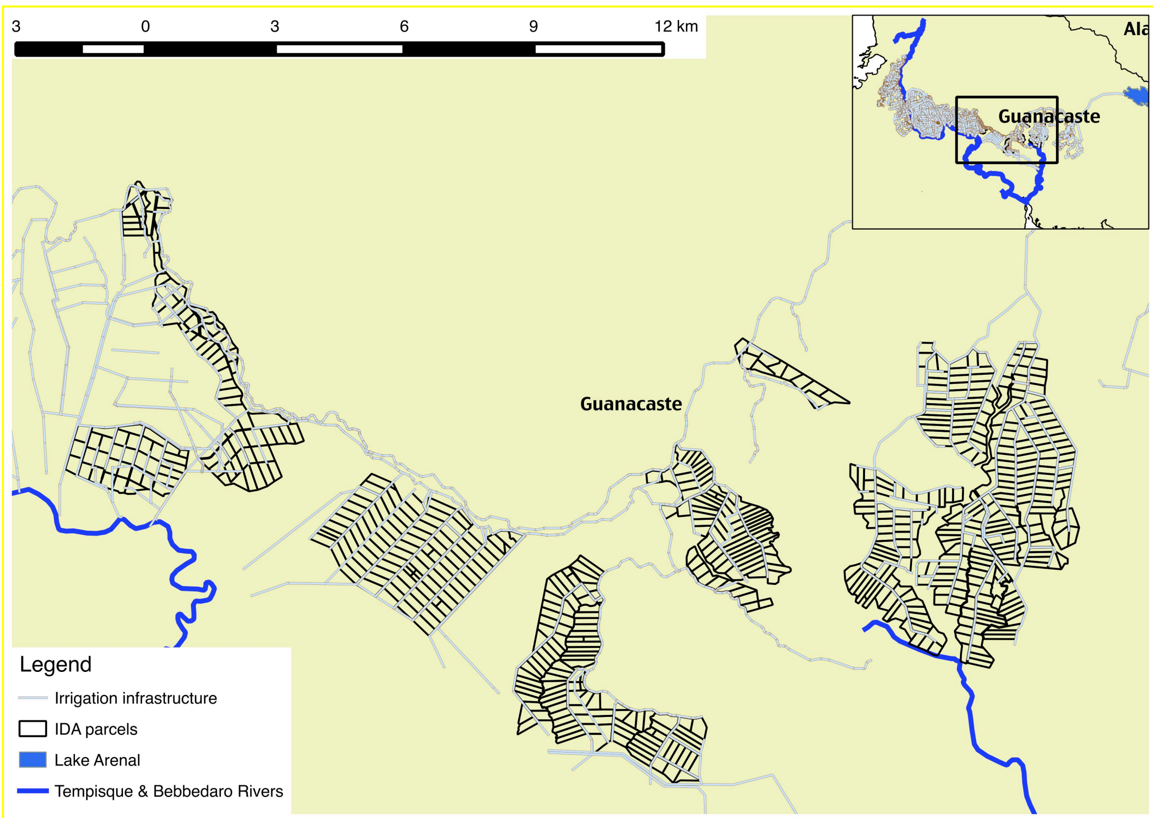


Figure 3.3 – IDA Parcels in the DRAT; parcels number 689 and account for approximately 25% of the total irrigated hectares shown in Figure 3.2.

The original intention of the PRAT was to provide smallholder farmers with plots of land and governmental extension services for support. The PRAT was to supply farmers with irrigation water during the dry season (November-March) to allow them to produce two rice crops per year (as opposed only one crop without irrigation), promoting higher yields. Market access was to be provided to smallholder farmers by agro-industrial companies relying on smallholder farms for production. These companies, funded in part and regulated by the state, were to provide post-crop processing capacities for smallholder farmers. While the original goals of the PRAT have not changed, the ability of the government and PRAT managers to meet those goals has changed. The Latin American debt crisis, beginning in the early 1980s triggered a restructuring of Costa Rica's political economy (see Edelman, 1992; Honey, 1994; Marois, 2005). Consequently, the government abandoned many of their pervious public-private partnerships in the PRAT in order to meet new demands from this economic restructuring and to placate financial support from international lenders (Edelman, 1999).

4.1.1 Current state of smallholder agriculture in the PRAT

Since the PRAT's inception, until the mid 2000s, rice was the crop of choice for smallholder farmers, and virtually all smallholder farmers in the PRAT grew rice (Arriagada, Sills, Pattanayak, Cubbage, & González, 2010). This reliance on rice production developed through the inability of the government to provide extension services or market access for any other type of crop (see Chapter 2), combined with the provision of abundant irrigation water that allowed smallholder farms to produce two to three rice crops per year in the semi-arid region. Sugarcane, the other widely grown crop in the PRAT, was historically produced in the PRAT by three industrialized sugarcane industries, that together control approximately 65% of Costa Rica's sugar milling capacity (LAICA, 2013). The three industrial farms are vertically integrated, and they own approximately 25% of the 28,000 irrigated hectares in the PRAT, and they control all sugarcane produced in the in the PRAT. In 2012, the area planted with sugarcane in the PRAT was estimated to be almost 15,000 hectares, of the 28,000 total hectares (SENARA, 2012). This area increased from 2011 after smallholder farmers who have traditionally grown rice switched to sugarcane production.

Between 2007 and 2012 hectares planted with rice in Costa Rica have increased by 40% as large producers increased rice production efforts to garner newly created government-rice subsidies. However, traditionally stable rice production among smallholder farmers in the PRAT followed an entirely opposite trend, in opposition to market signals. While rice production across Costa Rica was increasing by 40%, rice production among smallholder farmers decreased by almost 30%. Sugarcane now makes up this deficit. By switching from rice to sugarcane, smallholder farms in the PRAT also switch the mechanism by which they sell their harvests. Rice farmers operate independently from large rice mills. Most smallholder farmers secure contracts with rice mills to sell their harvests at a fixed price prior to planting. However, it has become increasingly difficult for smallholder farmers to secure contracts with rice mills. Many continue to plant rice without securing a contract, and then they search for a mill to sell their rice to post-planting. This has created increased competition among smallholder farmers.

Smallholder sugarcane producers operate differently from rice producers because planting, harvesting and processing of sugarcane is closely tied to one of the three sugar mills in the PRAT. Rice farmers typically manage every stage of rice production, while smallholder farmers who have switched to sugarcane production rely much more heavily on support from one of the three mills to plant, harvest, and process the sugarcane, the terms of which are specified in their production contracts. Over the past five years, sugarcane mills have been pushing full land management sugar contracts in an effort to bolster production. These contracts have been gained through the purchase of smallholder farmers' rice debts, which smallholder farmers accrue through failed rice crops or through the inability of a rice farmer to sell their harvest. The sugarcane mills then manage and farm smallholders' plots, and smallholder landowners receive a flat fee per hectare depending on their debt, but on average they receive approximately 150,000 *colones* (US$300 US) per hectare per year.

One successful rice harvest on a 10-hectare farm brings approximately US$33,000 as of 2012. Over 75% of their gross income covers input and milling costs, which provides smallholder farmers with a stable livelihood above Costa Rica's average gross national income of US$8,820 (World Bank, 2012). Ten-hectare smallholder farms in the PRAT average two harvests per year to profit just over US$16,000 per year (CONARROZ, 2012). When the same farmer is unable to sell a harvest, they lose US$2,679 per hectare (ibid). The inability to sell a 10-hectare rice harvest leaves farmers with a debt of over US$26,000 per harvest. In comparison, the production of sugarcane on the same 10-hectare parcel would pay, on average, US$3000 per year. This is one-fifth what they would gain through successful rice production. In sum, as more smallholder farmers switch to sugarcane, the original development goals of the PRAT are being undermined.

4.2 Research design

My research design was composed of three parts. First, I conducted a participatory rural appraisal (Chambers, 1994) to define possible drivers of change to smallholder rice production in the PRAT. Then, I tested for correlations between each hypothesized driver and changes in smallholder rice production using a linear regression model. This model was a critical element in this case study because it allowed me to determine which of the multiple, hypothesized drivers of change, determined in my participatory rural appraisal, predicted changes to the smallholder rice-farming sector. I was then able to focus on and analyze those drivers of change. I did this by examining the underlying processes that explained the statistical correlations using a *process tracing* case study analysis (Bennet, 2010; George & Bennet, 2004), also called *explanation building* (Yin, 2014). I structured this analysis using the framework shown in Figure 3.1.

4.3 Data collection

A qualitative participatory rural appraisal (Chambers, 1994) was used to define potential drivers of change among smallholder farms in the PRAT. The appraisal consisted of two-multiday workshops with researchers, farmers, and PRAT managers. The first workshop, entitled "Coordinating sustainability science research in the Rio Tempisque Basin," was held on August 14th and 15th, 2010 in Palo Verde National Park, Guanacaste, Costa Rica. Attendees included 10 total researchers and farmers from multiple research organizations including CATIE, the Organization for Tropical Studies, and Arizona State University; all were engaged in sustainability research in the region. PRAT-sustainability problems raised throughout this workshop included (1) smallholder rice farmers are demanding more water, but the PRAT has been operating under scarcity since 2006, (2) smallholder farmers are increasingly selling and renting their lands to large-scale sugarcane companies to escape both agriculture and the debts accrued through rice production, and (3) smallholder rice farmers are losing access to the regional rice market due to changing regulations brought about by CAFTA-DR.

The second workshop, entitled "Guanacaste collaborative workshop on water governance," was held on March 14th, 2013 at the National University of Costa Rica, Nicoya, Costa Rica. Forty-six total workshop participants included representatives from 11 rural water administrations (*ASADAs*), farmers, agricultural water managers, and local water-environmental non-governmental organizations. Participants, including irrigation and agricultural managers, overwhelmingly agreed with farmers that a strong smallholder-farming sector is in Costa Rica's best interest, but that the challenge was determining how water should be managed to support smallholder farming. Participants agreed that water scarcity was heavily impacting agriculture in a negative way. See Kuzdas, Yglesias, & Warner (2013) for a detailed summary of workshop findings.

I reviewed findings about drivers of change and smallholder farm outcomes from each workshop and clustered my findings into like themes. To do this, I followed the coding and clustering methodology described by Yin (2014). Next, I collected data from multiple sources to create measurable variables based on each theme. These variables are shown in Table 3.1 as clustered according to the framework depicted in Figure 3.1.

Table 3.1 – Data type and collection summary

Framework components	**Variable code**	**Variable**	**Justification**	**Type/Units**	**Sources**
Climate Change	CC1	Average irrigation water deficit during rice planting	Represents climate change risk and water policy efficacy	Cubic meters per second	SENARA database access (SENARA, 2012)
	CC2	Yearly total rainfall in Tempisque River Basin	Represents risk from changes in climate and weather	Millimeters/ Year	*Instituto Mete orológico Nac ional* database access /Organization for Tropical Studies database access (IMN, 2006; OTS, 2014)
Globalizatio n	G1	Total rice planted in	Indicates changes in	Hectares	CONARROZ database

		Costa Rica from 1993 – 2012	political protection from imports, and expectation demand		access (CONARROZ, 2006 – 2013)
	G2	Total rice imported into Costa Rica between 1993 – 2012	Indicates changes in the demand for domestically grown rice	Metric tonnes	CONARROZ database access (CONARROZ, 2006 – 2013)
	G3	Average price paid to farmer for harvest from one hectare of rice	Indicates farmers' incentive to grow rice	U.S. dollars	CONARROZ database access (CONARROZ, 2006 – 2013)
	G4	Average price paid	Indicates farmers'	U.S. dollars	LAICA database

		to farmer for harvest from one hectare of sugarcane	incentive to grow sugarcane		access (LAICA, 2010, 2013)
Industrial rice farm responses	IF1	Number of rice mills in Guanacaste	Indicates vertical integration and consolidation of large rice farmers	Amount	Arroyo, Lucke, & Riveara, 2013, & CONARROZ database access (CONARROZ, 2006 – 2013)
Smallholder rice farm outcomes*	SF1	Total rice smallholder rice harvest from 1993 – 2012, includes up to three plantings	Reflects smallholder rice production between 1993 and 2012	Metric tonnes	Arroyo, Lucke, & Riveara, 2013, & CONARROZ database access (CONARROZ

		per farm per year**			, 2006 – 2013)

**Indicates dependent variable in statistical regression model

*Smallholder farms were represented in this data as those that grew rice or sugarcane on IDA plots ranging from 1.8 hectares to 50 hectares.

4.4 Data analysis

SPSS (IBM, 2013) was used for my quantitative data analysis. I used standard linear regression to identify correlations between globalization, global changes, and LSCF responses (all independent variables), and smallholder farmers' rice harvest in PRAT from 1993 to 2012 (dependent variable). All data was transformed into yearly averages, and then to avoid problems of 'random walk' and spurious regression I differenced my data across time beginning with the first time-step in 1993, and specified my regression in terms of these variations. By doing this, I explained changes in smallholder rice harvests on changes in the hypothesized drivers.

Before conducting the regression, I checked for and found no violations of the assumptions of normality, multicollinearity, and homoscedasticity among the variables. All variables were continuous and linearity was assumed. Then, significant correlations, as determined by the results of the standard linear regression, were qualitatively evaluated using the assumed causal links depicted in the framework in Figure 3.1. Finally, pathways (defined as a series of causal links) through which risks produced outcomes in my case were traced using the process tracing method described by Yin (2014, p149). I relied on multiple sources and types of data, described in Table 3.1, to trace the causal links in each pathway. I continued to collect evidence until multiple sources corroborated each causal link.

5. Results

Variables included in my linear regression model are shown in Table 3.2, and each was hypothesized to be a likely cause of livelihood losses among smallholder farmers during my rapid rural appraisal. Variables represent changes in climate (CC1 and CC2), changes in crop markets (G1, G2, G3, and G4) and LSCFs' responses to changes in crop markets (LR1).

Table 3.2 – Independent variables hypothesized to influence changes in smallholder rice harvests in the PRAT used in linear regression model, N=20

						Percentiles		
Variable	**Unit**	**Mean**	**Range**	**Min**	**Max**	**25**	**50**	**75**
YEAR	-	-	-	1993	2012	-	-	-
CC1	m^3/s	2	11	0	11	0	0	4
CC2	mm	1,430	1,750	714	2,464	1,088	1,243	1,773
G1	Hect-ares	57,639	40,149	40,967	81,116	49,800	56,256	66,071
G2	m tons	165,819	182,340	51,268	233,608	80,291	224,150	230,830
G3	U.S.	1,484	2,534	532	3,066	841	1,271	2003

	$							
G4	U.S. $	3,077	1,453	2,206	3,659	3,010	3,115	3,357
LR1	No.	9	6	5	11	6	11	11

The total smallholder rice harvest in the PRAT was used to indicate changes in smallholder rice production. This trend is shown in Figure 3.4 along with the total harvest in Costa Rica during the same time period. It was assumed all smallholder farms that dropped out of rice production during this time period transferred to sugarcane production (SENARA, 2012).

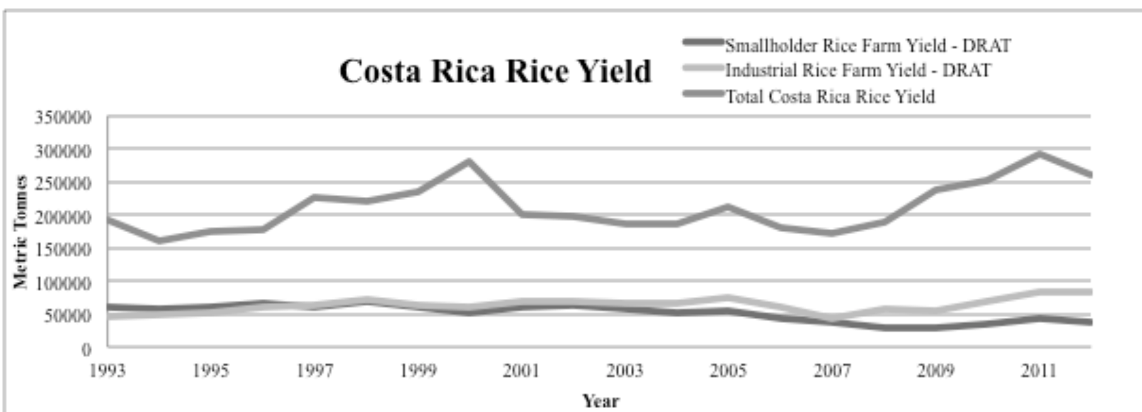


Figure 3.4 – Domestic rice harvest in Costa Rica (Arroyo et al., 2013; CONARROZ, 2007, 2008, 2009, 2010, 2011, 2012); this data is the summed total of up to three rice harvests per year per farm in the DRAT; smallholders in the PRAT typically grow two crops per year, and some grow three, and this is reflected in this figure, and it represents the dependent variable (SF1) in my regression.

The results of my linear regression model, provided in Table 3.3, show that the number of rice mills in the PRAT and the average irrigation water deficit during rice planting are significantly correlated with reductions in smallholder farmers' rice harvests from 1993 to 2012. Smallholder farmer rice harvest reduction is a function of (1) farmers switching to sugarcane production, (2) farmers voluntarily reducing their rice harvests, and (3) involuntary rice-yield reductions caused by water scarcity. Through my rapid rural appraisal, these three components were determined to be the primary outcomes that were driving smallholder farmer livelihood losses in the PRAT. These results show that a one-unit decrease in the number of rice mills in the PRAT is correlated with a decrease in smallholder rice production of 2,688 metric tonnes. Similarly, a one-unit increase in the average irrigation water deficit during rice planting (i.e. total water deficit during the months of December and January in m/s3, averaged over that time) is correlated with a reduction in smallholder rice yield of 1,293 metric tonnes.

Table 3.3 – Results of linear regression modeling

Variable	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
CC1	-1293.4	500.997	-0.42	-2.58	0.02**
CC2	2.533	1.879	0.107	1.348	0.203
G1	-0.036	0.04	-0.11	-0.91	0.379
G2	-0.042	0.03	-0.25	-1.37	0.193
G3	0.399	4.844	0.025	0.082	0.936

G4	-4.135	5.35	-0.13	-0.77	0.455
LR1	2688.27	1294.225	0.471	2.077	0.06*

Dependent Variable: SR3; R Square: 0.93, Adjusted R Square: 0.90

**Significant at the 0.05 level

*Significant at the 0.10 level

6. Discussion

6.1 Exploration of effect of rice mill consolidation on smallholder rice farming

In the early 2000s, almost all smallholder farmers in the PRAT produced rice. Therefore, they were very exposed to any changes in Costa Rica's rice-policy responses. In 2002, threats of international trade liberalization, specifically the pending ratification of the "Dominican Republic – Central America Free Trade Agreement" (CAFTA-DR) drew attention by nationally and internationally owned industrial rice farms in the PRAT to vulnerabilities in Costa Rica's rice sector (Frajman, 2012). Both industrial rice producers and *arrozarias* (i.e. industrialized rice mills) in the PRAT lobbied San Jose and argued that Costa Rica should keep its tariff protection for rice imports intact, thereby supporting domestic producers (Monge-González, Rivera, & Rosales-Tijerino, 2010). However, current rice production in Costa Rica was not able to meet the increasing consumption demands. So, on May 23, 2002, CONARROZ was created (Law 8285) as a publicly funded, privately operated hedge fund, managed by a board that included in its entirety representatives from industrial rice farms and *arrozarias*. CONARROZ was granted the exclusive right to import rice into Costa Rica with zero tariffs. A right given to the board under the assumption that CONARROZ would import rice only when it was required to meet national demand.

Since 2002 rice imports by CONARROZ have increased, which is the result of lower international prices (Monge-González et al., 2010), compared to Costa Rica's high fixed rice prices. Rice on the world market is consistently and considerably less expensive than domestically produced rice due to the production efficiency of rice produced in the USA, China, and Thailand (Arroyo et al., 2013). From 2005-2012, approximately 40% of rice consumed in Costa Rica was imported (Arroyo et al., 2013). CONARROZ sells the imported rice to the *arrozarias* (that smallholder farmers attempt to sell their rice to), which also transfers the zero-tariff-based rents, based on a performance clause in Law 8285 (CONARROZ) that dictates that imported rice will be distributed to industrial mills and producers based on the amount of domestically produced rice they have acquired. This initiated a rapid consolidation and vertical integration of industrial rice producers and *arrozarias*. This in turn has displaced smallholder farmers from the rice market because mills no longer need to buy smallholder farmers' rice harvests. This trend was most significant in the Tempisque River Basin, which grows 45% of the country's rice (CONARROZ, 2012). Large mills and industrial rice producers in the PRAT have been able to gain significant economic rents through consolidation. In 2001, there were 11 *arrozarias* operating in the PRAT (Arroyo et al., 2013). In 2012 there were 5 (CONARROZ, 2012). The larger the mill, the more inexpensive, tariff-free rice they obtain and sell to the domestic market at prices equivalent to the more expensive, domestically produced, smallholder rice.

The economic rents won through the concentration of industrial rice producers and rice mills allowed for even more drastic vertical integration, which in turn brought more tariff-free rice into the PRAT. This process has helped extricate smallholder rice farmers from rice production – for each mill-consolidation in the PRAT, 2,688 metric tonnes of smallholder-produced rice is extricated from the domestic market. As of 2013, two types of rice producers exist in the Tempisque River Basin: (1) non-integrated and independent smallholder producers, with no guarantees that their rice harvests will be purchased; and (2) integrated agribusinesses who purchase imported rice from CONARROZ and supplement their supply with domestic harvests, first from their production, and then through contracts with smaller farmers. Faced with mounting debts due to their inability to sell their rice, smallholder farmers have voluntarily reduced their rice plantings or transitioned to less lucrative, but in some ways more secure sugarcane production. Netting (1998) argues that security, not profit, often motivates farmer's decisions about risk management. This may be the case among some smallholder farmers in the PRAT.

6.1.1 Idiosyncratic risks from globalization

In agriculture in general, globalization includes multiple, simultaneously occurring processes: 1) Changes in demand for different types of crops; 2) redistribution of power and profit among farmers engaged in global crop production systems; and; 3) transformations of resources and labor across scales (Leichenko & O'Brien, 2008). In the PRAT, one type of agricultural globalization initiated these processes: Trade liberalization. Trade liberalization refers to the reduction of tariffs on and barriers to agricultural trade, to the corresponding reductions in state agricultural subsidies and institutional support (Kennedy & Koo, 2002), and to the restructuring of state support that often entails “reworking” this support in ways that are less visible in the market (Eakin, 2014).

In Costa Rica, the threats of liberalized trade have caused politically powerful farmers to change the national crop production and agricultural business policies, which I have shown has produced uneven gains among farmers in the PRAT. It was not trade liberalization itself that drove these changes, as has been the case in agriculture in many other sectors throughout Latin America. Rather, large mills and farms, in response to threats of trade liberalization, rigged the game so that the domestic rice market was protected while also capturing the rents of lower priced imports, rather than passing those rents on to other Costa Rican farmers and consumers. In this case, those with political power rigged liberalization processes. A reduction in smallholder farmer rice-market access is the idiosyncratic risk that was created through the adaptations of more politically powerful industrial farms.

6.2 Effect of irrigation water deficit on smallholder rice farming

At the start of the New Year in 2013, the PRAT experienced its largest irrigation water shortfall to date due to unprecedented drought through the previous summer’s rainy season (May-November). Water shortages throughout the PRAT primarily occur during the dry season from November to January due to the high water demand resulting from the new season’s rice and sugarcane plantings. The system operated under scarcity for the first time September 2006, and because there was no precedent for water scarcity in the

PRAT, no allocation plan existed. The PRAT water management agency, SENARA (*Servicio Nacional de Aguas Subterráneas Riego y Avenamiento*), devised a plan to irrigate by sector on a rotating cycle in an attempt to provide farmers with enough water to plant without yield reductions. The water managers informed farmers that irrigation would be provided in 'shifts' by sector regardless of farmers' requests for water. SENARA then alternated irrigation allocations between sectors on a weekly alternating basis until the rice planting was completed and demand reduced. Within this scheme, even though some are forced to wait to plant, all farmers should receive ample water to plant, and then harvest prior to the next rainy season.

SENARA allocates water in times of scarcity on the basis of farmer equality, regardless of crop type or farm size. SENARA only has the power to cycle irrigation to manage scarcity and prevent yield losses. This allocation strategy has delayed smallholder farmers' rice plantings up to one month, in some years. While water cycling doesn't directly affect yields at harvest, it does limit the ability of smallholder farmers to sell their harvests to increasingly vertically integrated mills. Because mills no longer need to rely heavily on smallholder rice harvests, they have increasingly shortened the window of time in which they buy non-contract rice from smallholders. This rice is purchased by mills early in the harvest season on a 'first-come first-served' basis. Delayed water allocations, delay smallholder harvests. This, in combination with limited access to the rice market during harvest, has forced farmers to fight for water, and has caused water piracy throughout the PRAT. This process has created water scarcity for many smallholders.

Smallholder farmers in the PRAT illegally modify irrigation infrastructure to gain early access to water allocations so they can plant and harvest as early in the season as possible. Many farmers furthest down stream plant rice but then lose their water access as a result of the actions of upstream farmers, and therefore many farmers have been forced to abandon rice crops. Water scarcity and the subsequent conflict among smallholder farmers can be attributed to the adaptations of more powerful rice farmers to the threat of trade liberalization. Those farmers in the PRAT without illegal access to alternative water sources lose both their crop harvests and their access to the market. This redistribution of wealth and global change risk has undermined the development goals of the PRAT. In December of 2012, the situation reached a boiling point resulting in death threats to SENARA employees and upstream farmers, and the attempted murder of a SENARA employee who confronted a farmer about illegal water access. Ultimately many farmers furthest downstream have been forced to abandon their rice harvests and transition to sugarcane production since 2006.

6.2.1 Idiosyncratic risks from Climate Change

All farmers in the PRAT rely on water distribution infrastructure for irrigated crop production due to the region's semi-arid climate. Drought, while well managed by SENARA, has nonetheless resulted in water scarcity for some farmers. The power to alter water access was in the hands of upstream farmers, who were able to manipulate irrigation infrastructure to plant and harvest their rice crops before the purchasing windows at *arrozarias* closed. Interestingly, if *arrozarias* did not gain access to the rents from the import of tariff-free rice, they would still rely almost entirely on rice supplies from smallholder rice farmers. Increasing drought would have likely had negligible affects on smallholder farmers' livelihoods because SENARA's water cycling scheme would provide all farmers with enough water to successfully produce rice each season. Smallholders would have had no incentive to plant and harvest before their neighbors. However, because CONARROZ now imports rice, *arrozarias* only purchase smallholder harvests if they have production and storage capacity that has not been met through imports or vertical integration. Farmers who are able to harvest their rice early in each harvest season have the best chance of selling their harvests. This interaction of systemic stressors has created new idiosyncratic risks that have caused many downstream farmers to lose rice harvests and suffer livelihood losses.

6.3 Pathways of idiosyncratic risks: lessons from the PRAT

The production processes of some idiosyncratic risks in industrial-based development programs may appear to be easily understood, which means the cause for the risk appears to be known, the negative consequences seem to be obvious, and the uncertainty about the risk's origins seems to be low. The example of upstream farmers limiting water availability to downstream farmers in the PRAT appears, at first, to be relatively simple from a political economic perspective: Upstream farmers have the power to manipulate irrigation infrastructure to meet their own need in the face of drought, and so they do so. However, I have shown that the actual pathway through which water scarcity emerges in the PRAT can only be understood by analyzing the relationship between regional drought and trade liberalization. This added complexity from the interaction of these two systemic risks reduces the ability of water managers in the PRAT to address the root causes of this idiosyncratic risk because they only have the authority to combat livelihood losses through water allocation; they have no control over smallholder farmers market access. The passage of CONARROZ in response to threats of Costa Rican trade liberalization also generated uncertainty among smallholder farmers about the future of rice production in the PRAT. I consider this to be a second idiosyncratic risk to smallholder farmers. This uncertainty, while difficult to quantify, requires a deeper understanding of a region's political economy.

Reflecting on this case study, and on my theoretical framing of idiosyncratic risks, I posit there are four interacting pathways through which idiosyncratic risks may develop that must be assessed simultaneously to understand the actual impacts of systemic risks on industrial-based rural development programs:

1. *Amplification of exposure to impacts* – farmer responses to systemic risks can amplify systemic risk exposure for others. For example, as drought increased, farmers upstream in the PRAT were able to manipulate infrastructure and shirk allocation institutions in order to gain access to scarce water; this left downstream farmers with less water. While drought was not the only driver of water scarcity in the PRAT, the adaptations of upstream farmers ultimately amplified the impacts of drought on downstream farmers.
2. *Increasing sensitivity to impacts* – farmer responses to systemic risks can increase the sensitivity of other farmers to impacts by modifying the biophysical or institutional context of a development program. Most development programs provide some buffer between global risks and their local impacts through, for example, resource provisioning at subsidized rates or crop insurance programs.

Farmers can respond to the threat or impacts of risks by manipulating a development program's context to further buffer themselves from impacts. However, this process may leave other farmers more sensitive to the impacts of systemic risks.

3. *Reducing adaptive capacity* – Some farmer reactions to systemic risks can directly limit the adaptive capacity and adaptation options of other groups. For example, in the PRAT, farmers with the financial means to install wells have done so as an adaptation to drought. Many neighboring farmers without the capacity to drill wells have adapted by drawing water from rivers and streams to supplement water supplies, given they have access to surface water. Through time, increasing drought combined with water tables being drawn down by well extractions may limit surface water availability. This risk is a common worry among smallholder farmers in the PRAT with access to surface water.
4. *Redirecting impacts* –some farmers can redirect or deflect the impacts of global risks onto others. This type of idiosyncratic risk often occurs prior to impacts. Those groups with access to information can deliberately take advantage of the uncertainty of others. The passing of CONARROZ in response to threats of Costa Rican trade liberalization illustrates this pathway from my case study. Industrial rice farms were able to protect themselves from an influx of inexpensive rice by manipulating Costa Rica's rice policy and unintentionally redirecting the impacts of trade liberalization onto smallholder farmers.

These pathways begin with overlapping global change (e.g., drought) and globalization (e.g., trade liberalization) processes that individually affect rural development, posing interacting, systemic risks. Farmers within the PRAT – an industrial-based development system – were exposed in different ways to the impacts from these systemic risks. Large industrial farms and mills, controlling rice-market access for everyone, responded to risks of trade liberalization in anticipation its impacts, and maneuvered politically to alter Costa Rican rice-market policies to gain substantial economic rents. The outcomes of this adaptation fed back and changed the status quo for smallholder rice farmers – this produced an idiosyncratic risk. Industrial farms redirected the impacts of trade liberalization and acted to profit from their adaptation. Smallholder farmers lost access to the domestic rice market, and in turn, were forced to fight for water to plant early to gain the little-remaining market access. This produced water scarcity for the most vulnerable farmers in the PRAT.

This study of idiosyncratic risks in the PRAT provides an example of the utility of the concept in understanding multiple and interacting pathways through which idiosyncratic risks may emerge by focusing researchers and practitioners on the variables necessary to understand how the interdependencies among farmers may create vulnerabilities for some groups. This application shows the insights gained from my proposed framing of idiosyncratic risks, as opposed to current paradigms that may only focus on systemic risks to development projects, provides new and useful information on the particular risks faced by the most vulnerable.

7. Conclusion

We have long known that many smallholder farm-based communities in developing regions can be characterized as complex, diverse and risk-prone, and that they are often plagued by persistent poverty, limited access to resources, and environmental degradation (Chambers, Pacey, & Thrupp, 1989). Agro-industrialization programs are one category of solutions to these rural development problems that has proven effective among diverse smallholder farm-based economies. These industrial-based development projects link agricultural supply chains between smallholder farmers and larger commercialized farms to increase production efficiency and access to markets, thereby bolstering rural livelihoods. These projects may also advance the use of agro-technologies with the aim of increasing the resilience of all farmers to climate hazards. However, industrial-based rural development may also produce unique, or idiosyncratic risks to the rural poor, as I have shown in the case of the industrial-based PRAT. These risks may emerge from industrial-agriculture responses to globalization and climate change that calls into question the ability of agro-industries to promote rural development and poverty-fighting strategies in the face of global changes.

Increasingly, uncertainties about change are key features of rural development programs. The capacity of the poor and vulnerable to cope with and adapt to idiosyncratic risks is at the core of a changing role for rural development, and it inextricably links the capacity of less powerful players to successfully adapt within the context of larger rural development programs. Through this lens, rural development programs are required to conceptualize the production of risks as a product of the interaction between global changes and the feedbacks produced by different groups' adaptations to these risks within the rural development context. As industrial-based rural development programs expand with the support of UNIDO, we must be cognizant of new risks to the rural poor that can emerge from the adaptations of different groups to systemic risks. I presented the new concept of idiosyncratic risk, and demonstrated the efficacy of this concept by applying it to the current situation in the Guanacaste agricultural region of Costa Rica. I suggest that future research should compare case studies of industrial-based rural development programs across LDCs to refine and better define our theoretical understanding of the origins, implications, and pathways of idiosyncratic risks. We must better understand how and what types of policy interventions should be used to manage the pathways through which idiosyncratic risks in rural development programs emerge, in order to promote the goals of increasing living standards, and equitable distribution of resources, benefits, and risks.

CHAPTER 4

ADAPTING TO INTERACTING GLOBAL CHANGE RISKS: DETERMINANTS OF ADAPTATION LIMITS AMONG NORTHWEST COSTA RICAN SMALLHOLDER RICE PRODUCERS

1. Introduction

Multiple types of global change processes increasingly impact rural development programs in arid and semi-arid areas; these include regional drought and changes in international crop markets and trade liberalization policies, among others. The interplay between these processes can impact rural livelihoods in unforeseen and surprising ways (Leichenko, Brien, & Solecki, 2010; Leichenko & O'Brien, 2008; O'Brien & Leichenko, 2000). The study of climate change induced drought, or the study of impacts of global economic changes on rural livelihoods by themselves may not account for the dynamic interrelations and feedbacks between these global change processes. In order to promote the sustainability of rural development in arid and semi-arid regions, we must begin to systemically address these global changes, and focus on outcomes of these processes at the local scale (Morton, 2007). Global change scientists have studied how these changes can transfer among spatial scales (Turner et al., 1990), and how they increase the vulnerability of the poor (Turner et al., 2003). Here, I study how global changes can and do interact to increase the vulnerability of the poor, and then force households to confront adaptation limits beyond which they may no longer meet valued livelihood goals, and therefore are forced to live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss.

Recent research and understanding about adaptation limits in rural areas provides a working framework to address the impacts of climate changes on local smallholder farm populations (Dow, Berkhout, & Preston, 2013; Martin, Müller, Linstädter, & Frank, 2013; McDowell & Hess, 2012). Research on the determinants of adaptive capacity has shown that the household socio-economic context often dictates differences in the outcomes of climate change impacts at the local scale (Below et al., 2012). These contexts dictate the specific adaptation limits of households throughout lesser-developed countries (Dow, Berkhout, Preston, et al., 2013). To date, much of this research has focused on the impacts of and adaptations to climate change, and more commonly climate change induced drought. However, smallholder farming communities often face and interact with multiple risks simultaneously, and the outcomes of the impacts of these risks vary among individual households (Morton, 2007). Some are forced to cope, only to become more vulnerable to future impacts and move closer to adaptation limits, while others are able to better manage the impacts of multiple global change risks by pursuing new opportunities.

In this research, I seek to understand how socio-economic determinants of adaptive capacity among smallholder farmers in Northwest Costa Rica determine their ability to meet valued livelihood goals in the face of the impacts of multiple global change risks. I analyze the significance of household-level socio-economic variables to farm adaptations to the impacts of two interacting global change risks. I focus on those adaptations that represent an adaptation limit, indicated by a forced livelihood transformation, and on those determinants that are more or less likely to make some farmers confront an adaptation limit. I discuss the trade-offs between determinants that may make farmers less vulnerable to one type of risk, but more vulnerable to another. Specifically I ask: How do socio-economic determinants of adaptive capacity among smallholder farmers in Northwest Costa Rica determine their ability to avoid adaptation limits in the face of the impacts of multiple global change risks?

My research approach follows Morton's (2007) ontological framework, that dictates that research on smallholder farm adaptations and vulnerabilities should (1) recognize the complexity and location specificity of production systems and (2) incorporate both climate and non-climate stressors on rural livelihoods and their contributions to vulnerability. The Arenal-Tempisque Irrigation Project (*Projecto de Riego del Arenal-Tempisque*, PRAT) in Guanacaste, Costa Rica, my chosen case study, has been heavily impacted by drought and trade liberalization. These interacting global changes have caused many smallholder farmers to cope and ultimately to confront adaptation limits, indicated by their abandonment of valued livelihood pursuits.

In this paper, I first describe my theoretical framework, which builds off Morton's (2007) work by incorporating insights from recent studies of the impacts of multiple, interacting global changes on rural livelihoods in less-developed countries (LDCs). I then describe my case study and data collection methods that included workshops, focus groups, and household surveys and interviews. Finally, I report the results of my analysis and discuss their significance in the context of the Arenal-Tempisque Irrigation Project and the body of research on the determinants of adaptation and vulnerability among smallholder farmers.

2. Theoretical framework

Morton's (2007) ontological framework underlies the theoretical framework used in this study. I build on this work by integrating recent research that has considered how groups or individuals adapt to the impacts of global change processes, which include changes in both the economy and the climate (Adger, Eakin, & Winkels, 2009; Christoplos, 2010; Eakin, Winkels, & Sendzimir, 2009; Eakin, 2003, 2005; S. Eriksen & Silva, 2009; R. M. Leichenko, Brien, & Solecki, 2010; R. Leichenko & O'Brien, 2008; Neil Adger, 1999; O'Brien & Leichenko, 2000; O'Brien, Quinlan, & Ziervogel, 2009). I focused on rural smallholder farming households in the Arenal-Tempisque Irrigation Project (*Projecto de Riego del Arenal-Tempisque*, PRAT), and conceptualized global change processes as impacting vulnerable farmers in different ways, resulting in determinate outcomes for rural households. These outcomes depend on household exposure and sensitivity to an impact, and on whether and how households can and do adapt; exposure represents the condition of being impacted (Leichenko & O'Brien, 2008). Farmer vulnerability is also determined by sensitivity and exposure to global change impacts. For the purposes of this study, I define vulnerability as the degree to which an individual or group may be impacted adversely by the consequences, or the potential consequences, of global change risks (Eriksen & O'Brien, 2007; Eriksen et al., 2011).

I define adaptations as livelihood responses to observed or expected global change risks—their effects and impacts—in order to alleviate adverse impacts of change or take advantage of new opportunities (Adger, Arnell, & Tompkins, 2005; IPCC, 2001). These adaptations, including coping measures, can be taken either in anticipation of or following from exposure. Marshall & Marshall (2007) show these adaptations are a function of (1) a farmer's perception of risk associated with change, (2) the ability of a farmer to change, (3) their proximity to adaptation limits (i.e., the point at which a farmer is forced to give up valued livelihood goals) and (4) the level of interest in change.

I distinguish coping mechanisms as specific to a type of adaptation practice (UNDP, 2005). I define coping mechanisms as adaptations taken by farmers that diminish their ability to meet valued livelihood goals in the face of future impacts (Smit & Wandel, 2006). As farmers cope with global change impacts, their proximity to adaptation limits changes, as do their perceptions of risks and their ability to continue coping. Adaptation limits represent thresholds beyond which farmers can no longer adapt or cope with the impacts of global change risks to meet existing valued livelihood goals. As risks associated with global changes increase toward these thresholds, risks to valued objectives may become intolerable, at which point farmers must either live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss (Dow, Berkhout, & Preston, 2013). Research on farmer responses to global change impacts shows that repeated or prolonged coping can reduce their capacity to cope and thereby force farmers past these limits, beyond which they cannot recover (Jones, 2001; Roncoli, Ingram, & Kirshen, 2001).

Farmer livelihood goals are critical within this theoretical framework. Smallholder farmer adaptations to global changes that result in their ability to better meet valued goals are considered successful within this context. These successful adaptations are a function of their ability to pursue new opportunities and to utilize adaptive capacity to reduce their sensitivity and exposure to the impacts of global change risks. The ability of a farmer to modify their vulnerability to the impacts of global change risks to meet valued livelihood goals depends on their capacity to adapt; this is dependent on the underlying socio-economic context and on the larger political economy (Cohen, Demeritt, Robinson, & Rothman, 1998; Klein et al., 2007; Yohe et al., 2007).

Some farmers have the capacity to incrementally adapt to the impacts of global change risks without limiting their ability to adapt to future impacts; they may pursue opportunities that may distance them from adaptation limits. Others may only have, or they may only utilize, their capacities to adapt to the same risks by coping; this may make them more vulnerable and more likely to confront adaptation limits in the future. Livelihood transformations, or transformative adaptations, at adaptation limits may be necessary as the final response taken by some households to escape the impacts of current risks to current livelihood goals. Adaptation limits represent thresholds beyond individuals and groups can no longer adapt or cope with the impacts of global change risks to meet existing valued livelihood goals (Dow, Berkhout, & Preston, 2013). As risks associated with global changes increase toward these thresholds, risks to valued objectives may become intolerable. At this point, one must live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss.

For the most vulnerable in less-developed countries (LDC), perceptions of rural individuals about the efficacy of transformation and adaptation capacities may be closely linked to their ability to manage adaptation limits and avoid devolution into long-term poverty. Following this logic, the determinants of adaptation limits may provide insight into farmer vulnerabilities that can be addressed in rural development programs to better allow farmers to meet valued livelihood goals in the face of global change risks. However, the same socio-economic determinants of successful adaptation to one type of impact may increase farmer vulnerability to another type. This interplay is not well understood in many rural development programs, but it is critical to their success in the face of interacting global change risks.

3. Research site and design

3.1 Research site

The Arenal-Tempisque Irrigation Project (*Projecto de Riego del Arenal-Tempisque*, PRAT) in Guanacaste, Costa Rica provides up to 5,616,000 m^3/day of water to farmers in the Tempisque River Valley from Lake Arenal to the east (Figure 4.1). Water provision occurs through a series of irrigation channels and aqueducts. A series of expansions between 1983 and 2006 have increased the PRAT's size to just over 28,000 hectares of irrigated land in 2014. The PRAT is the largest irrigation system in Central America, and the largest rural development project in Costa Rica (Ballestero et al., 2007). Roughly 1125 farms benefit from the project, generating over 20,000 jobs (~40% are seasonal) and income of approximately US$163 million annually (SENARA, 2013). The Agricultural Development Institute of Costa Rica (*Instituto de Desarrollo Agrario*, IDA) transferred at no cost, or at greatly reduced cost, over 600 of those farms, totaling just under 5,300 hectares, to smallholder farmers through the agrarian reform initiatives of the PRAT between 1983 and 2006. The remaining 22,700 hectares were brought under irrigation through a series of public-private agreements requiring lands to be used "effectively" in exchange for subsidized water.

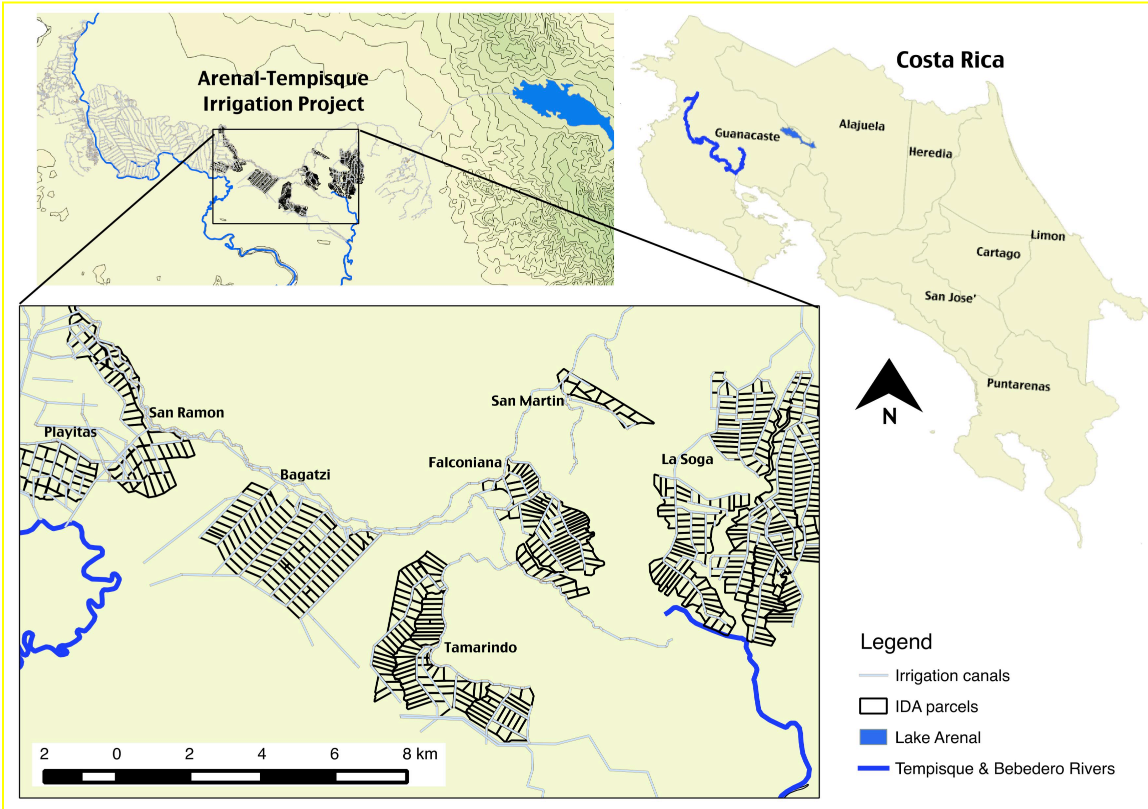


Figure 4.1 – Arenal-Tempisque Irrigation Project within the Tempisque River Basin in Guanacaste, Costa Rica; this map shows topography, PRAT canal infrastructure, and IDA parcels.

The original goals of the PRAT were (1) to take advantage of the waters discharged by the hydroelectric dam at Lake Arenal; (2) to improve living conditions in the semi-arid Tempisque River Valley by generating agro-employment, redistributing land from large land owners to smallholder farmers, and changing cropping systems; and (3) to promote integrated regional development with complementary smallholder and agro-industrial sectors. To reach these goals, the government provided smallholder farmers with parcels of land ranging in size from one to 12 hectares, and then the PRAT was to supply these parcels with irrigation water during the dry season (November-March). Market access was to be provided to smallholder farmers by agro-industries who relied on smallholder farms for the production of rice.

While these original goals of the PRAT never changed, the government's capacity to successfully implement them did change. The Latin American debt crisis, beginning in the early 1980s brought a restructuring of Costa Rica's economy, and along with it a restructuring of its agrarian institutions (see Edelman, 1992; Honey, 1994; Marois, 2005). The Costa Rican government abandoned many of its public-private partnerships in the PRAT in order to meet the economic restructuring demands of the International Monetary Fund, the World Bank, U.S.AID, and the Inter-American Development Bank in return for financial support. Today, smallholder farmers in the PRAT are adapting to increasing water scarcity and decreasing rice-market access. These global changes are undermining farmer livelihoods as farmers are forced to abandon their traditional rice production and rent their land to industrial sugarcane mills, resulting in yearly incomes well below the Costa Rican poverty line. Between 2002 and 2012, 40% of farmers represented in this study abandoned rice production by transferring their lands to industrial sugarcane mills, and many more claim they will abandon agriculture within the next five years. I consider farmer abandonment of rice production through the transition to sugarcane production as representing an adaptation limit. This abandonment may also be considered a livelihood transformation. In either conceptualization, the hardship associated with a farm's transition to sugarcane production must not be discounted. And, while there are always tradeoffs among livelihood strategies, a transition to sugarcane production brings many great economic hardship and forces farmers to forfeit their valued identities as rice farmers (see Chapter 5 for a discussion of the importance of rice in smallholder farmer identities).

3.2 Data collection

A qualitative participatory rural appraisal (Chambers, 1994) was applied in the PRAT to initially assess farmer vulnerabilities, the impacts of global changes, and farmer responses to these changes. The appraisal consisted of two workshops with researchers, farmers, and PRAT managers. The workshops were held in 2010 and 2013. The first workshop, entitled "Coordinating sustainability science research in the Rio Tempisque Basin," was held on August 14th and 15th, 2010 in Palo Verde National Park, Guanacaste, Costa Rica. Attendees included 10 researchers and farmers from multiple research organizations including CATIE, the Organization for Tropical Studies, and Arizona State University; all were engaged in sustainability research or farming in the region. PRAT-sustainability problems raised throughout this workshop included (1) smallholder rice farmers are demanding more water, but the PRAT has been operating under scarcity since 2006, (2) smallholder farmers are increasingly selling and renting their lands to large-scale sugarcane companies to escape both agriculture and the debts accrued through rice production, and (3) smallholder rice farmers are losing access to the regional rice market due to changing regulations brought about by the "Dominican Republic – Central America Free Trade Agreement" (CAFTA-DR). We defined these as sustainability problems because their solutions lie in contradictory, piecemeal, and varying requirements that were difficult to understand. See Rittel & Webber (1973) for a complete definition of sustainability, or “wicked,” problems as we defined them in this workshop.

The second workshop, entitled “Guanacaste collaborative workshop on water governance,” was held on March 14th, 2013 at the National University of Costa Rica, Nicoya, Costa Rica. Forty-six total workshop participants included representatives from 11 rural water administrations (*ASADAs*), farmers, agricultural water managers, and local water-environmental non-governmental organizations. Participants, including irrigation and agricultural managers, overwhelmingly agreed with farmers that a strong smallholder-farming sector is in Costa Rica’s best interest, but that the challenge was determining how water should be managed to support smallholder farming. Participants agreed that water scarcity was heavily impacting agriculture in a negative way. See Kuzdas, Yglesias, & Warner (2013) for a detailed summary of workshop findings.

I used the findings from this participatory rural appraisal to formulate and revise a household survey that included questions that would allow me to understand how household level socio-economic variables correlate with farmer abandonment of livelihood goals (indicated by their transition from rice production to sugarcane production) due to either water scarcity or limited rice-market access. If farmers had transitioned to sugarcane production, questions were asked to collect socio-economic data about their time as a rice farmer. Also, all questions were structured to collect socio-economic data that could be categorized using all eight of Yohe & Tol’s (2002) determinants of adaptive capacity. These include (1) resources and their distribution, (2) critical and functional institutions, (3) human capital including education and security, (4) social capital including the definition of property rights, (5) access to risk spreading processes, (6) ability and credibility of decision-makers to manage information, (7) available technical options for adaptation, and (8) perceived attribution of the source of stress and the significance of exposure.

The household survey was developed following the guidelines for the collection of quantitative primary data in developing countries as described by the United Nations Department of Economic and Social Affairs (2008). Each survey also included a short semi-structured interview to collect farmer perspectives on their efforts to adapt to risks and on the future of smallholder farming in the PRAT. Following the iterative process defined by the United Nations Department of Economic and Social Affairs, I refined my household survey by holding three focus groups with smallholder farmers in the IDA districts of San Martin and San Ramon (shown in Figure 4.1) in February 2013. Each focus group lasted approximately one hour and included 4-8 farmers, and each was held in or outside the home of a farmer. In each focus group I asked farmers to talk openly about, and then attempt to reach a consensus description of:

1. Smallholder farmer valued livelihood goals;
2. The adaptations smallholder farmers employ to adapt to water scarcity and limited rice-market access.

A Spanish/English speaking research assistant, trained at Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) in facilitation techniques, facilitated all focus groups. Focus groups were documented using facilitator notes, and analyzed using the content analysis method described by Sandelowski (2000). I looked for major themes, insights, common phrases and words, and specific moods and tones across the notes from all three focus groups. The facilitator first coded all focus group documentation, and then I recoded the documentation to ensure consistency.

The revised household survey was pretested by surveying five households in the San Martin district. I then further revised the survey for clarity based on the feedback from these farmers. The final survey was comprised of questions structured in order to collect socio-economic data including information about demography, assets and wealth, access to markets and services, and perceptions of climate risks. If farmers had switched to sugarcane production (40% of farmers surveyed had rented their land to sugarcane companies), they were asked to specify if the switch was in response to the debts accrued through a failed crop resulting from water scarcity, or in response to limited rice-market access.

A Spanish/English speaking research assistant administered all surveys. My sampling frame were all smallholder farmers in each of the seven IDA districts. According to our sampling strategy, I visited every household in each of these seven districts, shown in Figure 4.1, on a regular basis, multiple times, and at random times. During these visits, farmers who were found in their homes or in their fields were interviewed, if they agreed to be. In total, 94 surveys were administered from February to November 2013. Each survey lasted from 20 minutes to 30 minutes. Some farmers invited us into their homes for the interview portion of each survey, which lasted up to 1.5 hours. I audio recorded interviews and the University of Costa Rica, School of Anthropology transcription service transcribed all recorded interviews. No names and no specific locations were recorded with surveys or interview data to ensure the responses of farmers remained anonymous, in accordance with my IRB certification.

3.3 Data analysis

The data from the quantitative household survey were analyzed using descriptive statistical methods and logistic regression models, which are described below. Frequencies of nominal socio-economic variables and measures of the central tendency of scalar socio-economic variables were used to describe farmer socio-economic household characteristics and farm characteristics. This description was supplemented with data from the workshops and the focus groups. Predictors of farm transitions to sugarcane production were analyzed using IBM SPSS Statistics 22.0 software (SPSS Inc., www.spss.com). Qualitative and contextual data was then used to describe these predictors as determinants by drawing assumed causal links between each predictor and a household switch to sugarcane production. Binary and multinomial logistic regression models were assumed to be appropriate for my analysis because continuous and categorical predictor variables were included in my model and my dependent variables were dichotomous and categorical.

3.3.1 Logistic regression models

I analyzed and transformed farmer socio-economic data into independent variables to meet the assumptions of logistic regression, including assumptions of independence and non-co-linearity. I analyzed the relative influence of the socio-economic variables on farm transitions from rice to sugarcane production using a binary logistic regression model. I used a multinomial regression model to determine correlations of predictors of farm transitions to sugarcane production due to both water scarcity and limited rice-market access. The functional form of the logistic function I used was:

$$g_i = ln\left[\frac{p_i}{1-p_i}\right] = \beta_0 + \beta_1 x_{1,i} + \cdots + \beta_m x_{m,i} + \varepsilon_i$$

where g_i was a "log odds" (i.e., the logarithm of the odds $p/(1-p)$, where p is probability), β_0 was constant, β_1 to β_m were vectors of coefficients and ε_i was an error term. In this equation, the coefficient calculated change in log odds of the dependent variable, not the change in the variable itself. Therefore, I simplified the model's interpretation by converting it to an odds ratio using the exponential function:

$$Odds\ ratio = \left[\frac{p_i}{1-p_i}\right] = e^{\beta_0 + \beta_1 x_{1,i} + \cdots + \beta_m x_{m,i} + \varepsilon_i}$$

The odds ratio is the ratio of the probability that the household will transition to sugarcane relative to the probability that they will not convert. The multinomial logistic regression model utilizes two logistic functions of the same form, each relative to the reference group (rice production). I utilized a multinomial regression in this study because my dependent variable in question consisted of more than two categories (i.e., (1) rice production, (2) transition to sugarcane due to limited rice-market access, and (3) transition to sugarcane due to water scarcity).

For dichotomous independent variables in both models, the exponential of the respective coefficient gives the proportion of change in odds for a shift in the given variable. If the variable was scalar, both the coefficient and exponential of the coefficient were associated with the effect of per unit change. The sign of the coefficient revealed the direction of change in both types of variables. Socio-economic independent variables were incorporated into both logistic regression models to control for each distinct category in Yohe & Tol's (2002) framework to interpret the results while holding other important adaptive inputs constant. The omnibus test and the Hosmer and Lemeshow goodness-of-fit test were used to test model fit and significance. The null hypothesis was that no relationship existed between a household transition to sugarcane and any socio-economic variable.

4. Results and discussion

In this section I use descriptive statistics, focus group and workshop findings to describe changes in smallholder farmer livelihoods between 2002 and 2012. I provide a descriptive analysis of farmer livelihoods, and then I present and discuss the results of my logistic regression analysis and describe the determinants of farm transitions to sugarcane production. I analyze why some farmers have confronted adaptation limits by presenting and discussing the results of my logistic regression analyses. I look for similarities and differences between the determinants of adaptation limits due to water scarcity, and those due to limited rice-market access. I compare my findings to Yohe and Tol's (2002) determinants of adaptive capacity.

4.1 Limited rice-market access, water scarcity, and smallholder farming in the PRAT

Since the PRAT began providing irrigation water to farmers in 1983, rice has been the crop of choice for the smallholder farmers represented in this analysis. Arriagada, Sills, Pattanayak, Cubbage, & González (2010) show that in the early 2000s, almost all farmers in my case study produced rice. This percentage has decreased and today, 40% of the farmers surveyed have transitioned to sugarcane production (see Table 4.1). These transitions were driven by the impacts of two interacting global change risks (described in detail in Chapters 2 & 3). First, a rapid vertical integration of industrialized rice mills has occurred in the region, brought about by State rice-policy responses to CAFTA-DR. This vertical expansion greatly limited rice-market access for smallholder farmers in the PRAT. Second, increasing regional drought has forced many rice farmers in the region to abandon rice crops between 2006 and 2014. The remaining smallholder rice farmers in the PRAT continue to plant rice because if they are able to grow and sell their harvest, they may earn a fair profit.

Table 4.1 – Number and percent of surveyed farmers that abandoned rice production to produce sugarcane due to (1) water scarcity or (2) limited rice-market access; N=94.

Number that switched due to water scarcity: 17	Percent that switched due to water scarcity: 18%	Number that switched due to limited market access: 21	Percent that switched due to limited market access: 22%	Total number that switched: 38	Total percent that switched: 40%

The successful production and sale of a 10-hectare rice harvest brought approximately US$33,000 in 2012 (CONARROZ, 2012). Over 75% of their gross income covers input and milling costs, which provides smallholder farmers with a stable livelihood above Costa Rica’s average gross national income of US$8,820 (World Bank, 2012). However, without securing a sales contract from any one of the remaining five industrial rice mills in the region, they have no guarantee that their harvests will be purchased, and they must search for remaining capacity at regional mills after every harvest to sell their rice. The increasingly vertically integrated rice mills now produce much of their own rice, which means they rely less on the purchase of smallholder-farm rice harvests. The limited amount of rice that is purchased by rice mills from smallholder farms is purchased early in the harvest season. This has created competition among smallholder farmers to harvest and sell rice earlier in the growing season, before mills reach storage and processing capacities.

4.1.1 Water scarcity in the PRAT

The Tempisque River Basin experienced drought conditions in six of the eight years between 2006 and 2014. Downscaled regional climate models for Northwest Costa Rica predict higher temperatures and water deficits in the region within the next two decades (Anderson, Flores, Perez, Carrillo, & Sempris, 2008). Wet season precipitation is expected to decrease as much as 27% during this time, creating soil-moisture deficits and reducing the amount of surface water available for irrigation by half (Karmalkar, Bradley, & Diaz, 2008). These changes are already apparent in the Tempisque River Basin and farmers included in this study overwhelmingly realize this; 99% of farmers interviewed perceived decreases in rainfall and almost 90% perceived warmer temperatures from 2002 to 2012.

Beginning in September 2006, for the first time, the PRAT operated under conditions of water scarcity. The PRAT water managers devised a plan to cycle irrigation water by sector in an attempt to provide farmers with enough water to plant and harvest and not lose harvests. Water shortages primarily occurred during the high water demand months of December and January, during which time both rice and sugarcane are planted. Both rice and sugarcane require large inputs of water during planting, and both crops must be planted near the start of the dry season so they can be harvested prior to the beginning of the next rainy season. The water-cycling program was designed to spread farmer-planting dates across a series of 6 weeks, thereby allowing all farms to successfully plant and harvest prior to the beginning of the next rainy season, which usually begins in May of each year. Allocation priorities are created anew each December when the seven agronomists, employed by the PRAT water management to oversee each of the seven IDA districts in the PRAT, meet to determine which sections of the districts gain priority during the water-cycling program. Interviews with water managers indicated this process was "fluid," as no legal precedent exists to dictate allocation priorities through time. While this water-cycling program could allow all smallholder farmers to plant their rice crops and harvest before the rains begin, farmers who are forced to wait to plant have more difficulty selling their harvests because their later harvest dates limit their ability to sell their harvests before rice mills stop buying smallholder rice harvests for the season. And, while it is possible for smallholder farmers to store their production, the debts accrued through the planting and harvesting process necessitate the timely sale of their harvests.

Delayed water allocations, in combination with limited access to the rice market during harvest, have caused water piracy among farmers throughout the PRAT. This has created water scarcity for some. Farmers upstream in the PRAT illegally modify irrigation infrastructure to gain early access to water allocations (Figure 4.2 shows examples from 2012). Many farmers furthest down stream plant rice but then lose their water access as a result of the actions of upstream farmers, and therefore many downstream farmers have been forced to abandon rice crops.

Figure 4.2 – The picture on the left is of a pump illegally drawing irrigation water from a PRAT canal; when water managers are not patrolling the canals, farmers can use pumps to transport water from the canals to their crops during the cycling process, and this limits water availability downstream. The picture on the right is of a makeshift dam, built by a farmer in a remote region of the irrigation district (an area that is infrequently patrolled). Farmers build these dams to gain access to water, and their neighbors typically destroy them as they are affected by the water loss.

4.1.2 Transitions to sugarcane production, the outcome of global change impacts on smallholder farmers

The transition of smallholder rice production to sugarcane production is brought about by one of two impacts: (1) the debt accrued through a the inability of a farmer to sell their rice harvest, or (2) through the loss of one or more rice crops to water scarcity, which leaves farmers without income. When a smallholder farmer switches to sugarcane, they do so by entering into long-term (>10 years) full-land-management-production contracts with one of three industrialized sugarcane mills in the PRAT. Full-land-management-production contracts between smallholder farmers and sugarcane mills are often negotiated through the purchase of the smallholder farm rice debts. The sugarcane mills then plant, manage, and harvest smallholder farm fields, and smallholder landowners receive a flat fee per hectare depending on their debt. On average they receive approximately 150,000 *colones* (US$300 US) per hectare per year, well below the Costa Rican poverty level for the majority of landholding sizes.

Farmers and PRAT water managers overwhelmingly agree that a strong smallholder-farming sector is needed in the PRAT because it would promote Costa Rican food security and bolster the region's non-migrant based economy. Farmers in my focus groups agreed that their valued livelihood goals included security of well-being for their households and the preservation of their identities as rice farmers. Household interviews further verified this finding and provided rich insights into these values (see Chapter 5). Allowing smallholder farmers to achieve these livelihood goals would strengthen the PRAT smallholder-farming sector. Despite this seemingly unanimous agreement regarding the importance of smallholder-rice farming in the PRAT, few solutions have been proposed to help farmers overcome the impacts of water scarcity and limited rice-market access. This has left farmers struggling to adapt to these impacts with little support from local, regional, or State institutions. Because of this, many have reached the point at which their valued livelihood goals cannot be met through adaptive actions, meaning they have abandoned valued livelihood goals and transferred their land to one of the three sugarcane companies in the PRAT. These valued goals, identified and articulated within my three focus groups, fell sharply along two lines: security of well-being and personal identity. Farmers sought (1) security of education, healthcare, and the maintenance of assets and land for all family members, and (2) the maintenance of their rice-producer-specific identities as *parcelaros* (i.e. smallholder rice-farmers who were given land or who were sold land at discounted rates by the government). A farm-transition to sugarcane production most often forced farmers to sacrifice both (which resulted in increased poverty and destitution), or to trade-off their identities for security and seek alternative employment if those opportunities existed for them. See Chapter 5 for a detailed explanation of valued livelihood goals within the context of PRAT smallholder farming.

The transition to sugarcane production represents a long-term loss of the smallholder rice-farmer *parcelaro* identity. The transition to sugarcane entails long-term land-management contracts, required because sugarcane mills purchase rice debts and in return require long-term use of the land to justify the purchases. While smallholder farmers could independently plant sugarcane and independently sell it to a mill, the price they would receive is much less per hectare-yield than that of rice. The sugarcane economy of scale is much greater than that of rice. Given the high cost of human and mechanical inputs that are unique to sugarcane, labor and machinery must be utilized efficiently on larger scales to profit through sugarcane production. This creates the opportunity for syndication to exploit economies of scale in sugarcane harvesting, loading and transport by spreading high capital and management costs over a large tonnage (Moor, 1998). Almost all sugarcane in the PRAT is mechanically loaded infield. Approximately 50% of sugarcane grown in the region is cut and windrowed manually (TABOGA, 2014), which requires large sources of migratory labor. The remainder is cut and windrowed mechanically, requiring substantial fixed capital investments by the mill. These investments require multiple sugarcane harvests over multiple years to become profitable. Therefore, sugarcane mills seek long-term land management contracts from smallholders, so no "fail safe" or "short-term" transitions to sugarcane currently occur in PRAT smallholder agriculture. There is substantial irreversibility in the transition to sugarcane that entails the loss of both livelihoods and *parcelaro* identities.

4.2 Determinants of adaptation limits: Smallholder farm transitions to sugarcane production

In my household survey, I asked farmers who had transferred their land rights to sugarcane mills to describe why they did so. While many farmers who had switched to sugarcane production reported to have suffered losses from both water scarcity and limited rice-market access, all could attribute a majority of their livelihood losses and their ultimate transition to sugarcane production directly to one of the two impacts. In all, 40% of all farmers surveyed had transitioned to sugarcane, and 45% of those switched due to the loss of one or more crops from water scarcity. The remaining 55% reported that they had switched to sugarcane production because they had accrued insurmountable debts due to the inability to sell their rice crops. These farmers had utilized their capacity to switch to sugarcane as a means to mitigate the impacts of water scarcity and the debts accrued due to limited rice-market access. However, this transition forced many farmers included in this study into conditions of food insecurity and poverty. There was also evidence (e.g., vacant homes on sugarcane producing parcels) of out-migration (complete abandonment of farming and change in values) in some sectors within my study site. While these farmers were not included in my study, it is important to point out that some farmers did appear to have the capacity to transition out of agriculture and migrate from the region.

I assumed that some household-scale socio-economic variables (Table 4.2), collected through my household survey would be predictors of farm transitions to sugarcane production, and I used logistic regression models to assess the correlation of each. Also, I coded each independent variable using Yohe & Tol's (2002) determinants of adaptive capacity to discuss my findings in the context of my theoretical framework. In total, I found that four of the 15 socio-economic variables were predictors of farmer transitions to sugarcane production in the PRAT.

Table 4.2 – Household-scale socio-economic variables expected to be significantly correlated with farmers' coping mechanisms, N=94

Categorical socio-	**Determinant following**	**Response category**	**#**	**Percent**

economic independent variables	**Yohe and Tol (2002)***			
Owns land	D2	0 = No	19	21
		1 = Yes	75	79
Owns equipment	D1, D2	0 = No	54	57
		1 = Yes	40	43
Has crop insurance	D6, D3	0 = No	60	64
		1 = Yes	34	36
Cattle ownership	D2	0 = No	44	47
		1 = Yes	50	53
Only receives market information from purchaser of harvest	D6	0 = No	30	32
		1 = Yes	64	68
Formal agriculture training among any member of household	D4	0 = No	70	75
		1 = Yes	24	25
Friends outside	D5	0 = No	67	71

of farming**		1 = Yes	27	29
Relatives with livelihoods outside of farming	D6	0 = No	53	56
		1 = Yes	41	44
Agriculture is sole income source	D6	0 = No	18	19
		1 = Yes	76	81
Perception of precipitation decrease	D8	0 = No	1	1
		1 = Yes	93	99
Perception of temperature increase	D8	0 = No	10	11
		1 = Yes	84	89

Scalar socio-economic independent variables		**Mean**	**Std. Dev**	**Range**	**Min**	**Max**	**20%**	**40%**	**60%**	**80%**
Years spent farming	D7	22	7.2	34	2	36	17	22	22	28
Age of head of household	D7	51	14.3	63	20	83	38	49	55	62

Children in household	D4	2.9	1.9	10	0	10	2	2	3	4
No. of household members who work on farm	D4	0.8	1.4	8	0	8	0	0	1	2
Size of Farm	D2	8.8	8.0	49.2	0.8	50	2.5	5	10	13

*(D1) available technological options for adaptation, (D2) resources and their distribution, (D3) critical and functional institutions, (D4) human capital including education and security, (D5) social capital including the definition of property rights, (D6) access to risk spreading processes, (D7) ability and credibility of decision-makers to manage information, and (D8) perceived attribution of the source of stress and the significance of exposure.

** Farmer has "close" friends outside of farming that they at lease four times per year.

4.2.1 Determinants of transitions to sugarcane production

In my analysis of the predictors of farm transitions to sugarcane, I first explored predictors of all farm transitions to sugarcane production included in my study. This analysis (see Table 4.3) included all farms that transitioned to sugarcane production for any reason and those that continued to plant rice at the time of the survey. My analysis showed that three predictors were significantly correlated with farm transitions to sugarcane; these were cattle ownership, agriculture as a principle income source, and years spent farming.

Table 4.3 – Parameter estimates from binary logistic regression model, N=94

Change crop type to sugarcane: total (0 = no change to sugarcane; 1 = change to sugarcane)								
Predictors	**B**	**S.E.**	**Wld**	**z**	**Sig.**	**Exp(B)**	**95% C.I.**	
Cattle ownership	**-0.97**	**0.38**	**6.52**	**2.55**	**0.011 ****	**0.379**	**0.18**	**0.79**
No. of household members on farm	-0.65	0.42	2.35	1.53	0.125	0.517	0.223	1.2
Size of Farm	0.037	0.03	1.00	1.00	0.317	1.037	0.966	1.11
Agriculture is/was sole income	**0.536**	**0.24**	**4.84**	**2.20**	**0.028 ****	**1.709**	**1.06**	**2.75**
Owns equipment	0.539	0.59	0.81	0.90	0.368	1.714	0.53	5.54
Friends outside of farming	0.096	0.53	0.03	0.17	0.858	1.101	0.385	3.15
Years spent farming	**-0.30**	**0.13**	**5.57**	**2.36**	**0.018**	**0.736**	**0.571**	**0.94**
Perception of temperature	19.30	1174	0	0.00	0.999	-	-	-

increase								
Has crop insurance	-0.48	0.60	0.63	0.79	0.424	0.617	0.189	2.01
Formal educational training in household	-0.94	0.67	1.95	1.39	0.162	0.388	0.103	1.46
Age of head of household	-0.02	0.02	0.82	0.90	0.363	0.979	0.936	1.02

*Significant at the 0.10 level; **Significant at the 0.05 level; ***Significant at the 0.005 level.

Cox & Snell R Square 0.396, Nagelkerke R Square 0.533

Omnibus tests of model coefficients: Chi-square 47.411, df 11, Sig. 0

Hosmer and Lemeshow Test: Chi-square 3.615, df 8, Sig. 0.89

Farms that had cattle (data included those that had cattle before their transition from rice production to sugarcane because some farms sold their herds after the transition) were 62% less likely to transition to sugarcane production. Among rice farmers in the PRAT, cattle were used as buffers against the impacts of risks. As the only type of livestock reared by farmers in my study, they were regularly bought and sold between farms, and at regional auction houses. Farmers did so, in large part, to overcome debts assumed through the inability to sell a rice crop, or to supplement income if farms lost rice crops to water scarcity. In global change research, selling cattle is often considered a coping mechanism, in contrast to an adaptation in pursuit of an opportunity.

This is often the case because cattle are considered to be a primary source of capital; by selling cattle, farmers become more vulnerable to future impacts. Cattle have also been shown to play a role in the adaptations of some farming households following traditional risk management strategies of income diversification – farmers may complement their crop income with livestock income (for some discussion of the role of livestock ownership in farmer adaptation, see Eakin & Bojórquez-Tapia, 2008). While these processes were occurring among farmers in this study, surveyed farmers also perceived cattle as "supporting" their rice-crop production. They did not perceive cattle as a part of their identities. This distinction is critical. I had originally classified cattle per Yohe & Tol's (2002) adaptive capacity classification as a "resource" that made farms more adaptive to risks. However, among farmers in the PRAT, the process of cattle rearing operates more as a "risk spreading process," or as a form of savings to smooth out variations in income. The rich history of cattle rearing in Guanacaste provides ease of market access, and the renewable nature of the resource seems to draw farmers to invest in cattle rather than other types of economic or physical capital. Farmers often described cattle ownership as a premeditated coping mechanism. For example, one farmer described smallholder cattle rearing within his livelihood in this way:

> *The small cattleman is extinct [in the PRAT]. I own cattle because rice is bad business, and I am a rice farmer* (Survey respondent #53, 14-hectare rice farmer, February 24th, 2013).

Another farmer provided a description of the role cattle play in his ability to avoid losses from water scarcity as he “plays the lottery” (Eakin, 2003) and plants rice.

> *I lose my harvest [to water scarcity], but I have 11 Brahman and a Parda so it doesn’t matter, we can still eat* (Survey respondent #56, 1.4-hectare rice farmer, February 24th, 2013).

However, Dercon (2002) shows that risk and “lumpiness” limit the opportunities to use cattle as insurance for some farmers, and that informal risk-sharing provides only limited protection, leaving some of the poor exposed to very severe negative impacts of risks. This insight calls into question this risk spreading process for some farmers in the PRAT as conditions of water scarcity and limited rice-market access worsen. While my data shows cattle have allowed farmers to better manage risks of water scarcity and limited rice market access, this strategy may only be useful to a point.

A second significant determinant of farm transitions to sugarcane production was a sole reliance on farm-related income before the transition. Those rice farmers who solely relied on farm income were 1.7 times more likely to transition to sugarcane compared to those farms with multiple income sources. Yohe & Tol (2002) show that the access to risk-spreading processes is a determinant of adaptive capacity, and I categorized diversified income sources as such (similar to my re-categorization of cattle). A majority of farms represented in this study relied solely on farm-related income, but twenty percent of farms had diversified their income sources. This allowed them to spread the risks of both water scarcity and limited market access. This risk spreading process better allowed these farming households to continue meeting their valued livelihood goals of security of well-being and retain their identities as rice farmers. The standard methods of livelihood diversification among households represented in this study were *chambas* (i.e., odd-jobs), and transportation- and tourism-sector employment. While the "number of household members who worked the farm" was not significantly correlated with a transition to sugarcane in my study, Eakin (2006) found that among irrigated farms in Mexico, labor-intensive farming prohibited diversification because it demanded more household labor to be dedicated to production. However, farmers who transferred to less intensive grain production gained opportunities to diversify, which in turn subsidized agricultural production. Rice production in the PRAT is very household-labor intensive, and a transition to sugarcane frees this labor. Many of the farmers interviewed in this study had recently transitioned to sugarcane, and so many were still in the process of adapting household labor. However, there was some evidence of this labor adaptation process as some farmers were pursuing employment in the transportation and tourism sectors.

The third significant determinant of a household transition to sugarcane production in this study was "years spent farming" by the head of the household. I classified this determinant as "the ability and credibility of a decision-maker to manage information" within Yohe & Tol's (2002) classifications of adaptive capacity. Farmers included in this study farmed between 2 and 36 years. I had assumed that increased "years spent farming" would better allow a farmer to manage risk and make good decisions that would allow them to continue farming. However, many of the farmers included in this study who had farmed the longest also resided in those PRAT-sectors that were first incorporated into the PRAT in 1983. The older sectors had a higher percentage of rice growers than the newer sectors. So, while experience did seem to play a role in the ability of a farmer to avoid the livelihood losses, it seemed collective action was also incorporated into this variable. Farmers in the oldest sectors were better organized around rice production. They cooperatively rented and shared planting and harvest equipment. This collective action seemed to allow small groups of rice farmers to better adapt. Also, it seemed “years spent farming” might be related to the insecurities associated with younger farm families. Farmers who were beginning to farm and who had not yet had the opportunity to acquire key assets to face significant insecurity may have been drawn to forfeit their *parcelaro* identities (which were limited in younger farmers) to pursue alternative livelihoods.

4.2.2 Limited rice-market access-driven transitions to sugarcane production

Twenty-two percent of all farms included in this study claimed to have transitioned from rice to sugarcane production as a result of increasingly limited rice-market access. My analysis found two predictors of this transition among those farmers: “size of farm” and “cattle ownership” (Table 4.4). Farmer cattle ownership was shown to decrease the odds that a farm would transition from rice to sugarcane production. Farms with cattle were 56% less likely to transition to sugarcane for reasons described above.

Table 4.4 – Parameter estimates from multinomial logistic regression model, N=94

Driver	**Predict**	**B**	**S.E.**	**Wald**	**z**	**Sig.**	**Exp(B)**	**95% C.I.**	
Transition to sugarcane because of reduced rice-market access	**Size of Farm**	**0.088**	**0.047**	**3.582**	**1.893**	**0.05 ***	**1.092**	**0.9**	**1.1**
	Cattle owners	**-1.49**	**0.729**	**4.223**	**2.055**	**0.04 *****	**0.223**	**0.0**	**0.9**
	No. of member on farm	-0.94	0.628	2.268	1.506	0.13	0.388	0.1	1.3
	Ag is/was sole income	0.247	0.348	0.505	0.711	0.47	1.28	0.6	2.5
	Years spent farming	-0.26	0.175	2.241	1.497	0.13	0.769	0.5	1.0
	Age of head of house	-0.00	0.031	0.091	0.302	0.76	0.991	0.9	1.0
	Owns equip	-0.61	0.811	0.571	0.756	0.45	0.542	0.1	2.6
	Percep	-14.7	2040	0	0.000	0.99	-	-	-

	Temp inc								
	Formal training in house	1.67	1.016	2.701	1.643	0.1	5.312	0.7	38.
	Friends outside of farming	3.352	2319	0	0.000	1	-	-	-
	Has crop insuran-ce	0.472	0.84	0.316	0.562	0.57	1.603	0.3	8.3
Transition to sugarcane because of water scarcity	**Size of Farm**	**-0.31**	**0.156**	**4.009**	**2.002**	**0.04 ****	**0.732**	**0.5**	**0.9**
	Cattle owners	**-0.82**	**0.481**	**2.94**	**1.715**	**0.08 ***	**0.438**	**0.1**	**1.1**
	No. of member in house	-0.64	0.579	1.238	1.113	0.26	0.525	0.1	1.6

	Ag is/was sole income	**0.74**	**0.301**	**6.037**	**2.457**	**0.01 ****	**2.096**	**1.1**	**3.7**
	Years spent farm	**-0.31**	**0.163**	**3.722**	**1.929**	**0.05 ***	**0.731**	**0.5**	**1.0**
	Age of head of house	-0.02	0.031	0.625	0.791	0.42	0.976	0.9	1.0
	Owns equip	-0.19	0.815	0.056	0.237	0.81	0.825	0.1	4.0
	Percept of temp increase	-14.5	2284	0	0.000	0.99	-	-	-
	Formal ed training in house	0.301	0.859	0.123	0.351	0.72	1.351	0.2	7.2
	Friends outside	-17.4	0.93	352.8	18.78	0	-	-	-

	of farming								
	Has crop insuran-ce	-0.64	0.95	0.453	0.673	0.50	0.527	0.0	3.3

Reference category is: Rice producer

*Significant at the 0.10 level; **Significant at the 0.05 level; ***Significant at the 0.005 level

Cox & Snell R Square 0.576, Nagelkerke R Square 0.674, McFadden 0.445

Goodness-of-Fit: Pearson Chi-square 194.938, df 160, Sig. 0.031

Increasing farm size was significantly correlated with a transition to sugarcane production due to the impacts of limited rice-market access. For every hectare increase in farm size, a farm was 1.1 times more likely to transition to sugarcane production. Larger farms included in this study, over ten hectares, were typically mechanized and they greatly relied on labor from outside the household. Farmers would assume large debts through the planting and harvesting of rice each season. Average debts assumed by farms in this study were US$2,679 per hectare (CONARROZ, 2012). The successful sale of a 10-hectare rice harvest could bring up to US$33,000, and this sale was used to pay debts and to support household livelihoods. Larger farms that were unable to sell their rice crops were sometimes able to access credit to pay their debts, and then sell their harvests to one of the remaining rice mills during the next harvest. However, the inability of larger farms to sell multiple rice crops often left them with insurmountable debts. Larger smallholder farms would often transition to sugarcane production because of these debts. The transition to sugarcane farming included the purchase of smallholder farm rice debts in return for decade-long rental agreements with sugarcane mills. Smallholder farming households would then be free of debts, but they were no longer independent farmers.

4.2.3 Water scarcity driven transitions to sugarcane production

Eighteen percent of farmers surveyed had transitioned to sugarcane production as a result of lost rice crops due to water scarcity. I found four significant predictors of farmer transitions to sugarcane in this context (Table 4.4). "Cattle ownership," "farm is sole income," and "years spent farming" were again found to have significant correlations for the reasons stated above. The third determinant was "size of farm." Larger farms were less likely to suffer losses from water scarcity. As described above, larger farms represented in my study were largely mechanized, and most had access to large amounts of credit. Most highly mechanized farms installed and relied on wells and surface water sources on their properties to supplement decreases in irrigation water. Larger farms typically had the capital and expertise to install wells that could be used season after season. While this practice is illegal under Costa Rican water law, the lack of enforcement mechanisms limits the usefulness of the law. Larger farms may have also had the political capital to better avoid the ramifications of enforcement. Smaller farms included in this study, less than five hectares, rarely relied on groundwater to supplement their water supplies because they lacked the resources necessary to access it. Few had access to credit, and few could pay the high costs of well installation. Smaller farms sometimes did pump water from surface water sources if they were fortunate enough to have access to a river.

When water managers initiate the PRAT water-cycling program during December and January of each year, smaller farms downstream are made vulnerable to water scarcity. Many lose their access to water supplies during planting due the now commonplace practices of water piracy throughout the PRAT. Smaller farms are often forced to abandon their harvests if they plant rice with the expectation of receiving irrigation water, but then fail to receive that allocation due to water piracy upstream. Through interviews with the smallest farm households, I learned that these farms are typically able to avoid debts when they lose rice crops because much of the planting is done by household labor, and they are relatively non-mechanized. However, while the loss of a rice crop does not indebt smaller farming households, the loss of a rice crop means the loss of household income for the season. This is why many of the smallest farms have given up their rice-production livelihoods and have transitioned to sugarcane production.

Eakin (2006) showed that a similar process of transition occurred among vegetable farmers in Mexico transitioning to maize production. While no market existed for maize in the region, farmers were able to remain in agriculture through subsistence farming. Among those rice farmers most vulnerable to water scarcity in the PRAT, many were able to cope with lost crops for multiple seasons through the same process. However, ultimately a “retreat” to sugarcane often resulted after multiple seasons of coping. Thereby, farmers sacrificed agriculture, but did gain some income security.

Unfortunately, this security often appeared to come at the price of poverty and food insecurity, unless smallholders were able to diversify their livelihoods.

4.3 Adapting to water scarcity, the "catch-22" of successful adaptations to multiple risks in the PRAT

In my analysis, "size of farm" was shown to be a determinant of farm transitions to sugarcane production, driven by both water scarcity and limited rice-market access independently, but contradictory depending on nature of transition. "Farm size" represents a resource within Yohe & Tol's (2002) classifications of adaptive capacity. Those farms with more debt were more vulnerable to limited rice-market access, but they were better able to adapt to water scarcity due to their increased access to resources. Smaller farms, with few resources and that were heavily reliant on household labor, were shown to be better able to cope with the impacts of limited rice-market access, yet were more vulnerable to the impacts of water scarcity. From the perspective of farmers most vulnerable to water scarcity in the PRAT, this situation is akin to Heller's (1961) "catch-22." As smallholder farmers pursue their livelihood goals, which are structured around rice farming, the pursuit of increased rice production efficiency through mechanization or through the purchase or rental of additional land and resources would make them more vulnerable to the impacts of limited rice-market access. If farmers attempted to expand their farms and grow their livelihoods, they would accrue debts that may ultimately undermine their livelihoods if they failed to sell a rice crop. However, without attempting to expand their livelihoods by making investments in either additional land (to gain access to surface water) or in wells or water saving technologies, they would continue to be vulnerable to the impacts of water scarcity. This, also, could undermine their livelihoods and ultimately force them into sugarcane production.

This situation also seems to place many smallholder farmers within Banerjee & Duflo's (2011) “S-curve.” Those farmers who do not believe they can adapt successfully to water scarcity to “get over the hump” may not try. They may give up and stop taking interest in adaptation. However, this behavior creates a poverty trap, even where none existed in the first place. If farmers give up, they will never find out if they could have successfully adapted to water scarcity. In contrast, those farmers who assume that they can adapt, or those that don’t want to accept the consequences of non-adaptation, tend to be those larger farms with more access to resources.

It was not apparent that a subset of medium sized farms in the PRAT existed that was less susceptible to both forms of risk. There seemed to be a threshold above which farmers produced sufficient surplus to have more clout in rice markets, which required some specialization of labor and capital. Therefore, no smallholder farms, regardless of size would be viable in rice markets since mills are increasingly selecting for larger producers. Smallholders who could not participate in the rice market were forced to diversify to meet livelihood stability goals or become sugarcane producers. Both may be considered adaptations to stabilize volatility rather than get out of poverty or increase wealth (Eakin, 2014). Ultimately, it is the combination and interaction of both risks that has forced these farmers to face adaptation limits in the PRAT between 2002 and 2012.

From the perspective of water and agriculture managers in the PRAT, any solution, seeking to promote smallholder farming and meet the original development goals of the project must address both the impacts of limited rice-market access and water scarcity on the most vulnerable farmers. That said, water scarcity is largely driven by competition among smallholder farmers for water to plant early in each season, which is driven by their limited rice-market access. The water cycling scheme, developed and implemented by water managers, has been shown to successfully allow smallholder farmers to plant and harvest rice without losing yields. Therefore, a focus on rice-market provisioning through storage schemes (as the State provides in Thailand) or pay-forward schemes, would largely resolve problems with water scarcity in the PRAT for the time being.

The two primary challenges faced by PRAT managers in developing a sustainable solution to these problems are (1) the region's increasing aridity, and (2) a lack of authority to change rice-market access in the PRAT. Lake Arenal, the source of PRAT irrigation water, is predicted to continue to decrease in water volume over the next two decades (Karmalkar et al., 2008). This will continue to increase water-cycling times and further delay rice planting each season. If water allocations push planting dates into February of each year, farmers will be forced to harvest in the rainy season, thereby forcing them to pay expensive drying fees or abandon their harvests. While increasing aridity in the PRAT is driven by global climate change, the management of its impact in the PRAT is a regional issue, for which regional decision makers are largely responsible. Drought resistant rice varieties and the implementation of water saving agro-technologies could greatly prolong smallholder rice production in the drying region.

Limited rice-market access among smallholder farmers was created by the Costa Rican policy response to threats of international trade liberalization, and these decisions were made at the national level. Local PRAT managers have little authority over national rice-market policies, even as the PRAT produces 45% of the rice consumed in Costa Rica. Costa Rican rice politics throughout the 2000s initiated a rapid consolidation and vertical integration of industrial rice mills. In 2002, there were 11 rice mills purchasing smallholder harvests in the PRAT; in 2013, there were five (CONARROZ, 2007, 2008, 2009, 2010, 2011, 2012). In Chapter 3, I show that the consolidation of one mill in the PRAT corresponds to the elimination of 2,688 metric tonnes of smallholder-produced rice from the market. This in turn displaced smallholder farmers from the rice market because mills no longer needed to buy smallholder farm rice harvests.

Current Costa Rican protectionist rice policies only benefit large-scale, commercialized rice producers and mills, and they drive the increasing inequities in Costa Rican agriculture (Hidalgo, 2014). The current Costa Rica agro-economic model is designed to benefit more powerful farmers at the expense of smaller farmers, particularly the most vulnerable (Hidalgo, 2014; Monge-González et al., 2010). Today, rice production in Costa Rica exists as an oligopsony, where a few powerful farms control almost all the entire market. Any solution that may curtail the loss of the PRAT smallholder-farming sector must incorporate rice-market reforms that compete with or eliminate the power of domestically and internationally owned rice mills to completely control rice market access for smallholder farmers. This type of reform, be it smallholder rice-farm cooperatives or other, would reduce competition for water among smallholder farms in the PRAT, and better allow smallholder farmers to maintain their rice-farming-based identities and meet their goals of security of household well-being.

6. Conclusion

In this study of determinants of adaptation limits, I attest that Morton (2007) was correct in his proposition that farmer adaptations to climate change cannot be understood without incorporating the impacts of multiple global changes and place-based complexity. I show that while some socio-economic determinants can allow farmers to overcome water scarcity, they can simultaneously make farmers vulnerable to market changes, as was the case with increasing land size in the PRAT.

Farmer livelihood goals of are critical in the understanding of adaptation limits. Among smallholder farmers in the PRAT, farmers agreed that their goals of preserving their rice-farmer identity were valued, and these aligned closely with State development goals. However, farmer goals of security of well-being for their households did not entirely depend on agriculture. Some farmers explored other livelihood opportunities as they transitioned to sugarcane production, and some farmers were shown to trade-off their valued identities to seek more secure livelihood sources. More research is needed to understand how farmers trade-off valued livelihood goals as they make decisions to adapt near adaptation limits, how much heterogeneity in one's livelihood matters for identity, and the costs one is willing to incur to continue to adapt to maintain an identity. Lerner & Appendini (2011) show that farmer identities may be malleable; farmers in peri-urban Mexico were shown to maintain their "*campesino*" identities even when they were no longer farming.

As rural development programs in arid and semi-arid areas are increasingly impacted by multiple, interacting global changes, this interplay can stand as a barrier to farmer livelihood goals and to sustainable rural development. The development and application of solutions to singular risks may prove fruitless because they may not address underlying causes of problems, or they may not address the interaction between multiple risks. Continued research on the impacts from interactions between market and climate change on local systems is needed as global changes increase in scope and scale.

CHAPTER 5

EXPLORING ADAPTATION LIMITS AMONG SMALLHOLDER FARMERS TO RISKS OF WATER SCARCITY AND DECREASED RICE-MARKET ACCESS IN NORTHWEST COSTA RICA

1. Introduction

The majority of studies on the local impacts of global changes report on recent and incremental changes (Park et al., 2012), characterized by short-term adaptations that reduce the losses or enhance the benefits of variations in climate (Kates et al., 2012; Pelling, 2010). Recently, scientists and policy-makers have started calling for research on forward-looking adaptations to global changes (Kates et al., 2012). Some of these calls prioritize emphasis on limits to individual adaptations (Dow, Berkhout, & Preston, 2013). The benefit of perception-focused adaptation research is that it should allow us to better understand how short-term adaptations to global change may link to future options to ensure that management decisions do not undermine the abilities of farm households to avoid adaptation limits (Howden et al., 2007).

The abilities of households to avoid adaptation limits in the face of risks are dependent on their capacities to adapt to these changes, which include their perceptions about (1) the efficacy of their adaptations (Grothmann & Patt, 2005), or (2) their ability to revise their valued goals and transform their livelihoods. For the purposes of this study, I define a livelihood transformation as a fundamental change in the foundations of a livelihood from one form to another, thereby enhancing the capacity for desired values to be achieved given perceived or real changes in the present or future environment (Park et al., 2012). These future adaptations and future impacts are also a product of present adaptations because these will determine future outcomes and limits. For the purposes of this paper, adaptation limits represent thresholds beyond which farmers can no longer adapt or cope with the impacts of global change risks to meet existing valued livelihood goals. As risks associated with global changes increase toward these thresholds, risks to valued objectives may become intolerable. At this point, farmers must live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss. For the most vulnerable in less-developed countries (LDC), the efficacy of transformation and adaptation may be closely linked to the ability to manage adaptation limits and avoid devolution into long-term poverty.

For the purposes of this study, I define vulnerability as the degree to which an individual or group may be impacted adversely by the consequences, or the potential consequences of a risk (Eriksen & O'Brien, 2007; Eriksen et al., 2011). I define risk as the possibility that adverse consequences from events or activities will negatively affect something that people value (Kates, Hohennemser, & Kasperson, 1985). The intrinsic vulnerability of smallholder farmers in arid and semi-arid regions has been shown to be a product of the diverse non-climate risks to which smallholder farmers are subject (Morton, 2007). Therefore, research on limits to adaptation in this context must consider multiple types of risk.

The interactions of non-climate risks with risks posed by a changing climate may limit the capacity of vulnerable farmers to manage change (Adger, Huq, Brown, Conway, & Hulme, 2003). These conditions have been shown to drive smallholder farmers in arid and semi-arid regions beyond recoverable adaptation limits (Jones, 2001; Roncoli, Ingram, & Kirshen, 2001). However, these limits are rarely explicitly defined, and we know little about how and if farmers perceive and manage them. Drawing from recent literature on adaptation limits (Dow, Berkhout, & Preston, 2013; Dow, Berkhout, Preston, et al., 2013), I argue we must better understand what constitutes adaptation limits within any one system among any one group; what researchers and policy-makers perceive as adaptation limits may not always correlate with farmer perceptions of adaptation limits. Also, we must better understand how some successfully transform livelihoods to manage adaptation limits while others are forced to live with intolerable risk of losses.

In this study of smallholder farming in Northwest Costa Rica, I asked: What are adaptation limits in smallholder rice farming in the region? How do farmers perceive adaptation limits given plausible impacts of future global change risks? To answer my questions, I structured this research using the adaptation-limit framework proposed by Dow et al. (2013). I begin this paper by I describing the theory upon which I based my study. I describe the methods I used to understand adaptation limits and garner farmer perceptions of adaptations given different plausible near-term risks. I present my results and discuss their significance in the context of adaptation limits.

2. Theoretical framing of adaptation limits

When we study farmer perceptions of adaptation limits, given plausible risks, we must inherently consider the ability of individuals to consider future risks. Our ability to consider the future and act on our perceptions has been a significant part of our success as a species (Suddendorf & Corballis, 1997). Although the importance of thinking about future risks is apparent to many researchers and policy-makers, and this has been done in global change research for decades, the study of our ability to perceive *ex-ante* adaptation is less robust. While there are relatively few studies of the role of human perception on adaptation to plausible global change risks, even less focus on limits to adaptation and livelihood transformations among the rural poor in LDCs.

The ability of an individual to contemplate an adaptation limit lies in the efficacy of their adaptation appraisal, which is defined as perceptions about their ability to successfully react to changes in external factors to meet valued livelihood goals. Such perceptions are based on individual cognition that include their perceptions about the objective adaptive capacity available to them (Grothmann & Patt, 2005). According to the framework proposed by Dow et al. (2013), an adaptation is only appraised if an individual perceives a risk to a valued livelihood goal because a minimum level of concern must exist before individuals will consider the need for action and thus deliberate on their ability to take action.

As risks change in severity and complexity, individuals may appraise adaptations differently. If risks are perceived as non-threatening to livelihood goals, individuals may cease to consider them. Also, individuals may value many goals simultaneously, and some may be considered more valuable than others in terms of what personal cost, monetary or otherwise, individuals will take on themselves to try to achieve different goals. The valuation of goals may be different from individual to individual across a group. Some may give up a great deal to meet any one specific goal, others less so. The challenge in understanding adaptation limits among individuals in any group is not to conflate "cannot adapt" with "chooses not to adapt" (Abbott, 2014). Understanding how some may live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss to adapt to secure revised or new livelihood goals is crucial to adaptation limit research as it speaks to the fluidity of adaptation limits among farmers. However, the hardship of livelihood transition cannot be discounted in the study of adaptation limits among the most vulnerable with few alternative livelihood options.

3. Research site and design

3.1 Research site

The Costa Rican government established the Arenal-Tempisque Irrigation Project (*Projecto de Riego del Arenal-Tempisque*, PRAT) in 1983 to increase the livelihood stability of smallholder farmers in the area. The Inter-American Development bank, which funded its development, states that 1125 farms benefit from the project. These farms primarily produce rice and sugarcane. In the early 2000s, almost all smallholder farmers in the PRAT grew rice (Arriagada, Sills, Pattanayak, Cubbage, & González, 2010). The PRAT (Figure 5.1) supplies farmers with 100% of their irrigation water for five months of each year during the dry season (November-March), but due to prolonged drought in combination with a changing domestic rice market, smallholder farmers have suffered livelihood setbacks. The Costa Rican government has responded to the increasing regional drought in Guanacaste by attempting to expand the PRAT and thus the number of farmers receiving irrigation water. The Central American Bank of Economic Integration loaned approximately US$20 million to the Costa Rican government in 2014 to expand the PRAT by 8,000 ha. The government claims that this irrigation expansion will increase the competitiveness of Costa Rican agriculture, increase agricultural innovation and development, and promote the livelihoods of smallholder farmers outside the PRAT who rely on rain-fed crops in this increasingly arid region because they will be provided with steady supplies of irrigation water. However, both water managers and smallholder farmers increasingly worry that the expansion will further over-allocate scarce water. Furthermore, a dwindling water supply is only one of the complex global change risks facing smallholder farmers in the region.

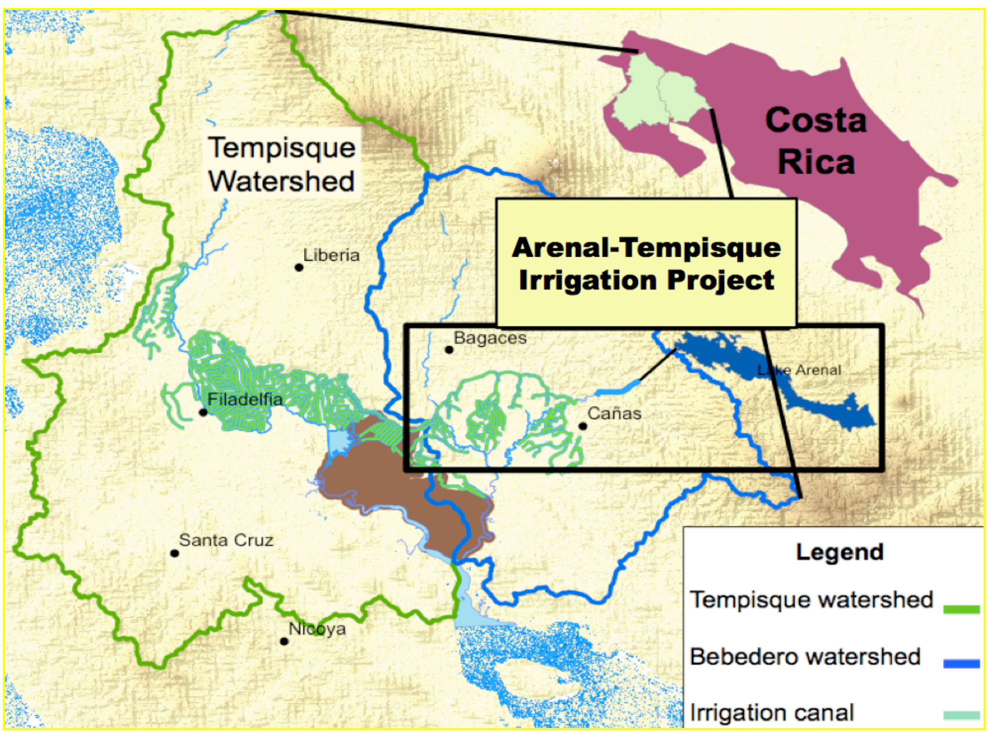


Figure 5.1 – The PRAT provides up to 5,616,000 m3/day of water to farmers from Lake Arenal in the east to irrigation channels (shown in green) near Bagaces and Cañas. The PRAT irrigates approximately 28,000 ha. The total investment in the PRAT infrastructure shown here is estimated at US$67 million. This does not include the 8,000 ha expansion.

The risks faced by smallholder farmers in the PRAT stem from the interactions between regional drought and threats of international trade liberalization. From 2005-2012, approximately 40% of rice consumed in Costa Rica was imported (Arroyo, Lucke, & Riveara, 2013). The Costa Rican agency overseeing these imports sells the imports to rice mills (the same mills that control market access for smallholder farmers). Along with these sales comes a transfer of economic rents (i.e., a return in excess of the resource owner's opportunity cost; Tollison, 1982); rice on the global market is less expensive for rice mills to buy compared with domestically produced rice. Imported rice is allocated to these industrial mills based on the amount of domestically produced rice they have acquired. This has initiated a rapid consolidation of industrial rice mills in Guanacaste, where 45% of Costa Rican rice is grown. This in turn has displaced many smallholder farmers from the rice market because mills no longer need to buy more expensive rice from local smallholder farmers. The situation is expected to become worse as Dominican Republic-Central America-United States Free Trade Agreement (CAFTA-DR) increasingly requires Costa Rica to diminish import tariffs on rice, and ultimately dissolve them by 2025. As smallholder farmers are displaced from the rice production supply chain, they are forced to live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss. While income from sugarcane production is stable, the production of sugarcane typically leaves smallholder farmers unable to secure well-being for their families because yearly incomes are well below Costa Rica’s poverty level. Many smallholder farmers are forced to live with intolerable risk of losses, which drives them further into poverty.

Smallholder farmers in the PRAT are being forced to adapt to these complex and interacting risks from global climate change and globalization. Reductions in smallholder-farm rice harvests are a function of: (1) farmers switching to sugarcane production, (2) farmers voluntarily reducing hectares planted with rice, and (3) involuntary rice harvest reductions caused by water scarcity. These three components were the primary outcomes of the impacts of risks that were driving smallholder farmer livelihood losses in the PRAT. The consolidation of two rice mills in the PRAT was correlated with a loss of 2,688 metric tonnes of smallholder rice from the market. Similarly, a one m^3 sec^{-1} increase in the average irrigation water deficit during rice planting was correlated with a reduction in smallholder rice yield of 1,293 metric tonnes.

3.2 Scenario development

I developed six plausible future scenarios of the PRAT following the guidelines proposed by Kriegler et al. (2012), van Vuuren et al. (2012), and Vuuren et al. (2013), which include: (1) the number of scenarios should be as small as possible; (2) scenarios should include different levels of global changes to span a range of plausible futures; (3) scenarios should facilitate comparison by providing common assumptions about climate outcomes and socio-economic developments; (4) scenarios should be scalable to support development of assumptions for studies at finer scales; (5) scenarios should be structured in a consistent way, and; (6) scenarios should be contextually accurate to ensure policy relevance.

3.2.1 Development of plausibility across scenarios

I used scenarios of plausible risks to gain insight into how farmers thought about avoiding limits, and into the costs farmers perceive themselves as bearing to incrementally adapt to meet valued livelihood goals. The two primary risks facing farmers in the PRAT are water scarcity and decreased rice-market access. I designed my six scenarios (Table 5.1) to incorporate plausible impacts of each of these risks. My "best case" scenarios mimicked the intensities of both risks from 2002 to 2012. During this time, farmers in the PRAT faced 15% reductions in water availability at the time of planting (a reduction of approximately 10 m^3 sec^{-1} across the PRAT) and 30% reductions in rice market access on average (Chapter 3). My "worst case" scenarios were developed using recent regional global change predictions. The first three scenarios present only risks of water scarcity. Risk intensities increase between each subsequent scenario, thereby creating an analytical connection between all three. The final three scenarios, labeled CM1, CM2, and CM3, include subsequently increasing intensities of both water scarcity and decreased rice-market access, also in an effort to create an analytical connection between the three.

Table 5.1 – Scenarios provided to each farmer designed to garner perceptions about how they would adapt to future changes

Scenario #*	**Scenario description provided to farmers**

C1	*Let's assume all debts are cleared, and you are once again growing rice* [this first sentence was only read if smallholder farmer had switched to sugarcane production]. *Over the next ten years, assume you* ***were guaranteed*** *rice-purchase contracts with fair purchase prices that ensured you could sell anything you produced to a rice mill, but you were not able to purchase insurance to protect against insufficient water during planting* [December-January]. *Then, if the increasing drought reduced the water that SENARA* [Costa Rican ministry responsible for water allocation in the PRAT] *was able to allocate to you by* ***1/6****, which of the following actions would you take, and what would be required to take each action? And, if you would do something differently, what would it be?* [A list of adaptive actions taken by farmers in the PRAT from 2002 to 2012 was then provided to each survey participant]
C2	*Let's assume all debts are cleared, and you are once again growing rice. Over the next ten years, assume you* ***were guaranteed*** *rice-purchase contracts with fair purchase prices that ensured you could sell anything you produced to a rice mill, but you were not able to purchase insurance to protect against insufficient water during planting. Then, if the increasing drought reduced the water that SENARA was able to allocate to you by* ***1/3****, which of the following actions would you take, and what would be required to take each action? And, if you would do something differently, what would it be?*

C3	*Let's assume all debts are cleared, and you are once again growing rice. Over the next ten years, assume you **were guaranteed** rice-purchase contracts with fair purchase prices that ensured you could sell anything you produced to a rice mill, but you were not able to purchase insurance to protect against insufficient water during planting. Then, if the increasing drought reduced the water that SENARA was able to allocate to you by **1/2**, which of the following actions would you take, and what would be required to take each action? And, if you would do something differently, what would it be?*
CM1**	*Let's assume all debts are cleared, and you are once again growing rice. Then, assume you **were not guaranteed** a contract with a fair purchase price, and assume mills and middlemen reduced their purchases from parcelaros* [smallholder farmers who were given land or who were sold land at discounted rates by the government; surveyed participants were *parcelaros*] *by **1/3** over the next ten years. Also, if no insurance was available to protect against insufficient water during planting and increasing drought reduced the water that SENARA was able to allocate to you by **1/6**%, which of the following actions would you take, and what would be required to do so? And, if you would do something differently, what would it be?*
CM2	*Let's assume all debts are cleared, and you are once again growing rice. Then, assume you **were not guaranteed** a contract with a fair purchase*

	price, and assume mills and middlemen reduced their purchases from parcelaros by ***1/2*** *over the next ten years. Also, if no insurance was available to protect against insufficient water during planting and increasing drought reduced the water that SENARA was able to allocate to you by* ***1/3****%, which of the following actions would you take, and what would be required to do so? And, if you would do something differently, what would it be?*
CM3	*Let's assume all debts are cleared, and you are once again growing rice. Then, assume you* ***were not guaranteed*** *a contract with a fair purchase price, and assume mills and middlemen reduced their purchases from parcelaros by* ***2/3*** *over the next ten years. Also, if no insurance was available to protect against insufficient water during planting and increasing drought reduced the water that SENARA was able to allocate to you by* ***1/2****%, which of the following actions would you take, and what would be required to do so? And, if you would do something differently, what would it be?*

*The designation 'C' (climate) represents scenarios including only water scarcity; the designation 'CM' (climate-market) represents scenarios including both water scarcity and decreased rice-market access.

**Scenario CM1 was designed to mimic changes in water availability and market access from 2002 to 2012 among smallholder farmers in the PRAT.

The 2007 Intergovernmental Panel on Climate Change reported strong consensus among climate models that temperature will increase and precipitation will decrease in much of Pacific Central America in the next four decades (Magrin et al., 2007). Downscaled regional climate models for northwest Costa Rica predict higher temperatures and water deficits in the region within the next two decades (Anderson, Flores, Perez, Carrillo, & Sempris, 2008). Wet season precipitation is expected to decrease as much as 27%, creating soil-moisture deficits and reducing the amount of surface water available for irrigation by half. Dry season river flow is also expected to decrease due to reduced cloud cover on mountain ridges (Karmalkar, Bradley, & Diaz, 2008). A trend towards increasing aridity is already evident in NW Costa Rica (Birkel & Demuth, 2006), and this is already having impacts on agriculture and water availability (Poveda, Waylen, & Pulwarty, 2006; Waylen, Quesada, & Caviedes, 1996). These studies indicated that a reduction of irrigation water in the PRAT of 50% (32 m^3 sec^{-1}) is not an unreasonable future scenario. Also, the upcoming expansion will increase the irrigated area by over 8,000 hectares, almost certainly leading to further over-allocation of scarce water resources.

Costa Rica ratified CAFTA-DR in 2007, and the treaty took effect on January 1, 2009. Under CAFTA-DR, approximately 80% of industrial and consumer goods from the United States can enter Costa Rica tariff-free. However, Costa Rica was able to preserve its high import tariffs on many agricultural goods, at least initially. As part if its ratification, Costa Rica agreed to a slow phase-out of its 35% import tariff on rice. By 2025, there will be no import tariff for rice in Costa Rica, and domestic producers will be competing with even cheaper imported rice. Notably, rice is already less expensive on the world market than domestically produced rice. This is due to the production efficiency of rice in the USA, China, and Thailand, which averages 7 metric tons per hectare, compared with Costa Rica's average of 4 metric tons per hectare (Arroyo et al., 2013). Many worry that this slow phase out of the import tariff will drive small rice producers from the market. My scenarios reflect this slow reduction in rice import tariffs between 2013 and 2025. While exact predictions of reduced market access per year for smallholder rice farmers were impossible, a complete reduction by 2025 may be expected unless government price supports are enacted.

3.3 Data collection and analysis

Three types of data—focus groups, household surveys, and household interviews—were collected and analyzed in different ways to understand limits to adaptation. I drafted a household survey that included questions about how farmers have adapted to changes in water scarcity and decreased rice market access over the last ten years, and about how farmers would adapt given my six scenarios that portrayed differing severities of future water scarcity and decreased rice-market access. The household survey was developed following the guidelines for the collection of quantitative primary data in developing countries as described by the United Nations Department of Economic and Social Affairs (2008). Following the iterative process defined by the United Nations Department of Economic and Social Affairs, I refined the household survey by holding three focus groups with smallholder farmers in the communities of San Martin and San Ramon, within the PRAT, in February 2013. Each focus group lasted approximately one hour and included 4-8 farmers, and each was held in or outside the home of a farmer.

Focus groups were documented using facilitator notes. In each focus group I asked farmers to talk openly about, and then attempt to reach a consensus description of:

1. Smallholder farmer valued livelihood goals;
2. The strategies smallholder farmers employed to adapt to water scarcity and decreased rice-market access;
3. Which strategies were used to adapt to tolerable and intolerable levels of risks (as described below, tolerable risks are perceived as threatening but worth assuming in pursuit of livelihood goals, and this perception initiates individual adaptations to these risks within reasonable levels and intolerable risks are those that exceed the value of pursuing current valued livelihood goals), and;
4. The capital required to implement each strategy.

A bilingual research assistant, trained at *Centro Agronómico Tropical de Investigación y Enseñanza* (CATIE) in facilitation techniques, facilitated all focus groups. Focus groups were documented using facilitator notes, and I analyzed these notes using the content analysis method described by Sandelowski (2000). I looked for major themes, insights, common phrases and words, and specific moods and tones across the notes from all three focus groups. The facilitator first coded all focus group documentation, and then I recoded the documentation to ensure consistency. Common themes in these data were categorized into clusters representing different livelihood goals and adaptation resources. The clusters were used to develop a picture of the different valued livelihood goals and resources used by farmers to adapt. Scoones's (1999) classification typology of “capital,” including human, social, physical, financial, and natural was used categorize each adaptation resource.

The household survey was pretested by surveying five households in the San Martin district of the PRAT. I then revised the survey for clarity based on the feedback from these farmers. The final survey was comprised of (1) questions structured in order to collect data on demography, assets and wealth, access to markets and services, and perceptions of climate changes; (2) the six scenarios described in Table 5.1, and; (3) questions structured in order to collect data about which adaptations farmers had undertaken in response to changes in the climate, and to combined climate and crop market changes between 2002 and 2012. Farmer adaptations were classified by their yes or no replies. I also included a short, semi-structured interview in each household survey. During these interviews I asked farmers to elaborate on their scenario-based adaptations. I also asked farmers: "do you think these adaptations will be necessary in the future, and why or why not?"

A bilingual research assistant administered all surveys and interviews. My sampling frame consisted of smallholder farmers from each of the seven Costa Rican Agricultural Development Institute (*Instituto de Desarrollo Agrario*, IDA) districts in the PRAT. According to my sampling strategy, I visited every household in each of these seven districts, on a regular basis, multiple times, and at random times. During these visits, farmers who were found in their homes or in their fields were interviewed, if they agreed to be. In total, 94 surveys were administered from February to November 2013. Each survey lasted from 20 minutes to 30 minutes. Some farmers invited us into their homes for the interview portion of each survey, which lasted up to 1.5 hours. I recorded interviews and the University of Costa Rica, School of Anthropology transcription service transcribed them. No names and no specific locations were recorded with surveys or interview data to ensure the responses of farmers remained anonymous, in accordance with my IRB approval.

4. Results and discussion

Rice was the crop of choice among surveyed farmers, and it was traditionally the only smallholder crop that drew profit in a consistent market. In 2002, virtually all smallholder farmers in the PRAT grew rice (Arriagada et al., 2010). This percentage has decreased as farmers have switched to sugarcane production because it has become increasingly difficult for smallholder farmers to secure contracts with rice mills, and because water scarcity is increasingly threatening rice crops. In my analysis, 40% of farmers declared sugarcane as their primary crop type (Table 5.2), and 60% continued to plant rice, many without gaining the livelihood security of a contract from a rice mill. Rice production without a contract means that farmers must search for remaining capacity at regional mills to sell their rice after harvest. Those farmers who transitioned to sugarcane production did not identify themselves as 'farmers' in the same way that rice farmers did, and they were often ostracized by their rice-producing neighbors. They claimed that they were forced to abandon their agricultural goals because the risks to rice production were not worth the opportunities that it afforded them.

Table 5.2 – Summary of livelihood characteristics of surveyed farmers (N=94)

Description (categorical variables)	**Type**	**Frequency**

Primary crop (type)	Rice	60%
	Sugarcane	40%
Land Tenure (type)	Own	72%
	Rent	20%
	Both	7%
Farm equipment ownership (type)	Own	34%
	Rent	57%
	Both	9%
Respondent has crop insurance	No	64%
	Yes	36%
Respondent owns livestock	No	47%
	Yes	53%
Presence of formal educational training in household	No	75%
	Yes	26%
Farming is household's principle income source	No	19%
	Yes	81%

Description (scalar variables)	**Mean**	**Std. Dev.**	**Min**	**Max**
Years spent farming (years)	22	7.2	2	36
Age of head of household (years)	51	14	20	83
Children in household (count)	2.9	1.9	0	10
Children in agrarian employment	0.8	1.4	0	8

(count)				
Size of Farm (hectares)	8.8	8.0	0.8	50

4.1 Defining farmer adaptation limits

4.1.1 Valued livelihood goals among smallholder rice farmers in the PRAT

Within the framework proposed by Dow et. al. (2013), adaptation limits represent thresholds beyond which farmers can no longer adapt or cope with the impacts of global change risks to meet existing valued livelihood goals. As risks associated with global changes increase toward these thresholds, risks to valued objectives may become intolerable, at which point farmers must live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss. To understand the conditions under which rice farmers in the PRAT may abandon their goals, I first identified and articulated these goals.

Among the farmers included in this study, these goals fell sharply along two lines: security of well-being and personal identity. Farmers sought (1) security of education, healthcare, and the maintenance of assets and land for all family members, and (2) the maintenance of their identities as *parcelaros* (i.e. smallholder farmers who were given land or who were sold land at discounted rates by the government). The preservation of household well-being was a primary concern among smallholder farmers because many had suffered livelihood setbacks between 2002 and 2012, and most were worried about the impacts of future risks. Many farmers cited recent examples of neighbors' misfortunes and resulting abandonments of farming. Both security and well-being were defined as broad concepts, but participants were clear that either concept, independently, would not constitute a valued livelihood goal. Farmers sought a condition of prosperity within their households (i.e., well-being), but the maintenance of this condition was only possible if it was protected from risk (i.e., security).

Participants also referenced the past and a perceived disappearance of their "*parcelaro* identity." In these references, farmers portrayed themselves as rice farmers that were being forced out of their trade by the Costa Rican government, international rice imports, and by rice mills. Torres (1997) shows that most *parcelaros* throughout the 1990s refused all efforts by the Ministry of Agriculture to provide extension services to assist in a transition to "non-traditional" crop types as required by the demands of the Costa Rican economic restructuring. Extension agents promoted non-traditional agriculture as a means to increase the production of internationally valuable crop types, but *parcelaros* refused, citing their history in rice production.

This *parcelaro* identity is unique among Costa Rican farmers, and it reflects the wider *Guanacasteco* identity—one of conservative self-reliance—that reflects the long-standing agrarian culture of Guanacaste Province. Guanacaste, and specifically the Tempisque River Basin, is rich in arable land, with large expanses of flat, fertile alluvial soils, so agriculture developed as a primary economic sector within the region. *Parcelaros* have traditionally considered themselves the "last holdout" in Costa Rica against increasingly globalized agriculture (see Edelman, 1999 for rich historical descriptions of smallholder agriculture in Guanacaste). In this context, *parcelaros* referenced their identity as self-reliant, community-oriented, loyal to their own, and deeply respectful of their lands and environment. This identity is unique to rice production in Northwest Costa Rica because *parcelaros* perceive rice to be of greatest importance to Costa Rican culture and food security, and less impactful on the Guanacaste environment. This pride was evident among farmers in my study. Participants referenced a transition to sugarcane as giving up on these values. One farmer explained why his decision to continue to farm rice entailed more than profit.

> *"Even though the banks no longer finance rice [for smallholder farmers], and even though everyone who used to buy rice no longer does so, I still sow rice. Now some people tell me to plant sugarcane, but the sugarcane impoverishes the land and the sugarcane removes the vitamins from the land. It is like I will be removing the food from the land. That is why I grow rice, even if I will not gain what I used to. Here in Bagatsí, it is not worth it, it is not worth it. I do not ever sow sugarcane"* (Interviewee #25, 11.2-hectare rice farmer, February 20th, 2013).

Another farmer explains his traditional ties to rice production, and contrasts this with his perceptions of the environmental damage caused by the harvest of sugarcane (sugarcane fields are burned before harvest to remove leaves).

> *"I do not like sugarcane in the least. For me, I do not like sugarcane because I have always sowed rice, and I always like to see it grow. When you flood [the rice paddy], it is something that is totally beautiful, when it sprouts and you see the green – beautiful. Sugarcane is not this way. I do*

not like what sugarcane does to the environment. When they burn [sugarcane], and then when they cut the sugarcane it is extremely, for me, it is extremely polluting. Because when they harvest, even [when they harvest sugarcane] miles from here, you just see smoke, and we are surrounded by about 2000 hectares, or more than 2000 hectares of sugarcane" (Interviewee #64, 5-hectare rice farmer, March 4th, 2013).

A third farmer describes the process of transition to sugarcane production in the PRAT and compares this with his own values.

> *"Before, this area used to be all rice. Now it is all sugarcane, and rice will disappear. Why? Because there is no financial support, you cannot sell it, the government lets in rice from other countries and they forget the small producer. Sugarcane has some advantages–you rent your land to the 'ingenio' and they take care of everything, but I lose everything"* (Interviewee #22, 2-hectare rice farmer, February 20th, 2013, note: 'ingenio' is Taboga S.A., the largest industrial sugarcane producer in Costa Rica, see TABOGA, 2014).

Within the adaptation-limit framework used in this study, an adaptation limit would entail that the risks to household security of well-being or to the *parcelaro* identity have become intolerable and thus change is required. This would require farmers to live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss and conserve goals. Livelihood goals are widely acknowledged to play a significant role in defining adaptive actions (Dow, Berkhout, & Preston, 2013; Pelling & Dill, 2009; Renn, 2008). The integration of these goals into my examination of adaptation limits was critical because the ultimate objective of any farmer adaptation to global change risks is to meet valued livelihood goals (Füssel, 2007). Following this logic, increased incremental demand for adaptive actions among rice farmers in the PRAT was driven by individual perceptions of increased risks to valued livelihood goals, to a point. Among farmers represented in this study, increased severity of risks to their identity and security of well-being should be associated with increased efforts to adapt, but the ability to increase adaptive efforts relies on the availability of resources (i.e., objective adaptive capacity) and on the perception of costs of adaptation compared to the value of livelihood goals.

Grothmann & Patt (2005) defined objective adaptive capacity in terms of resources such as time, money, staying power, knowledge, entitlements, and institutional support. The ability of smallholder rice famers in my study to adapt to pursue livelihood goals depended, in part, on those resources to which they had access. I asked farmers in my focus groups to define both the actions they used to adapt to water scarcity and decreased market access and the resources required to implement each (Table 5.3). I classified the resources required to implement each action using Scoones's (1999) classification typology. This typology includes five different types of capital: human, social, physical, financial, and natural. Following this logic, farmers in my study may combine the capital endowments to which they have access and control in order to respond to water scarcity and decreased rice market access. Through time, these capital portfolios were dynamic as farmers responded to risks. Continued adaptation to risks may deplete the portfolio of a farmer, thereby forcing them to take an action that undermines their goals of security or identity.

Table 5.3 – Summary of farmer adaptations to global change risks in the PRAT, including the corresponding acceptability and objective adaptive capacity required to perform each adaptation; this capacity is defined in terms of capital types, and costs of each adaptation.

Farmers adaptations	**Description**	**Acceptability of risk**	**Objective adaptive capacity required: types and 'costs' of capital required for adaptation (cost levels in parenthesis)**
Voluntarily decrease planted area	Farmers reduced their planted area in response to threats of water scarcity. Farmers also reduced the	Tolerable	*None*

	number of plantings per year, typically in response to a failure to sell their rice crop. Farmers in the PRAT may grow two or three rice crops per year if they obtain rice contracts.		
Diversify crops	Farmers switched their rice varieties to those better suited to a changing climate. These new varieties were more drought/heat tolerant and some have a shorter growing period. Some farmers also started experimenting with different crops that were better suited to a changing climate like watermelon.	Tolerable	*Human capital:* Knowledge of new type or variety (low) *Social capital:* Access to appropriate labor for new crops (low) *Natural capital:* Appropriate soil; appropriate micro-climate (varies) *Physical capital:* Access to planting, maintenance and harvest equipment (high) *Financial capital:*

			Capital to obtain equipment, and initial and continuing input costs (high)
Sell land	Some farmers sold their land in response to debts accrued through the loss of a rice crop, or the failure to sell a rice crop. These farmers in our study had sold their land, but still farmed that land under contract with other farmers or with larger mills.	Intolerable	*Social capital*: Access to buyer (low) *Financial capital:* Money to cover legal costs (low)
Rent land to other farmers	Farmers rent their land to neighbors or mills. Rental agreements vary widely, but many are long-term. This is especially true when farmers rent their land to sugarcane mills. These farmers often live on	Intolerable	*Social capital:* Access to renter (low) *Financial capital:* Money to cover legal costs (low)

	the parcel and continue to engage in agriculture as a *chambaro* (i.e. odd-job worker, or farm-hand).		
Sell assets (if owned)	Farmers sold their harvesting and planting equipment	Tolerable/ Intolerable	*Social capital:* Access to buyer (low)
Diversify household employment	Many households engage in less-climate-change-sensitive off-farm activities, which include either (1) *chambas* (i.e. odd jobs) or (2) a migration of household members to cities in search of employment.	Tolerable	*Human capital:* Alternative knowledge and skill set (depending on the job this varies in cost from low to high cost) *Social capital:* Access to labor market (high) *Physical capital:* Means of access to new locations (high) *Financial capital:* Money for transportation and the development of new skillsets (high)

Utilize river or ground-water	Farmers with access to river or ground water and an efficient means to maintain that access often install wells or pump water to their fields. Pumping rivers was the most common method of among farmers in this study. And, only those farmers with access to river water were able to utilize this adaptation.	Tolerable	*Social capital:* Access to drilling expertise (high) *Natural capital:* Groundwater/river availability (varies) *Financial capital:* Money to cover drilling and equipment costs (medium)
Engage in conflict	Conflict included threatening neighbors or water managers, destroying or altering irrigation infrastructure, and protesting.	Tolerable	*Social capital:* Support and collaboration from neighbors (high, as people engage in conflict when other actions have proven unsuccessful or are blocked) *Financial capital:* Money to cover transportation

			and lodging costs (low)
Change planting date	The majority of the farmers in our study have altered their cropping sequence by moving the planting date of their first rice crop back from mid-December into January at least one time; many have moved their planting date back four to five times between 2002 and 2012. This change is in response to reductions in water allocations for many farmers in the PRAT. Those farmers furthest downstream in the irrigation system are most affected.	Tolerable	*None*
Transition to sugarcane production	Sugarcane mills purchase smallholder farmer rice debts, and in return farmers	Intolerable	*None*

	grow sugarcane under the supervision of one of three industrial mills. Farmers retain their land but are unable to pursue valued livelihood goals.		

4.1.2 Risk tolerability

The 'time element' was a crucial part of the study of farmer limits to adaptation in this case because different farmers seemed to perceive their ability to efficiently use objective adaptive capacity through time differently. As farmers in this study expended capital to meet valued livelihood goals, in the face of increasing water scarcity and decreasing rice market access between 2002 and 2012, they adopted multiple, incremental adaptations (Table 5.4). This is consistent with, and supports Park et al.'s (2012) modification of Loorbach's (2007) Transition Management Cycle to reflect the relative difference between incremental and transformative adaptation processes in terms resources used. Farmers took multiple adaptations when risks were perceived as tolerable but increasing through time. Other, transformative adaptations were taken when farmers perceived risks as intolerable. Transformative adaptations to intolerable risks required farmers to revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss.

Table 5.4 – Adaptations taken by surveyed smallholder farmers to risks between 2002 and 2012. These risks included a reduction in local rice market access by one-third, and a water deficit during planting season of one-sixth. Not all farmers experienced these risks equally as some were able to respond to continue to pursue their valued livelihood goals while others were not. 'Climate specific adaptations' shown here reflect the total number of adaptations taken by surveyed farmers to water scarcity; 'Combined water scarcity and rice market adaptations' represent the sum of adaptations taken to both.

Farmers adaptations	**Climate specific adaptations**	**Climate freq.**	**Combined adaptations to water scarcity and rice market changes**	**Combined freq.**
Voluntarily decrease planted area	35	37%	35	37%
Diversify crops	22	23%	24	26%
Sell land	0	0%	1	1%
Rent land to other farmers	1	1%	9	10%
Sell assets	1	1%	10	11%
Diversify household employment	6	6%	26	28%

Utilize river or ground-water	22	23%	22	23%
Engage in conflict	13	14%	14	15%
Change planting date	65	69%	65	69%
Transition to sugarcane production	17	18%	37	40%
	TOTAL: 182		**TOTAL: 243**	

Dow et al. (2013) and Grothmann & Patt (2005) both stressed the need to incorporate individual perceptions of risks into the study of adaptation. Across farmers in this study, there were a range of attitudes and responses with respect to the acceptability or tolerability of risks. These differences translate to different adaptation limits among households. Leiserowitz (2005) argued that these discrepancies occur across any one group because the same global change process may appear very risky and intolerable for one individual, but tolerable for another. Dow et al. (2013) built on this understanding of a range of levels of risk acceptability or tolerability, and provided three categories into which individuals may perceive global change risks and initiate adaptive actions based on these perceptions:

1. *Acceptable risks* are perceived as not threatening to livelihood goals, and therefore no risk reduction efforts are needed.
2. *Tolerable risks* are perceived as threatening but worth assuming in pursuit of livelihood goals, and this perception initiates individual adaptations to these risks within reasonable levels.

3. *Intolerable risks* are those that exceed the value of pursuing valued livelihood goals, requiring individuals to live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss.

Farmers in this study maintained their livelihood goals and implemented incremental adaptations to tolerable risks when risks of water scarcity and decreased rice market access were perceived to be within tolerable levels, and livelihood goals were more highly valued than the costs of the adaptations to preserve them. Other adaptations were adopted in the face of intolerable risks. Those adaptations adopted in the face of intolerable risks represented adaptation limits. Of the ten types of adaptations utilized by farmers in this study (Table 5.4), three were classified by farmers as adaptations to intolerable levels of water scarcity and decreased market access. The implementation of those adaptations required farmers to revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss. One adaptation, "sell assets," was employed in the face of both tolerable and intolerable levels risks, depending on the context. Some famers may sell their harvesting and planting equipment to pay debts, then rent that equipment back to pursue their valued livelihood goals. This allowed farmers to maintain their identity and continue to provide security of household well-being. However, many farmers who liquidated their assets also did so as part of a transition out of rice farming.

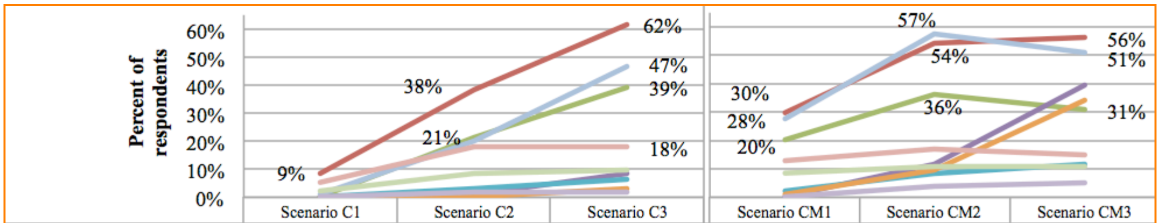
The adaptation "renting land to other farmers" was typically used to escape debts accrued through rice farming. Most farmers who rented their land continued to involve themselves in agriculture, but they no longer self-identified as *parcelaros*. Rental agreements varied widely, but many were long-term (e.g., 10 years). These farmers often lived on the parcel and continued to engage in rice-related agriculture as *chambaros* (i.e. odd-job worker, or farm hand). Farmers who sold their land, a third adaptation to intolerable risks, typically did so in a response to debts accrued through the loss of multiple rice crops due to water scarcity, or the failure to sell multiple rice crops. Those farmers who had sold their land often farmed that land under contract with other farmers or with larger mills. These farmers also typically worked as *chambaros* to diversify their household incomes.

The "transition to sugarcane production" was also considered an adaptation to intolerable risks of water scarcity and decreased rice market access. This adaptation was the most common transformative adaptation to the impacts of intolerable levels of risks among farmers included in this study, as 40% had implemented this adaptation. Between 2002 and 2012, sugarcane mills pushed full land management sugar contracts in an effort to bolster production (Stange & Attaché, 2013). These contracts involved the purchase of rice debts that smallholder farmers accrued through failed rice crops or through the inability to sell their harvests. Under these contracts, the sugarcane mills managed and farmed plots, and smallholder landowners received a flat fee per hectare depending on their debt, but that fee often left farmers below the Costa Rican poverty level. Most farmers were able to retain their homes and land through a transition to sugarcane production, but this transition required farmers to forfeit their *parcelaro* identities as well as considerable well-being. Many farmers in this situation tried to engage in full-time non-farm employment after transitioning to sugarcane, typically in the transportation, farm equipment maintenance, and tourism sectors. However, many were (at the time of this study) forced to live with losses as they had few alternative livelihood options due to their remote location, lack of education, and limited connections outside of agriculture.

The common thread to farmer adaptations to these intolerable risks is that they have an element of irreversibility about them in the sense of giving up a livelihood goal, and therefore requiring some type of livelihood transformation. Farmers could not "transition livelihoods for one-year," to then return to rice production. Farmers seemed to only implement such adaptations if the alternative was even worse (e.g., dealing with debt collection services or suffering from food insecurity). This irreversibility forces farmers to make difficult adaptation choices about trade-offs among goals and values, or about their ability to radically change behavior, which for many, came at large costs.

4.2 Smallholder farmer adaptation appraisal

I used scenarios of plausible risks to gain insight into how farmers thought about avoiding limits, and into the costs farmers perceive themselves as bearing to meet valued livelihood goals. Among farmers included in this study, the impacts of water scarcity and decreased rice market access were apparent, but the processes driving these risks were debated. Therefore, I designed my six scenarios to elicit adaptation responses from farmers regardless of farmer believes about the causes of risks. After presenting each scenario to all farmers included in my survey, I asked each farmer to evaluate his or her ability to adapt to the proposed risks, along with the costs of taking such actions by defining all of the ten common adaptations they would apply in each case. I summed and ranked perceived adaptations across all farmers (Figure 5.2).



	Scenario C1	Scenario C2	Scenario C3	Scenario CM1	Scenario CM2	Scenario CM3
Voluntarily decrease yield	9%	38%	62%	30%	54%	56%
Diversify crops	0%	21%	39%	20%	36%	31%
Sell land	0%	1%	9%	0%	12%	39%
Rent land to other farmers	0%	3%	6%	2%	9%	12%
Sell assets	0%	0%	3%	1%	10%	34%
Diversify household employment	1%	20%	47%	28%	57%	51%
Utilize river or ground-water	5%	18%	18%	13%	17%	15%
Engage in conflict	2%	9%	10%	9%	11%	11%
Change planting date	88%	87%	83%	78%	70%	68%
Transition to sugarcane production	0%	2%	2%	0%	4%	5%

Figure 5.2 – Summary of adaptations to scenarios presented to farmers during household surveys; "sell land," "rent land to other farmers," "sell assets," and "transition to sugarcane production" are adaptations used by farmers when faced with intolerable risks, the remainder are used to adapt to tolerable risks.

The four most widely used adaptations to increased water scarcity across water-scarcity-only scenarios (C1, C2, and C3) were "change planting date," "voluntarily decrease planted area," and "diversify household employment." In scenario C3, having the largest number of perceived adaptations in response to risks, "change planting date" and "voluntarily decrease planted area" were typically cited as the first (84% of farmers indicated their first adaptation would be to "change planting date") and second (35% of farmers indicated their second adaptation would be to "voluntarily decrease planted area") adaptations to be taken, respectively. "Diversify household employment" was cited as the third adaptation to water scarcity (30% of farmers indicated their third adaptation would be to "diversify household employment"). This ranking again supports Park et al.'s

(2012) idea of incremental adaptation to tolerable risks. None of the four adaptations to intolerable risks were widely perceived as necessary given the risks presented in scenarios C1, C2, and C3. Almost all farmers perceived themselves as being able to successfully and incrementally adapt to conditions of 50% less water in the future without needing to abandon their household security of well-being or their personal identity as *parcelaros*.

The adaptations most relied upon among farmers to the conditions presented in water scarcity/limited rice-market access scenarios CM1 and CM2 were (in order of application) “change planting date,” “voluntarily decrease planted area,” “diversify crops,” and “diversify household employment.” Farmer responses to the conditions presented in both of these scenarios included very few adaptations to perceived intolerable risks. Roughly one in eight farmers perceived themselves as responding to the risks presented in scenario CM2 by selling their land, and most farmers would first rent their land and sell their assets.

A transition in farmer perceptions of the tolerability of the risks presented in my scenarios for many farmers occurred between the risks presented in scenario CM2 and those presented in CM3. In CM3, 39% of farmers claimed that they would ultimately abandon agriculture if conditions in the PRAT matched those described in the scenario. Interestingly, few farmers perceived themselves as transitioning to sugarcane production. Many quickly realized that the risks presented in scenario CM3 were too costly and a transition would be needed. In scenario CM3, I also found a decrease in perceived reliance on household income diversification and crop diversification before a land sale, when compared to adaptations to the risks presented in scenario CM2. This drop was most likely a result of my scenario exercise because farmers seemed to quickly perceive the risks presented in scenario CM3 as intolerable, and therefore were less willing to take the time to cite and rank every adaptation they would take prior to an adaptation limit.

4.2.1 Costs of adaptations within an adaptation appraisal

Almost all surveyed farmers perceived themselves as assuming increasingly costly adaptations throughout my scenarios, and most agreed that they would continue to pursue their current livelihood goals under all scenarios rather than bear the costs of transitioning out of rice production. In each scenario, most farmers ranked adaptations in order of increasing cost. In this way, farmers seemed to think rationally about avoiding limits by implementing increasingly costly adaptations, but most were unwilling to admit that they would ever transition to sugarcane production. Even of the farmers who had transitioned to sugarcane production, few were willing to admit to another transition to sugarcane.

Grothmann & Patt (2005) showed that an adaptation appraisal process includes perceived adaptive capacity, which includes perceptions about the willingness to use available capital to adapt to risks. These perceived adaptation costs are the assumed capital costs of taking the adaptive response (shown in Table 5.3 as associated with specific adaptations). In this scenario exercise, farmers perceived themselves as relying heavily on those adaptations requiring the lowest cost of implementation. The cost of implementation of any adaptation is comprised of the capital and the transactions associated with an adaptation. The opportunity costs of another adaptation type are assumed to play a role in decisions of farmers to utilize one adaptation over another.

Within this definition, "change planting dates" and "voluntarily decrease planted area" were considered the least costly and most easily implementable, as both required few transactions and few resources.

"Crop diversification" and "household income diversification" were the costliest adaptations available to farmers in terms of cost, taken in response to tolerable risks in the PRAT. Each required multiple types of costly capital to enact, and both required much time and effort on the part of a farmer. "Crop diversification" typically represented the switching to rice varieties that were better suited to the changing climate. "Household income diversification" was primarily an adaptation to reductions in rice market access, which typically included either (1) *chambas* (i.e. odd jobs) or (2) a migration of household members in search of employment in transportation or tourism. In farmer rankings of their perceived adaptations to each scenario, farmers overwhelmingly perceived themselves as implementing the lowest cost adaptations first. As risks increased in severity, farmers perceived themselves as relying on higher-cost adaptations. There appears to be a continuum of more and more costly adaptations that come at increasing personal cost. As adaptations increase in costs, almost 40% of farmers seemed willing to contemplate adaptation to intolerable risk, which includes decisions between living with intolerable risk of losses, revising attitudes about what is a valued objective, or changing behavior radically to avoid the intolerable risk of loss.

4.3 Limits to adaptations and livelihood transformation

Dow et al. (2013) showed that individuals may revise their attitudes about what is a valued livelihood goal, or they may greatly change their behavior and perception to avoid intolerable risks. This is a key insight into the nature of adaptations to risks among farmers in this study, as it speaks to the fluidity of their limits to adaptation, and to their transformative capacity. In circumstances where an individual is given a lack of adaptation options or resources, or given high uncertainty about the nature of a risk, individuals may revise their attitudes and trade-off livelihood goals to transform their livelihoods. The perceived adaptations of farmers in this study to tolerable and intolerable risks constitute a range of perceptions of costs and irreversible commitments indicating differences in household risk exposure, sensitivity, capacity, and vulnerability to decreased rice market access and water scarcity. In the context of risks presented in my scenarios, many farmers were able to admit to the possibility that the future may bring intolerable risks, and this may suggest that farmers may be well grounded in the realities they face (Eakin, 2014). However, some farmers refused to consider the plausibility of the stated risks. This diversity, reflected in my results, may reflect the long-understood complexity among groups of smallholder farmers (Morton, 2007).

Responses to my semi-structured interviews provided insight into the complexity of limits to adaptation among those smallholder farmers who participated in my study. When asked, "do you think these adaptations [referencing scenario responses] will be necessary in the future, and why or why not?" farmers responded with a range of perspectives on the future. For example, one farmer responded with concern, but also with an unwillingness to discuss adaptation options. When asked about water scarcity, he responded by stating

> *"A big water shortage [of the magnitude described in scenario C3] has never happened, and it will not happen"*

(Interviewee #11, 17-hectare rice farmer, Playitas, February 11st, 2013).

Then, when asked about the plausibility of risks presented in scenario CM3, the same farmer responded by stating

> *"I do not know [what I would do], things have never been that bad"* (Interviewee #11, 17-hectare rice farmer, Playitas, February 11st, 2013).

His neighbor seemed more willing to discuss and contemplate his potential actions, and also seemed more willing to abandon agriculture rather than transition to sugarcane production. When asked about the risks presented in scenario CM3, he stated

> *"If I lose rice-market access, I will consider selling my land. I will not change [to sugarcane production]"* (Interviewee #12, 7-hectare rice farmer, Playitas, February 11st, 2013).

Another farmer in the same district seemed more willing to abandon rice production, but unwilling to abandon his farm. He stated

> *"If it becomes impossible to sell [rice], I will grow sugarcane and seek another job. I will never sell [my land]"* (Interviewee #13, 8-hectare rice farmer, Playitas, February 11st, 2013).

A farmer in the neighboring district offered a different perspective when asked what he would do in the face of the risks posed in scenario CM3.

> *"When things get bad, we get into fights with the government because they do not like small farmers. That is what we will do. We go to the docks to keep the ships from unloading their rice, and that forces the people to buy local rice. We have been maced [by the police] before and everything was alright"* (Interviewee #23, 8-hectare rice farmer, Bagatzi, February 20th, 2013).

Farmer willingness to consider these multiple types of responses, including alternative non-farm income, and trading-off their *parcelaro* identities to maintain a connection to agriculture or to maintain some level of security suggests that this may be an adaptive population. The switch to sugarcane is indicative of a resignation of a farmer to insurmountable change (a "limit"), but a section of surveyed farmers have already confronted this limit and, as a result, are transforming their livelihoods while maintaining a connection to agriculture. This speaks to their transformative capacity. However, the anguish and hardship associated with these choices and transformations was also apparent, and must not be discounted in a discussion about livelihood transformation.

Park et al. (2012) show that incremental adaptation decision-making processes have distinct characteristics, compared with those used in transformative adaptation. In my scenario exercise, I showed that most farmers in this study were easily able to think about incremental adaptations to tolerable risks, but less were willing to think about transformative adaptation, seemingly because of the difficult choices it required. My semi-structured interviews offered insight into these difficult choices. When asked if adaptations the risks posed in scenario CM3 will be necessary in the future, one interviewee provided his perception.

> *"In my opinion this is a complicated issue. Before, there was only rice, and when they dug the [irrigation] channels, the only farming was rice farming. Sometime later sugarcane came along. Sugarcane does not leave you with rice that you cannot sell. But [Sugarcane mills] rent the land and they take care of the entire process and we gain little. That's one of the problems we have now. With sugarcane everyone suffers. In about two years there will only be sugarcane, and we will all slowly disappear."* (Interviewee #27, 10-hectare rice farmer, February 21st, 2013)

Another interviewee concurred, but provided a downstream perspective on the difficulty of trading off or abandoning livelihood goals.

> *"The problem was that it was a very bad winter* (May-August is referenced by farmers as winter)*, and the lagoon, which is the reservoir for the PRAT was very low. SENARA* (irrigation water managers) *started giving us water once*

> *every 4 days. But as I am at the end of the channel, there was almost no water for me. I lost half of my crop and I have no rice-purchase contract. I do not know what I will do."* (Interviewee #15, 7-hectare rice farmer, downstream in the PRAT, February 13th, 2013)

One farmer with brothers in the transportation sector replied,

> *"I realized that this life is not going to lead to anything. There is no future. Although I planted rice, I could not sell it and I could not get ahead. Why do I not do transportation [with my brother]"* (Interviewee #55, 15-hectare rice farmer, February 28th, 2013)?

Another farmer with relatives outside of agriculture, who had recently switched to sugarcane, concurred by saying,

> *"The idea was for us to stay here, the idea was that if we could dedicate ourselves to rice, we could get ahead. But the circumstances did not allow for this. So, out of fear had to leave rice"* (Interviewee #73, 7-hectare sugarcane farmer, March 12th, 2013).

A final farmer shared his thoughts about the future of smallholder farming in the PRAT in terms of the migrations of his family by stating,

> *"In about two or three years there will be very few people who live here. My family is large and even they are almost all gone. The only one left in my house is me, I have a total of nine brothers… they are all gone. Only I am here"*
> (Interviewee #82, 5-hectare rice farmer, March 18th, 2013).

Through these discussions with farmers, it was apparent that the implementation of an adaptation to an intolerable risk for many farmers was largely a 'negative' loss in terms of identity and security of well-being. However, at the time of this study it was unapparent if this loss would force households into long-term poverty. These adaptations to intolerable risks that require farmers to live with intolerable risk of losses, revise attitudes about what is a valued objective, or change behavior radically to avoid the intolerable risk of loss, while difficult and negative in the short-term, may not necessarily be failures in adaptation. Stated another way, a limit to adaptation does not necessarily equate to the inability of a farmer to transform their livelihood to meet revised or new livelihood goals. In the short-term, adaptation limits may force farmers to make difficult choices about adaptations and valued livelihood goals. A failed adaptation may be one that sends a household into poverty for a short time, which was apparent among some farmers in this study. However, most were critically thinking about their future options, which indicates they were not complacent or content bearing the risks of intolerable losses.

This analysis has shown that the successful adaptation of a farmer to intolerable risks in this context must incorporate some degree of transformative capacity to be successful. Marshall, Park, Adger, Brown, & Howden (2012) show that among some farmers in Australia, attachment to place may limit their abilities to respond to intolerable drought because it may act as barrier to transformative adaptation through discouraging migration to meet other valued livelihood goals. Hence, changes in objectives of adaptation and the in definition of risk may actually comprise successful adaptation near limits for farmers in the PRAT. And, the ability of a farmer to make these changes is based upon their ability to pursue transformative adaptive responses. In thinking about where incremental adaptation ends, and livelihood transformations begin among farmers in the PRAT, we may consider both as sub-sets within the broader suite of available adaptation strategies (Park et al., 2012). The key difference between the two lies in the extent of change, but the suffering and anguish associated with choices to trade-off goals and transform livelihoods cannot be discounted.

5. Conclusion

Forty percent of farmers included in this study had confronted adaptation limits and transitioned to sugarcane production between 2002 and 2012. Some of those farmers have maintained their homes and lands and have seemingly begun modifying their livelihood goals. Others have been forced into poverty, at least at the time of this study. The risks faced by the smallholder rice-farming sector in the PRAT are predicted to increase in scale and intensity. Following this logic, more farmers may abandon rice production and this means that transformations of valued livelihood goals will be required by some to successfully adapt to intolerable risks. These transformations may represent a switch to distinct new livelihoods where different sets of goals become valued and different sets of risks become intolerable. Our goal as researchers and development practitioners must be to provide options to limit the suffering accompanied with these transitions. To do this, we must better understand the trade-offs between transformational capacity, necessary to adapt to intolerable risks, and the capacity to meet valued livelihood goals in the face of tolerable risks. These trade-offs may be inherent in some agricultural systems, and successful adaptation to tolerable risks may act as a barrier to transformational change.

CHAPTER 6

CONCLUSION

1. Introduction

Between 1980 and 1982, Costa Rica experienced its worst economic crisis since its 1948 civil war. During this time the Costa Rican economy compressed by 9.4% and annual inflation reached 90%. During these two years, the proportion of the population living below the poverty line increased from 35% to 54% (Hidalgo, 2014). The roots of the crisis were in the decline of the country's economic model that was based on the import-substitution-industrialization (ISI) concept, which promoted the local production of industrialized goods and services over imports of foreign-produced products. Between 1950 and 1982, numerous inefficient state-owned enterprises arose within the ISI model. The ISI model was adopted in Costa Rica in 1949 in an effort to fight mass poverty and to compete with more developed nations. The government protected its new industries using import tariffs in the hopes that capital and a comparative advantage would develop, and it supported and managed many sectors of industrial and agricultural supply chains to promote this advantage.

The ISI model in Costa Rica encouraged a growing financial burden that overwhelmed the economy. Government spending was 54% of the gross domestic product by 1980 and Costa Rica's debt quadrupled during President Rodrigo Carazo's (1978–1982) term in office (Edelman, 1992). The cost of government financing also increased with increasing international borrowing rates, and President Carazo responded to the government's deteriorating finances by printing money, which devalued the currency. Inflation skyrocketed, sending hundreds of thousands of Costa Ricans into poverty (Hidalgo, 2014). Following this crash, in 1980s and early 1990s the Costa Rican economy underwent significant structural reforms. The International Monetary Fund (IMF), World Bank (WB), U.S.AID, and the Inter-American Development Bank (IADB), in return for financial support, mandated these reforms. Reforms included the privatization of most state-owned enterprises and the reduction or abolition of tariffs on many consumer goods. In 1985, the mean tariff rate was 55% while in 2013 it was 5.4% (Gwartney, Lawson, & Hall, 2013). While Costa Rica is no longer beholden to the IMF, WB, USAID, or the IADB, these reforms restructured economic institutions and contributed to Costa Rica's significant improvement in economic freedom. The State lost the ability manage many sectors of its economy, but the economy grew an average 4.7% per year between 1987 and 2013, one of the fastest rates in Latin America (Hidalgo, 2014).

Despite healthy growth rates, poverty in Costa Rica has remained at about 20% since 1990. In 2013 the poverty rate was 20.7% (INEC, 2014). Equally disturbing, and perhaps more concerning, is the fact that economic inequality has steadily risen across the country since 2000. Only three countries across Latin America have seen this kind of increase in economic inequity over the past decade, and Costa Rica is among them (CEPAL, 2014). The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) reported that Costa Rica's Gini Index (a comparison of income distribution used to measure inequity) increased from 0.47 to 0.50 between 2000 and 2011, which is a large decadal change (Hidalgo, 2014). This trend is nowhere more apparent than in Guanacaste, in northwestern Costa Rica – one of the two poorest provinces in the country. Within Guanacaste, this trend persists even as the government continues to fund agrarian development projects in this region, with the goal of using agriculture to boost households out of poverty. According to the National Statistics and Census Institute (INEC), the Tempisque River Basin region of Guanacaste is the poorest in the country, with almost 30% of the population below the poverty line and 15% living in extreme poverty (INEC, 2014). The region also has the highest rate of unemployment in the country—10.1%

The Arenal-Tempisque Irrigation Project (*Projecto de Riego del Arenal-Tempisque*, PRAT) in Guanacaste, Costa Rica is an agrarian development project that was initiated with the creation of the Agrarian Development Institute (*Instituto de Desarrollo Agrario*, IDA) in 1982, and the National Subterranean Waters, Irrigation, and Drainage Service (*Servicio Nacional de Aguas Subterraneas, Riego y Avenamiento*, SENARA) in 1983. These new agencies were given legal authority to dictate land use objectives for rural development. The development project was designed to address the high poverty rates in the region by providing irrigation water to farmers in the semi-arid Tempisque River Basin; the water comes from Lake Arenal in the east (see Figure 6.1). However, the project was born during this massive political economic transition.

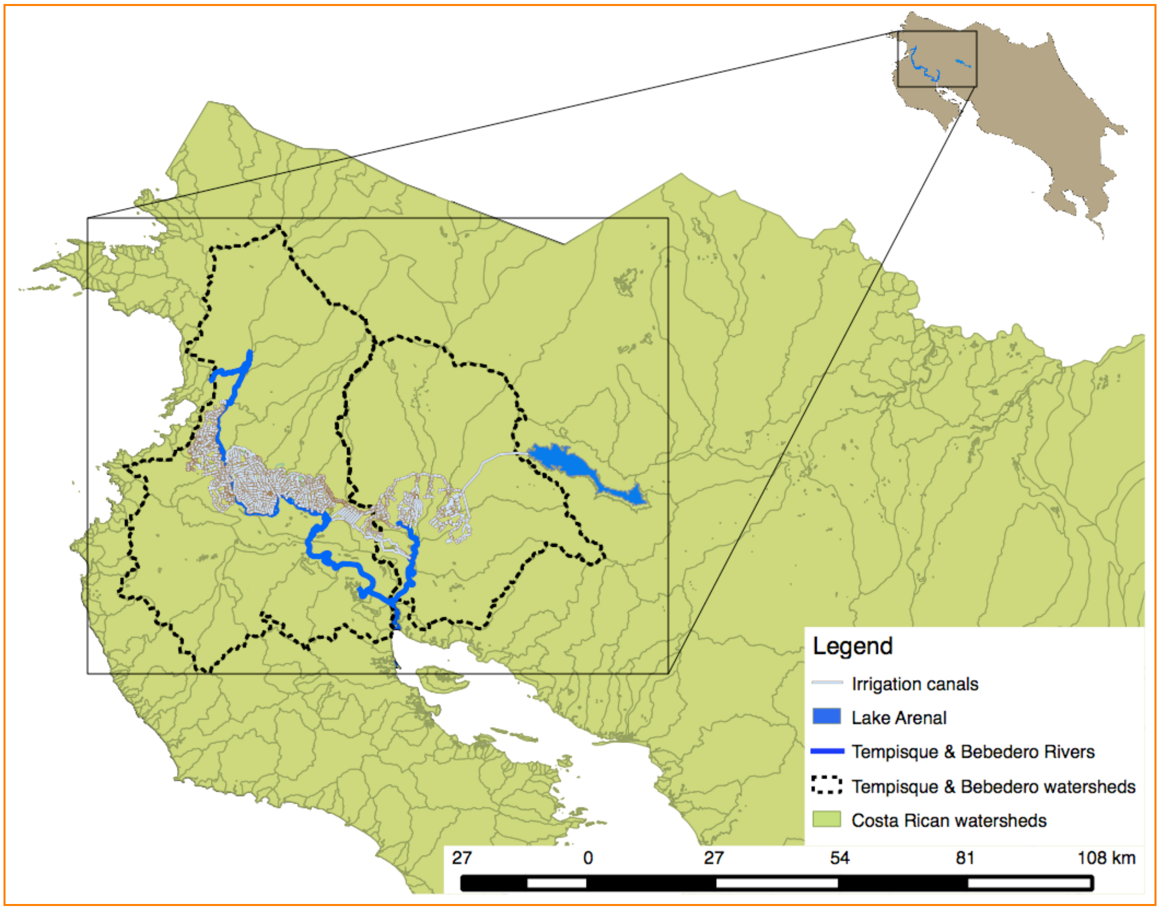


Figure 6.1 – Arenal-Tempisque Irrigation District (DRAT), Tempisque River Basin, Guanacaste, Costa Rica, watersheds, canal infrastructure, and water source

The PRAT was designed to address this extreme poverty that has persisted since before the structural reform. The idea was to provide smallholder farmers with plots of land, governmental extension services, and irrigation water. Market access was to be provided to smallholder farmers by the government. Agro-industries, funded in part and regulated by the state, were to provide milling and refining capacity for the smallholder farmers. While the original goals of the PRAT never changed, the government's capacity to see them through to fruition did, largely due to the structural reforms. Costa Rica's structural reforms during the 1980s and 1990s fundamentally changed the ability of the PRAT to support the most vulnerable farmers, and this vulnerability only became evident as global change risks began impacting Costa Rican agriculture. However, the reform itself did not undermine the project. Rather, the adaptations of large, economically and politically powerful farms manipulated structural reforms and created barriers to smallholder rice farmer adaptations. Specifically, these barriers to trade liberalization were created by foreign and domestically owned, large-scale industrialized rice farms, and these barriers limited rice market access for smallholder farmers. A perhaps unintended consequence of these political maneuvers was water scarcity for many vulnerable farmers in the PRAT.

Rice is the crop of choice for smallholder farmers in the PRAT. Because rice is a very water-intensive crop, it has become more difficult to produce in the region. As drought increasingly affects the region, the adaptations of industrialized farms to international trade liberalization have changed Costa Rica's rice production institutions. The combination of these two phenomena has increased livelihood losses among smallholder farmers in the Tempisque River Basin. These specific barriers to smallholder farm adaptations in the PRAT have developed at the national policymaking level and they now undermine the development program. Here, I recap and summarize barriers and limits to adaptation among smallholder rice farmers in Northwest Costa Rica that were detailed in my research. I summarize why they exist, and the relationship between them.

2. Barriers and limits to the adaptation of smallholder rice farmers in Northwest Costa Rica

Barriers to adaptation restrict an individual's ability to identify, assess and manage the impacts of risks (Monirul Islam, Sallu, Hubacek, & Paavola, 2014; Moser & Ekstrom, 2010). Adaptation limits are defined as the point at which a valued livelihood goal cannot be met through adaptive actions, at which point one must transform one's livelihood, or bear the intolerable risks of loss. An adaptation is an action aimed at maintaining valued livelihood goals in the face of global change risks by avoiding intolerable risks and by managing tolerable risks (Dow et al., 2013). Barriers impede individual adaptations to meet valued livelihood goals. Both limits and barriers to adaptation are the products of risks, individual and group vulnerabilities to those risks, and the political economies and ecosystems within which the individuals and groups operate.

The development of barriers and limits to the adaptation of smallholder rice farmers in the PRAT are deeply ingrained in the political economy of the region, and of Costa Rica in general. In the Arenal-Tempisque Irrigation Project (*Projecto de Riego del Arenal-Tempisque*, PRAT) in Guanacaste, 40% of smallholder farmers surveyed in my study switched from rice to sugarcane production between 2002 and 2013. This transition has undermined the primary development goals in the PRAT. These goals include (1) improving living conditions in the semi-arid Tempisque River Basin by generating agro-employment, (2) redistributing income, and changing cropping systems, (3) promoting integrated regional development with complementary smallholder and agro-industrial sectors, and (4) contributing to the improvement of the country's economic situation by exporting agricultural products.

2.1 Barriers to adaptation

The IMF, World Bank, and U.S.AID economic restructuring demands greatly changed Costa Rica's socio-economic development model. That model created and legitimized IDA/SENARA, and these entities have effectively dictated the development trajectory of the PRAT since 1983. The national economic restructuring impacted the PRAT in four primary ways:

1. The liquidation of Costa Rican Development Corporation, S.A. (*Corporación Costarricense de Desarrollo*, CODESA) made smallholder farmers dependent on private rice mills for market access.
2. The creation of private agricultural extension services that replaced state agricultural agencies were not viable for the smallholder farm sector throughout the 1980s and 1990s due to the high costs of these services, requiring smallholder farmers to continue producing rice or leave farming.
3. The abandonment of land size restrictions in the PRAT allowed vertical integration (i.e., the combination in one agro-business of two or more stages of production) by private farms and mills and enabled a competitive advantage for some. This ultimately excluded many smallholder farmers from lucrative agricultural supply chains.

As the national political economy changed, so did the PRAT's development path. Costa Rica's shift to a neoliberal development model eliminated the potential for State-driven wealth redistribution across the PRAT. The initial agrarian development goals of wealth, land, and water redistribution were never realized due to the inability of the State to prioritize rural development. The Agrarian Development Institute and SENARA continued to work toward the original goals of the project, but within the changed institutional structure. What has resulted is a resettlement program that redistributed land to the rural poor without providing them with the capacity to use that land for their own livelihoods or to respond to changing climate and crop markets, thus making them vulnerable to these changes.

Costa Rica's economic restructuring also instilled an institutional structure that disproportionately burdened the most vulnerable farmers in the PRAT by redistributing the impacts of global change risks. Global changes, specifically trade liberalization, drove rice mills lobby for domestic rice protection policies that limited the market access of smallholder farmers. Increasing drought in the Tempisque River Basin exacerbated smallholder farmer vulnerability. President Oduber Quirós's vision of agriculture in the Tempisque River Basin brought livelihood security to almost 700 smallholder farms and almost 2,500 farm hands (*chambaros*) throughout the 1990s. But in combination with the national economic restructuring his vision also created a dependence on government-supplied irrigation water and market access. As the economic restructuring stripped away state provisions in the PRAT, such as State-provided market access and extension services, smallholder farmers and the larger agrarian economy were left dependent on larger, private farms. Smallholder farmers were left vulnerable to risks created by the ability of larger farms to better adapt to the impacts of global changes. These vulnerabilities were exposed as the debate on the “Dominican Republic – Central America Free Trade Agreement” (CAFTA-DR) began.

Smallholder farmers, while very aware of the situation, were largely powerless to weigh in on the emerging trade-liberalization debates around CAFTA-DR due to their lack of influence on legislators in San Jose. Rice mills and large producers in the Tempisque River Basin were able to lobby legislatures through the efforts of the Costa Rican National Association of Rice Millers (*La Asociación Nacional de Industriales del Sector Arrocero de Costa Rica*, ANINSA), and thereby adapt to increasing trade liberalization and secure their goals by changing institutional structures. Through the efforts of ANINSA, large-scale rice producers were able to successfully lobby for a tariff on imported rice of 35% (Hidalgo, 2014), and for a domestic rice-price fixing scheme. Despite the CONARROZ rhetoric about protecting smallholder rice farmers, this agricultural protectionism in Costa Rica almost entirely benefits large producers and mills. All industrial rice producers and mills in the Tempisque River Basin, and most across the country, belong to a publicly funded but privately managed hedge fund called Corporación Arrocera (CONARROZ). CONARROZ is the only private entity allowed to import rice duty-free, per Costa Rica Law 8285.

With the formation of CONARROZ, ANISA was able to secure continued government price controls on rice, which is the only agricultural product in Costa Rica that is still subject to price controls. Since domestically produced rice only supplies half of consumer demand in Costa Rica, CONARROZ supplements supply by purchasing internationally grown rice, tariff-free, at a much reduced price and sell it to consumers at the same high fixed price as domestic harvests. Instead of passing the savings to consumers, the earnings are distributed among CONARROZ members according to the amount of rice they produce and process each year. There are over a thousand rice producers in Costa Rica but a group of 100 large producers is responsible for 70% of the country's production (Arroyo, Lucke, & Riveara, 2013), and they are the beneficiaries of the current protectionist scheme. The economic rents (i.e., profit from the price differences between rice bought on the domestic market and rice bought by the mills from the international market through CONARROZ) won by CONARROZ and transferred to industrial producers and mills reached $104 million in 2012 (Barquero, 2013).

The 11 rice mills in the Tempisque River Basin, responsible for almost half of Costa Rican rice production, gain half of the economic rents captured by CONARROZ each year. By doing so, they are simultaneously able to secure a larger share of the domestic production market. This is allowed because no limitations on land ownership exist in the PRAT as a result of the lobbying efforts of Guanacaste's private landowners during the passage of the IDA legislation in 1982. As mills and industrial rice farms increase production, they no longer need to purchase smallholder rice at the more expensive rate set by the federal government. This has increasingly limited rice-market access for smallholder farmers in the PRAT. As of 2013, mills only purchased smallholder rice to make up the difference between their harvests and their processing and storage capacities, and this smallholder rice is purchased early in the season. This means that those smallholder farmers who harvest early in the season have a better opportunity to gain access to the rice market.

Increasing drought in the Tempisque River Basin compounds barriers to adaptation among smallholder farmers posed by limited access to rice markets. Water shortages primarily occur in the PRAT during the high water demand months of December and January, during which time both rice and sugarcane are planted. Both rice and sugarcane require large inputs of water during planting, and both crops must be planted near the start of the dry season so they can be harvested prior to the beginning of the next rainy season, typically in May. A water-cycling program developed by SENARA was designed to spread farmer-planting dates across a series of 6 weeks, thereby allowing all farms to successfully plant and harvest prior to the beginning of the next rainy season. While the water-cycling program could allow all smallholder farmers to plant their rice crops and harvest before the rains begin, farmers who are forced to wait to plant have more difficulty selling their harvests because later harvest dates limit their ability to sell their harvests before mills stop buying smallholder rice harvests for the season. And, while it is possible for smallholder farmers to store their harvests, the debts accrued through the planting and harvesting process necessitate the timely sale of their harvests.

Delayed water allocations, in combination with limited access to the rice market during harvest, have led to conflicts such as water piracy among farmers throughout the PRAT. This has created water scarcity for some. Farmers upstream in the PRAT illegally modify irrigation infrastructure to gain early access to water, depriving downstream farmers of their water allocations. Many farmers furthest downstream plant rice but then lose their water access as a result of these actions of upstream farmers, and therefore many downstream farmers have been forced to lose their rice crops after planting. Water scarcity and the subsequent conflict among smallholder farmers result from the adaptations of more powerful rice farmers to the threat of trade liberalization. Those farmers downstream in the PRAT without illegal access to alternative water sources loose either their crops or their access to the market. Thus, the compounding impacts of drought and limited rice market access comprise the barriers to adaptation faced by smallholder rice farmers in Northwest Costa Rica.

2.2 Limits to adaptation

I defined adaptation limits among smallholder rice farmers in the PRAT based on their ability to meet valued livelihood goals of security of household well-being and preservation of their *parcelaro* identities. Based on this definition, 40% of farmers included in this study had faced adaptation limits and were forced to transition their livelihoods or bear the risk of intolerable losses. The risks faced by the smallholder rice-farming sector in the PRAT are predicted to increase in scale and intensity. Following this logic, more smallholder farmers may continue to face adaptation limits in the coming years unless barriers to their incremental adaptations are reduced through rice market reforms.

Some farmers I surveyed were better able to avoid crossing adaptation limits, and some seemed better able to transition livelihood goals after facing adaptation limits. Those farmers who were better able to avoid facing limits were those who were better able to spread the impacts of risks. Also, I found that those farms with more debt were more vulnerable to limited rice-market access. Smaller farms—those with few resources and that were heavily reliant on household labor—were better able to cope with the impacts of limited access to rice markets, yet were more vulnerable to the impacts of water scarcity. As smallholder farmers pursued their rice farming livelihood goals, the pursuit of increased production efficiency through mechanization or through the purchase or rental of additional land and resources made them more vulnerable to the impacts of limited rice market access. If farmers attempted to expand their farms to grow their livelihoods, they would accrue debts that often undermined their livelihoods—particularly if they failed to sell a rice crop. However, they continued to be vulnerable to the impacts of water scarcity if they didn't attempt to expand their livelihoods by making investments either in additional land (to gain access to surface water) or in wells or water-saving technologies. This, also, often undermined their livelihoods and ultimately forced them into sugarcane production.

3. Sustainable solutions in the Arenal-Tempisque Irrigation District

Policy reforms are required to address the current distribution of risk across farmers in the PRAT. To pursue sustainability in the irrigation district, these reforms must incorporate (1) long-term perspectives on the future, (2) synergies and trade-offs between current and future goals, and (3) open and transparent decision-making processes. The policy reform process may take the form of a systematic assessment of the sustainability of the irrigation district, and it must include an assessment of each of the district's five goals, and propositions about (1) modifications to those goals based on the new global changes, and (2) a solutions spaces within which modified goals can be met. Here, I define a solution space as the set of all possible resolutions to sustainability problems in a given context, which includes plausible futures and realistic constraints. The current PRAT-goals of hydropower effluent utilization, increased crop production efficiency, and increased production of exportable crop types have seemingly been met while increased living standards among the rural poor and supply-chain linkages between smallholder farmers and industrial mills have been largely overlooked. This is because these goals have been re-prioritized over the last thirty years by those with the political power to do so. Therefore, participation of all stakeholders will also be needed in the development of a solution space, and the creation of specific sustainable solutions in the district. This process may better address the political power differentials between groups of farmers, which limit the ability of the PRAT to meet its goals.

The two primary challenges faced by PRAT managers in developing any sustainable solutions in the district are: (1) the region's increasing aridity, and; (2) a lack of authority to change market access in the PRAT. Water scarcity, while driven by competition among smallholder farmers for limited water to plant early in the season, may ultimately limit agricultural productivity in the region due to increasing drought alone. Lake Arenal, the source of PRAT irrigation water, is predicted to continue to decrease in water volume over the next two decades due to climate change (Karmalkar, Bradley, & Diaz, 2008). This will continue to increase water-cycling times, will reduce overall water availability, and will further delay rice planting each season. If water allocation schedules push planting dates into February, farmers will be forced to harvest in the rainy season, thereby forcing them to pay expensive drying fees or abandon their harvests. While increasing aridity in the PRAT is driven by global climate change, the management of its impact in the PRAT is a regional issue, for which regional decision-makers are largely responsible. Drought-resistant rice varieties and the implementation of water saving agro-technologies are solutions that may stabilize smallholder rice production, but a sustainable solution must address increasing drought, and the solution space must include possible alternatives for those solely reliant on irrigation water for their livelihoods.

It is apparent that any solution seeking to connect smallholder farming to the larger agrarian economy, and thereby support smallholder livelihoods, must in some way provide market access for smallholder farmers. Access to the rice market was limited by the Costa Rican policy response to threats of international trade liberalization, and these decisions were made at the national level. Local PRAT managers have little authority over national rice market policies, even as the PRAT produces 45% of the rice consumed in Costa Rica. Current Costa Rican protectionist rice policies only benefit large-scale, commercialized rice producers and mills, and they are driving the increasing inequities in Costa Rican agriculture. The current Costa Rica agro-economic model is designed to benefit more powerful farmers at the expense of the most vulnerable smallholder farmers. Today, rice production in Costa Rica exists as a cartel, where a few powerful farms control most of the market. Any solution that would curtail the loss of the PRAT smallholder-farming sector must include fundamental market reforms that eliminate the power of domestically and internationally owned agribusinesses to completely control market access for smallholder farmers. The solution space needed to address market-access issues for smallholders must include changes in national-level policies. In their absents, agricultural solutions to smallholder farmer livelihood losses may not be sustainable. Furthermore, predicted increases in trade liberalization may necessitate that the solution space include the facilitation of livelihood transitions and the provision of alternative livelihood options that may limit the suffering associated with the devaluing of valued livelihood goals among smallholder farmers.

Finally, given predicted increases in the intensity and severity of the impacts of global change risks on Guanacaste, the development goals of the PRAT may prove to be unattainable regardless of actions by managers and policy-makers, and therefore may need to be reestablished. The original five goals of the Arenal-Tempisque Irrigation District were developed in 1978, during a time when climate change and globalization processes were not yet apparent, and the State played a much larger role in development. While a revision of these goals may result in winners and losers, an ex-ante revision, sponsored by and carried out by all stakeholders through a transparent and participatory process will limit the likelihood that risks of global changes will be felt most strongly by the most vulnerable. Farmers and members of agricultural supply chains in the Tempisque River basin may be forced to confront intolerable global change risks that require transformations of their livelihoods, supply chains and governance systems. If PRAT managers address these risks and solutions head-on, those with the power to manipulate the status quo may be less able to stack the odds of successful adaptation to global change risks in their favor. This may better protect the most vulnerable from becoming more exposed and more sensitive to these risks. As the Tempisque River Basin suffers from the highest rates of extreme poverty in the country, managers and policy-makers are left with little choice but to aid in the adaptations of these most vulnerable through the development of sustainable solutions in Guanacaste, Costa Rica.

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CHAPTER 6

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APPENDIX A

IRB CERTIFICATION

Office of Research Integrity and Assurance

To:	Daniel Childers GIOS Build
From:	Mark Roosa, Chair Soc Beh IRB
Date:	12/20/2012
Committee Action:	**Exemption Granted**
IRB Action Date:	12/20/2012
IRB Protocol #:	1212008599
Study Title:	Managing Water Allocation Equitably: A Case Study of Risks to Smallholder Farmers in Costa Rica' Irrigation District

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(2) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

You should retain a copy of this letter for your records.