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UNDERSTANDING PERCEPTIONS OF BARRIERS TO INTERNATIONAL, INTERDISCIPLINARY SCIENTIFIC TEAMWORK AND THE EXPANSION OF MEXICAN OIL PALM PLANTATIONS

Erin Pischke
Michigan Technological University, epischke@mtu.edu

UNDERSTANDING PERCEPTIONS OF BARRIERS TO INTERNATIONAL, INTERDISCIPLINARY SCIENTIFIC TEAMWORK AND THE EXPANSION OF MEXICAN OIL PALM PLANTATIONS

By

Erin C. Pischke

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Department of Social Sciences

Dissertation Advisor:	*Dr. Kathleen E. Halvorsen.*
Committee Member:	*Dr. Maryann Cairns.*
Committee Member:	*Dr. Jessie L. Knowlton.*
Committee Member:	*Dr. Chelsea Schelly.*
Department Chair:	*Dr. Hugh S. Gorman.*

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Preface

The research included in this dissertation was conducted under the supervision of Professor Kathleen E. Halvorsen in the Environmental and Energy Program, Department of Social Sciences, Michigan Technological University, between January 2015 and July 2016. All work included in this dissertation is my own and original, except where I make reference to others' work and ideas or quote an interviewee.

The research that this dissertation is based on was funded by the National Science Foundation's Partnerships in International Research and Education (NSF PIRE) and Research Coordination Network (NSF RCN) programs, as well as the Inter-American Institute for Global Change Research (IAI) CRN3 program. Through these projects, I had the opportunity to work with many scientists from different disciplines; thus, each chapter of this dissertation has multiple authors. Part of this work has been submitted or will be submitted to different journals for publication. In the following paragraphs, I explain my role in the research and writing of each manuscript in detail. I also explain the role of the co-authors of the manuscripts.

Pischke, E.C., Knowlton, J.L., Phifer, C. C., Gutierrez Lopez, J., Propato, T.S., Eastmond, A., Martins de Souza, T., Kuhlberg, M., Picasso Risso, V., Veron, S.R., Garcia, C., Chiappe, M., Halvorsen, K.E. (2017). Barriers and Solutions to Conducting Large International, Interdisciplinary Research Projects. Manuscript submitted to *Environmental Management.* Under Review.

This work was conducted in collaboration with researchers on the on the above NSF

PIRE, NSF RCN and IAI CRN3 funded projects. Between June 2015 and June 2016, I worked with my co-authors to develop the conceptual idea for this manuscript and worked with faculty oversight to develop and design and administer a quantitative survey for the research. Co-author Knowlton and I conducted data analysis, but I wrote the initial draft of the manuscript. We collaborated virtually, online often and in-person once a year to finalize the manuscript. As the lead author, I was responsible for coordinating research team members and preparing the manuscript for submission to the journal.

Pischke, E. C., Rouleau, M.D., Halvorsen, K. E. (2017). Public Perceptions Toward Bioenergy Development in Tabasco, Mexico. Manuscript submitted to *Biomass and Bioenergy* for inclusion in a special issue of the journal. Under Review.

And

Pischke, E.C., Mesa-Jurado, M.A., Eastmond, A., Abrams, J., Halvorsen, K.E. (2017). Community Perceptions of Environmental Change and Adaptation Strategies in Two Communities in Tabasco, Mexico. Manuscript to be submitted for publication to *Society and Natural Resources*.

These two chapters are based on research conducted in Tabasco, Mexico, from 2015 through 2016 while participating on the NSF PIRE research project. While I worked within the existing research topics of each project, I was able to identify and design my own areas of interest and invite collaborators to co-author the chapters contained in this document. I participated in the quantitative survey design, data collection in the field and analysis and took the lead on writing both chapters. I conducted fieldwork twice in

Tabasco, Mexico, in 2015. The first trip in January 2015 was to conduct qualitative interviews and the second trip was to conduct quantitative surveys orally. During each trip, I was responsible for planning, budgeting for and leading fieldwork with several American and Mexican colleagues in Tabasco. I conducted data clean-up and audio file transcription with several peers from the funded projects, but data analysis was wholly my own responsibility, with faculty oversight and guidance. I initiated the writing process for each chapter, but I received support from my peers and colleagues who expressed interest in collaborating. Writing became an iterative process, with each of us taking turns editing drafts of the chapters, meeting in person or teleconferencing when we needed to discuss the direction in which to take the paper. I was also responsible for writing the initial draft of the paper and for preparing the manuscript for submission to the journal.

Erin Pischke

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A final thank you to my husband Andy and my parents who always support and encourage me.

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Abstract

Understanding the multiple drivers of environmental change is essential for devising strategies for overcoming impacts and planning for the future. Anthropogenic causes and physical impacts of such environmental changes are not fixed in space; thus, it is necessary to conduct international research to solve such problems by integrating multiple disciplinary approaches. My dissertation research examines the public perceptions of socioecological impacts of oil palm production and uncovers barriers that international, interdisciplinary teams face when studying such impacts. In one chapter, I present research that identifies challenges that interdisciplinary researchers are confronted with when working in an international setting. Findings show five major barriers to conducting interdisciplinary, international research in Argentina, Brazil and Mexico: integration; language; fieldwork logistics; personnel and relationships; and time commitment. The types of barriers and the strategies for addressing them differ from country to country and between disciplines. I recommend strategies for preventing or overcoming each barrier based on our experiences and those found in the literature. In another chapter, I present public perceptions of the social, economic and environmental impacts of oil palm development in Tabasco, Mexico. Perceived impacts of future oil palm expansion are positively associated with attitudes toward support for current oil palm plantations, attitudes toward the oil palm's provisioning of environmental services, as well as oil palm production used to produce biofuels for export. The last chapter, in which I present research relating to political ecology of environmental change in Tabasco, Mexico, shows that past political and economic action impacts current environmental conditions and creates institutional and structural constraints in the region

to which people are adapting. Rural community members' adaptive capacity is determined by the resources communities have available to them, landscape features, as well as geographical location.

Chapter 1: Introduction

Global environmental change takes place in an international context, with demands from countries in one part of the world driving production in another (Byerlee et al., 2017). As natural resource demand (e.g. for energy) increases in developing countries like China and India, the brunt of socioeconomic and ecological impacts of extracting or producing such resources and energy will be experienced by people who live in the communities where these resources are being produced and/or extracted (Byerlee et al., 2017). Production and extraction may cause local land use change, for instance, as in Tabasco, Mexico, from forests to agriculture. Land use change that occurs during bioenergy feedstock production is one example of this type of change. These types of environmental changes can be difficult for rural residents of developing countries because of opaque governance structures and political unaccountability (Hevia et al., 2011; Valenzuela, 2014). The inability to create effective policy due to resource constraints is also major challenge to policy implementation (Jordana, 2010). Thus, unlike more developed countries, although a globally peripherial country might have the political will to enact effective pro-environmental policies, they may lack capacity to successfully enforce them.

1.1 Policy Context: Mexican Climate Policies

Mexico is seen as a serious participant in the global dialogue on climate change (Torres Ramirez, 2014). It has pledged to mitigate climate change from multiple angles: it was a signatory to the U.S. Framework Convention on Climate Change (UNFCCC), joined the Conference of the Parties (COP) to the Kyoto Protocol in 2000 and was one of the first

developing countries that pledged to reduce GHG emissions voluntarily (Octaviano et al., 2016; Torres Ramirez, 2014). Just as the Special Program on Climate Change set a climate change mitigation goal in 2009, President Felipe Calderon's 2012 climate change policy, the General Law on Climate Change, and his acceptance of the USA's invitation to join the Coalition for the Climate and Clean Air, further established the country as a leader in climate change policy among developing countries (Torres Ramirez, 2014; Valenzuela, 2014).

Mitigation, adaptation, geoengineering are three potential options for responding to climate change (Emanuel, 2012). Mitigation and adaptation can be done on a personal level (i.e. people choosing to save fuel by driving less to mitigate their impacts on the planet), but they usually involve policy solutions in order for them to be widely carried out (Emanuel, 2012). Geoengineering may offer large-scale fixes, cannot fix all climate problems at once, nor is there an agreed-upon approach that satisfies all scientists' and politicians' desires (Emanuel, 2012). Of the three options for dealing with climate change, attempts at mitigation and adaptation are more likely to be adopted in the near future, perhaps by local governments or citizen organizations, whereas geoengineering may only be used in the case of a climate disaster (Emanuel, 2012). The most drastic options that geoengineering offers will need to be tried and proven to be successful before the public is ready to accept it as a solution to climate change (Emanuel, 2012). Therefore, climate change mitigation efforts like promoting renewable energy may be most viable in the short-term.

1.2 Mexican Bioenergy Policies

Bioenergy and biofuel production could help meet Mexico's Intended Nationally Determined Contributions (INDC) as presented at the COP21 in Paris in December 2015. Part of Mexico's climate change adaptation plan consists of biodiversity conservation, land use planning and choosing crops that have fewer adverse effects on the environment and socioeconomic systems than others (UNFCCC, 2016). Several Mexican biofuel development plans were created because of drawdowns of national oil reserves (the primary domestic energy supply), the increased national oil and gas consumption (US EIA, 2014), insufficient exploration funds and maintenance of infrastructure for oil and gas production (US EIA, 2014) and outdated extraction technology and the need for the European Union (EU) to import renewable fuels to meet its own goals (Rodríguez et al., 2014). With the dwindling access to currently-tapped domestic oil and gas supplies, Mexico imports both from the United States (44% of oil and 38% of natural gas of total exports), reducing the need to invest in alternative fuels (US EIA, 2014).

As recently as 2008, Mexico had begun the process of writing a bioenergy plan and incorporating this alternative energy source into sectors as diverse as energy, agriculture and the environment (Romero-Hernández et al., 2011). The goals of the bioenergy law are to produce bioenergy in a way that ensures sustainable rural development while diversifying the energy sector and reducing the country's greenhouse gas (GHG) emissions (Diario Oficial de la Federación, 2008). There have been many proposed biofuel feedstocks from biomass—for making bioethanol and biodiesel—in Mexico: jatropha (jatropha curas), oil palm, soybean, sugar beet, rapeseed, sugarcane, sweet sorghum, cassava, castor oil, sunflower and safflower (Eastmond et al., 2014;

Rodríguez et al., 2014). The Bioenergy Law excludes the use of maize as a biofuel feedstock because it is an important food source and there are no set production targets for other crops, such as oil palm (Romero-Hernández et al., 2011).

International treaties are signed and promises are made to find ways to reduce national GHGs across the country at the national leve, but it has been challenging to meet those goals, not only because the federal government awards contracts to subnational governments to meet those goals, but also because the pledges themselves are voluntary (UN, 2011). Furthermore, in addition to limited funding and coordination efforts, subnational governments do not always have the technical expertise or human capacity necessary to meet their goals (Gay & Estrada, n.d.). However, participation could occur indirectly through growing oil palm to produce biofuels in the future.

1.3 Public Perceptions

Contemporary climate change policy has limited understanding of the social world and how it changes (Shove, 2010).

As renewable energy plays a larger role in government plans to reduce GHG emissions, the development of Mexico's biofuel industry is expected have both positive and negative impacts on the environment, society and the economy of the regions responsible for its production (German et al., 2011). This means that biofuel sustainability is about much more than the technical capacity to mitigate climate change. It is crucial that the people who live in communities where feedstocks are grown and processed also view oil palm plantations as an acceptable use of land (Ellis, 2000).

Knowing how the public and landowner-producers perceive biofuel development projects—which trade-offs people are willing to live with and which are deemed unacceptable—is an important way to gauge social acceptance (Barnes et al., 2013; Dunlap & Brulle, 2015). Given that public support is often critical to the success of an energy development project (McAdam & Boudet, 2012), assessing the social acceptance of biofuel is an important step toward understanding the sustainability of biofuel systems in general, evaluating Mexico's approach to mitigating climate change in particular, and gaining a broader appreciation for the potential impacts of biofuel development in Latin America or possibly the developing world as a whole. Furthermore, current systems-theory approaches to studying climate change ignore aspects of global environmental change, such as power relations and societal conflict—both within the social science domain—that can contribute to a better understanding of solutions to change (Dunlap & Brulle, 2015). Current approaches limit our understanding of such systems. Existing individual-level analysis of environmental change within the social sciences ignores the societal and institutional actions (Dunlap & Brulle, 2015).

Public perceptions and related individuals' attitudes, including policy makers and members of Mexican communities where people decide to grow oil palm, are at the heart of my research on Mexican oil palm development. The goal of the household-level interviews was to measure the level of support for oil palm plantations and public perceptions of the impacts of oil palm plantations to see if differences existed within our sample. My research on public perceptions—as a reflection of individuals' attitudes—of oil palm production can inform stakeholders on what individuals values might influence their acceptance of policies that benefit both the environment and citizen's livelihoods.

Perceptions of the environmental, social and economic impacts of bioenergy development, like oil palm plantations, will affect levels of public support for the plantations and the success of climate change mitigation policies. The general public is more likely to support a project that can be incorporated into the local community without disrupting it and without making life more difficult (Radics, 2015). Since Mexican bioenergy development has not yet expanded to commercial scales, studying public perceptions of bioenergy feedstock production can be important for learning what individuals value and how they may respond to changes in the local landscape and their communities (Eastmond et al., 2014; Sullivan, et al., 2010). This foresight can be used to design publically-acceptable bioenergy projects in the future.

Knowing how the public and landowner-producers perceive bioenergy development projects—which trade-offs people are willing to live with and ones that they deem unacceptable—is one way to gauge acceptance. It is therefore important to understand how oil palm cultivation projects are perceived by members of the communities where they are established. One way biofuels can be a sustainable solution is if they are accepted by the people who live in communities where feedstocks are grown and processed or accepted by the people who produce the feedstocks (Ellis, 2000). Not only should the bioenergy system not impose adverse effects on the environment or economy, but should allow those who manage it to benefit from it, such as through higher income or employment opportunities (Rist et al. 2010; Ellis, 2000).

Linkages between human end ecological research are exemplified by surveys of public environmental attitudes. This have been measured in America since the late 1970s using Dunlap and Van Liere's 1978 New Environmental Paradigm (NEP) Scale, the

dominant social paradigm (DSP) and Dunlap et al.'s (2000) new NEP in the 1990s, as well as other iterations of these studies (Kempton et al., 1996; Stern et al., 1995). They found that in Western societies, there is a conflicting duality in worldviews, suggesting that people can either believe in the utility of nature of in protecting it (Stern et al., 1995). Others have tested the assumption that countries have different worldviews and different environmental values by surveying students in the USA, Japan, Mexico and Peru using the human exception paradigm (HEP) and NEP scales (Bechtel et al., 2006) and surveying students in Mexico (Corral-Verdugo & Armendariz, 2000). In Mexico, the opposing, dualistic worldview was not found. Therefore, researchers have shown that worldviews matter in terms of making assumptions about the environmental values people hold.

Building on Dunlap and Van Liere's original 1978 NEP Scale, Dunlap et al. (2000) proposed an updated version that focuses more broadly on ecological issues. The authors (which include the original authors, Dunlap and Van Liere), named their scale the New Ecological Paradigm Scale and tested its strength in 1990 in Washington state (ibid). Stern et al. (1995) also expanded upon Dunlap et al.'s (2000) revised NEP scale to include individual psychological items to the scale, focusing on linkages between values, beliefs and attitudes (Stern et al., 1995). Social structure both constructs people's values and beliefs, as Babbie (1994) discussed, but also describes how it enables or prevents people to take action on their beliefs. Stern et al. (1995) confirm that the NEP measures correlations between people's beliefs and actions. Therefore, surveys like the NEP and ones that measure perceptions of environmental change can be used to gauge the

likelihood of specific sub-populations making particular environmental decisions, such as supporting alternative energy projects (e.g. biofuel feedstock production).

1.4 Sustainability Science

Research on the socio-economic impacts of bioenergy production contributes to sustainability science by highlighting important indicators of social and economic well-being that should be included in future sustainability criteria. It is also important to draw on interactions between society and nature using interdisciplinary socioecological research (Clark, 2007). It is also necessary to begin a dialog about the framing of sustainability and ask for *whom* the bioenergy production systems are being sustainably created (see Escobar, 1992, 1995).

The Health of the Planet survey was conducted in 1992 by various Gallup poll affiliates in 24 countries, which were divided into two categories: as either an industrialized or developing country (Dunlap et al., 1993). The survey—translated into each country's native language—was used to gather data about environmental opinions and beliefs (ibid). Despite popular beliefs that developing nations do not have the luxury of worrying about environmental problems, many of the responses from such countries were pro-environmental and showed a clear concern for the environment (Dunlap et al., 1993). The findings of Dunlap et al. (1993) may be indication that as developing countries continue to industrialize, the voting populace may be inclined to support pro-environmental climate policies. Surveys conducted in the 1990s (Kempton et al., 1996; Read et al., 1994) found that people commonly misunderstand scientific causes of environmental problems, such as thinking climate change is caused by the hole in the

ozone layer. Unfortunately for policy makers, this confusion could lead to lower levels of support for effective solutions that would mitigate climate change if the public perceives that proposed solutions are not directly related to the problem, as noted by Heberlein (2012).

Shove's work (2004, 2010) lends a macro viewpoint to the literature covered here, putting the discussion of environmental decision making into perspective. Shove (2004) argues that people (society) often ask the wrong questions when making decisions and quickly embrace "normality," instead of asking where we can make new tech developments to solve problems, we should examine, like she does, where we can make changes in the everyday. Reseach should question the broader societal norms and the practices that perpetuate and lead to poor environmental decision making. Shove (2010) writes that a focus on individual behavior reinforces the status quo and leaves radically transformative alternative solutions off the table. Transitions to sustainable ways of life and combating climate change involve a radical upheaval of the process of policy making as we know it (Shove, 2010).

1.5 Interdisciplinary, International Research

As environmental problems, like climate change, become more globally connected and interrelated, interdisciplinary, international research will become more commonplace. Research teams comprised of people from different disciplines are often required if the multi-faceted nature of the problems is to be addressed adequately (Halvorsen et al., 2015; Knowlton et al., 2014). Just as there can be challenges to conducting disciplinary research, interdisciplinary research can pose unique challenges to researchers. While

researchers face many challenges to conducting interdisciplinary research domestically, oftentimes the same challenges are magnified or exacerbated when placed in an international research context.

1.6 Political Ecology

The fourth chapter of this dissertation considers the impacts that national and international policies have on the environment using a political ecology lens (Robbins, 2012). Political ecologists have often focused on rural farmers in developing contexts (Robbins, 2012). When concepts such as sustainability and development are used to frame national or transnational projects such as bioenergy development, they are accepted or slightly modified, not rejected completely (Escobar, 1995). Most people who are affected by structural changes are not part of the discussion on how to resolve resulting impacts; however, they often find ways of adapting to or transforming to a changing environment or community (Folke et al., 2010).

Instead of isolating my research in a singular moment in time or field of reference, using a political ecology approach facilitates my understanding of land management in Tabasco, Mexico and lends important theoretical insights into adaptation strategies of people in rural Mexico (Clark, 2007). I use a political ecology framework in order to understand how current local land uses and labor practices in rural Tabasco, were shaped by historical political processes in Mexico (Robbins, 2012). Political ecology can also facilitate integration of research across disciplines in this way.

Many of the works discussed throughout the literature here show that not only are environmental decisions made by politics and policymakers who may rely on research

generated by academia, but social norms created and reinforced by path dependency also have a great influence on what decisions are made and what the outcomes are. Policy should not focus on personal choice because the drivers of and barriers to environmental behavior are arbitrarily chosen and can each be a driver or a barrier, depending on the context (Shove, 2010). A multitude of approaches at many levels, from the individual, the societal level through policy changes and transnationally, need to be brought together to continue to understand environmental decision making and move toward new theories and approaches to solving problems (Gardner & Stern, 2008; Shove, 2004; Shwom & Lorenzen, 2012). Moreover, solving environmental problems requires patience because values and norms change over long time scales (Heberlein, 2012). It is important to note that societal misunderstandings of science and environmental issues can perpetuate unsustainable practices (Gardner & Stern, 2008; Heberlein, 2012) and that educational campaigns are unlikely to change this (Heberlein, 2012).

1.7 Overview of Dissertation

The current trends in theory and scholarship in my areas of research include the study of public perceptions of bioenergy feedstocks, sustainability science and political ecology. My dissertation pertains to public perceptions surrounding the production of bioenergy feedstock production and the political ecology of such development policies in Tabasco, Mexico, and the challenges that interdisciplinary teams face while conducting research in an international context. This dissertation is composed of chapters representing three manuscripts that will be published as separate documents in the peer-reviewed literature. One chapter presents research that identifies challenges that interdisciplinary researchers

are confronted with when working in an international setting. Another chapter presents findings from an analysis of the relationships between public perceptions of the Tabasco, Mexico, oil palm plantations' impacts and support for their expansion. The last chapter includes a political ecology of environmental change in Tabasco, Mexico, and rural community members' responses to such change. A concluding chapter synthesizes and integrates my research findings.

Chapter 2 Overview

Global environmental problems such as climate change are not bounded by national borders or scientific disciplines, and therefore require international, interdisciplinary teamwork to develop understandings of their causes and solutions. Interdisciplinary scientific work is difficult enough, but these challenges are often magnified when teams also work across national boundaries. The literature on the challenges of interdisciplinary research is extensive. However, research on international, interdisciplinary teams is nearly non-existent. Our objective is to fill this gap by reporting on results from a study of a large, interdisciplinary, international National Science Foundation Partnerships for International Research and Education (NSF-PIRE) research project across the Americas. We administered a structured questionnaire to team members about challenges they faced while working together across disciplines and outside of their home countries in Brazil, Mexico, and Argentina. Analysis of the responses indicated five major types of barriers to conducting interdisciplinary, international research: integration; language; fieldwork logistics; personnel and relationships; and time commitment. We discuss the causes and recommended solutions to the most common barriers. Our findings can help other

interdisciplinary, international research teams anticipate challenges and develop effective solutions to minimize the negative impacts of these barriers to their research.

Chapter 3 Overview

Biodiesel from oil palm is an increasingly popular renewable energy option around the world, particularly in global southern countries like Mexico. Mexico's support for commercial scale bioenergy production began in 2008 with the Bioenergy Promotion and Development Law. Yet, few studies investigate the perceived impacts of national biofuel policies on local Latin American communities. This is a critical gap because many Latin American governments are promoting biofuel development as the best alternative to reduce reliance on fossil fuels, increase energy independence and stimulate rural development. This gap also has global implications because Latin America is expected to become one of the primary biofuel suppliers to Europe and North America, helping these regions to achieve their own climate change mitigation goals. Our study attempts to fill this gap by providing a voice to those whose views are often overlooked in these larger national or international energy policy discussions where energy is produced in one location and consumed in another.

We present results from our 2015 quantitative survey of 130 community members in Tabasco, Mexico, living close to areas of increased oil palm cultivation. One of the major findings in our study is the confirmed positive relationship between attitudes toward oil palm export production and perceptions toward the future impacts of oil palm expansion. Mexico has incorporated oil palm into an export-led growth strategy as a way to expand beyond the region's limited domestic market and provide rural job

opportunities. Our findings also indicate that perceptions about the future impacts of oil palm become more positive when respondents believe oil palm provides more ecosystem services. This means that while they are not currently the primary beneficiaries of biodiesel production, Tabasco residents perceive that they benefit from increased environmental services. Finally, our results show that perceptions about the future impacts of oil palm expansion become more positive as preferences for local energy independence increase. In light of rising energy costs and dwindling national oil reserves, respondents clearly see how growing biofuels locally makes it possible to minimize reliance on imported fossil fuels in the future.

Chapter 4 Overview

Rural inhabitants in many parts of the world face multiple stressors associated with global economic pressures, national-level neoliberal reforms and patterns of environmental change. Using a political ecology lens, this research examines historical Mexican structural adjustment policies to better understand current public perceptions of environmental change among members of five *ejido* communities, with a focus on understanding the options local people have for adapting to such change in the future. Our results show that societal responses to environmental change in Mexico are determined by past political processes and, in part, by geographical location and landscape features as well as the resources (including social, political and economic capital) perceived to be available to communities to adapt to these changes.

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Chapter 2: Barriers and Solutions to Conducting Large International, Interdisciplinary Research Projects[1]

Global environmental problems such as climate change are not bounded by national borders or scientific disciplines, and therefore require international, interdisciplinary teamwork to develop understandings of their causes and solutions. Interdisciplinary scientific work is difficult enough, but these challenges are often magnified when teams also work across national boundaries. The literature on the challenges of interdisciplinary research is extensive. However, research on international, interdisciplinary teams is nearly non-existent. Our objective is to fill this gap by reporting on results from a study of a large, interdisciplinary, international National Science Foundation Partnerships for International Research and Education (NSF-PIRE) research project across the Americas. We administered a structured questionnaire to team members about challenges they faced while working together across disciplines and outside of their home countries in Brazil, Mexico, and Argentina. Analysis of the responses indicated five major types of barriers to conducting interdisciplinary, international research: integration; language; fieldwork logistics; personnel and relationships; and time commitment. We discuss the causes and recommended solutions to the most common barriers. Our findings can help other interdisciplinary, international research teams anticipate challenges and develop effective solutions to minimize the negative impacts of these barriers to their research.

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2.1 Introduction

As our recognition of the global connection and interrelatedness of environmental problems such as climate change increases, interdisciplinary, international research composed of members from multiple disciplines, countries and cultures is becoming more common in the attempt to address these complex environmental problems (Halvorsen et al. 2016; Knowlton et al. 2014). While researchers face many challenges to conducting interdisciplinary research domestically, these same challenges are often exacerbated and new challenges arise when this research is placed in an international context. Our objective here is to expand on the extant literature on the challenges in conducting interdisciplinary research to include an international perspective. Our main research questions are: 1) What are the challenges or barriers that interdisciplinary, international research teams face in Argentina, Brazil and Mexico, and do the barriers vary by country? and 2) How can these barriers be overcome? We use a case study from a large interdisciplinary, international research project on the sustainability of bioenergy plantations across the Americas to answer these questions. We first present a literature review on the challenges of interdisciplinary research, give country-specific context for each country in which we worked and then report the results of a survey completed by our team members on the challenges of interdisciplinary, international research. Finally, we conclude with concrete suggestions for other interdisciplinary and international teams to use to overcome the described barriers to effective team-based science.

2.2 Literature Review

2.2.1 Interdisciplinary Research

There are several types of research that employ the tools and perspectives of more than one discipline. Multidisciplinary or cross-disciplinary research involves researchers from more than one discipline, but they do not attempt to integrate their research methods (Hickey and Nitschke 2005; Strober 2006). Transdisciplinary research is unique in that academic researchers work with non-academics who are involved in the communities or problems being studied (Buizer et al. 2015; Hadorn et al. 2006). This type of research takes into account opinions and goals of non-academics and attempts to find solutions to problems using local knowledge from the bottom up (Hadorn et al. 2006). Others identify transdisciplinary research as being heterogeneous and highly integrated, but do not acknowledge the involvement of non-academics in the research process (Hickey and Nitschke 2005; Strober 2006). Interdisciplinary research fosters linkages between disparate disciplines while some aspects of each discrete discipline are still recognizable and left intact (Strober 2006). Researchers may integrate methods and create a shared language so that they are able to approach a common problem more holistically than their own discipline would allow (Buizer et al. 2015; Hickey and Nitschke 2005). This paper focuses on interdisciplinary research.

2.2.2 Barriers to Interdisciplinary Research

The challenges of interdisciplinary research teamwork are well documented (e.g., Barlow et al. 2011; Gardner et al. 2013; Morse et al. 2007; Ross 1984; Strober 2006). These

challenges, or barriers, can include building an effective research team, finding a common vocabulary in which to communicate across fields, identifying a framework around which to build the research, integrating diverse methods and perspectives, and working within resource constraints. Here we review major barriers to conducting interdisciplinary research as identified by other researchers.

The difficulties in building an interdisciplinary research team include finding the appropriate personnel and research team members (Dieguez et al. 2015; Halvorsen et al. 2015; Ross 1984), disproportionate research responsibilities among all disciplines involved (Lang et al. 2012), and asymmetries between students and senior researchers (Dieguez et al. 2015). Each academic discipline has its own overt or subtle traditions to which researchers within that discipline adhere (Gardner et al. 2013). While shared vocabulary, theories and methods can enhance and streamline disciplinary research, trying to combine disciplinary traditions in interdisciplinary research can create acute challenges (Barlow et al. 2011; Strober 2006; Romero-Lankao et al. 2013). Interdisciplinary researchers have two main communication challenges: to develop common language and methods so they can work with their colleagues and to find a common language to share their results with a broader audience (Gardner et al. 2013; Strober 2006; Romero-Lankao et al. 2013). Clear communication is necessary both for the process of building the research team and successfully executing the proposed research, which can be especially challenging in the initial stages of a research project when these new modes of communication are being developed (Morse et al. 2007).

The more disparate each discipline's tradition is from another, the more difficult it is to find common ground when defining problems and developing a research plan

(Brown, et al. 2015; Lang et al. 2012; Morse et al. 2007). Differing expectations about protocols, treatment of subjects, ownership of and access to data, publication protocols or basic etiquette can also be challenging when working with people from different disciplines (Bosch and Titus 2009; National Research Council 2008). Often this involves trade-offs. For instance, depth within a single discipline's research may be lost when multiple disciplines are used to gain breadth of subject matter (Morse et al. 2007). Negotiating different disciplinary norms and integrating methods adds to the complexity of interdisciplinary research (Bosch and Titus 2009; Morse et al. 2007; National Research Council 2008; Strober 2006). Bringing together diverse groups of people who may have established hierarchical working relationships, unspoken rules for when and how to conduct collaborative research and a history of working within disciplinary boundaries can produce challenges when trying to find common ground (Barlow et al. 2011; Morse et al. 2007). Researchers who are accustomed to doing research in their own way using more traditional methods may be skeptical of the value of doing interdisciplinary research or might question the value of doing it at all (Barlow et al. 2011).

Integration of diverse research programs also extends beyond conceptual challenges when multiple researchers from different disciplines try to coordinate the logistics of carrying out interdisciplinary fieldwork (Morse et al. 2007; Romero-Lankao et al. 2013). Research is often limited by the volume of resources, mainly time and money, available. Interdisciplinary research may be hampered by the need for more time and more money than is necessary for a similar single, disciplinary project (De Torres 2013; Dieguez et al. 2015; Morse et al. 2007; Ross 1984). Good interdisciplinary, international research depends on quality fieldwork and data collection, which takes more

time than is usually expected or planned (Ross 1985). Moreover, short term funding is often not adequate for the long-term planning and execution of interdisciplinary research projects (De Torres 2013).

Beyond the basic challenges of conducting interdisciplinary research, there are other barriers that may prevent successful outcomes. These miscellaneous barriers include disciplinary departments devaluing or completely failing to recognize interdisciplinary scholarship (De Torres 2013; Dieguez et al. 2015), technical challenges in processing and managing different types of data (Gardner et al. 2013) and engaging students who are part of the research projectfor a short period of time (Barrett and Cason 1997; Morse et al. 2007). Not all the challenges listed are perceived as such to every interdisciplinary research group. Some of these challenges are actually embraced by researchers and used to bolster existing relationships, depending on the context (Morse et al. 2007).

2.2.3 Challenges to Conducting Research Abroad

While researchers face many challenges to conducting interdisciplinary research domestically, international research offers a variety of specific challenges and oftentimes the challenges facing domestic interdisciplinary teams are magnified or exacerbated when placed in an international context. Other problems posed by research conducted internationally are not related to the challenges of interdisciplinary research. The barriers to conducting international research include: a lack of familiarity with the local language or culture, dealing with fieldwork logistics, problems caused by suspicion and political

situations, resource needs and bureaucracy issues. The following section reviews the challenges identified in the literature.

Misunderstandings within international research teams can take many forms, stemming from different expectations, norms, priorities and values across cultures (Barrett and Cason 1997; Di Castri 1976; Ross 1984). Culture as a barrier to interdisciplinary, international research may manifest itself in the philosophical differences between research paradigms in different cultures or it may crop up as misunderstandings in everyday life (Gardner et al. 2013; Romero-Lankao et al. 2013). There are often differing expectations of workloads, sensitivity to deadlines, levels of supervision, mentoring among teams made up of people from different cultures (National Research Council 2008; Bosch and Titus 2009). Furthermore, a lack of familiarity with a local language or culture can lead to problems translating research materials or in communicating research needs to local communities (Lang et al. 2012; Ross 1984; Romero-Lankao et al. 2013).

There are many challenges to conducting research abroad, especially when working in a developing country. Fieldwork in a different country poses the typical challenges, such as accessing the necessary data (e.g., maps or sample frames) or equipment, traveling in rented vehicles on poor roads and finding the proper personnel or technical assistance (Barrett and Cason 1997; Ross 1984). International research teams also face the challenge of having to conduct many meetings, planning sessions and other correspondence among team members via phone, email or video conferencing rather than in person, which can lead to misunderstandings, slower progress and lack of coordination and consistency (Goddard et al. 2006).

Initial mistrust among members of interdisciplinary, international research teams is common, and often stems from dissimilarities of practice and asymmetries of power (Dieguez et al. 2015; National Research Council 2008; Palmer et al. 2016). Also, it is often found that researchers, especially foreigners, are viewed as outsiders by the local people with whom they are trying to communicate, which can create mistrust and misunderstandings (Morse et al. 2007). In international teams, collaborators in more developed countries are often seen as holding more power because they are the ones generally able to obtain large grants for this type of research (Romero-Lankao et al. 2013). If the principal investigators do not include their international collaborators in an equal and open way during the development stages of the research, asymmetries of power and less-functional teams will result.

Foreign researchers face several challenges when working abroad, including locals being suspicious of outsiders, mistaken expectations about what research projects are providing and suspicions about how collected data is used (Barrett and Cason 1997; Di Castri 1976; Ross 1984). Just as an Argentine farmer might not be willing to respond accurately to questions posed by an American researcher, an American farmer might not be as open to responding accurately to a Mexican researcher. All of these barriers can lead to biased data or withheld information. The political environment can present additional challenges, either through biased or hesitant respondents and inaccessibility to key informants (Barrett and Cason 1997; Ross 1984).

Conducting international fieldwork is often resource intensive. The amount of time, money and resources needed before, during and after fieldwork takes place is often underestimated, especially in countries where bureaucratic processes can stall research

for long periods of time (Freshwater et al. 2006; Ross 1984). It often takes more time and resources to obtain a visa to work in the United States than it does to enter and work in countries such as Argentina, Mexico or Uruguay. Budget constraints for international projects are greater than for national projects, mainly due to the costs of travel for face-to-face meetings and research (Goddard et al. 2006; Romero-Lankao et al. 2013). The amount of time spent making local contacts, introducing the researchers to field technicians or local communities and gaining access to field sites is also time and resource intensive (Gardner et al. 2013). These resources are unlikely to be expended in all field sites for the duration of the project; resources are likely to be spread thin to maximize their utility (Ross 1984).

While many of the articles referenced in our literature review focus on the inherent challenges to conducting interdisciplinary research in a domestic context (or without acknowledging the context at all), we argue that these same challenges are often exacerbated in international contexts and that new challenges arise when conducting interdisciplinary research internationally.

2.3 Case Study Background

The results presented in this paper stem from a project funded by the National Science Foundation's Partnerships in International Research and Education grant (henceforth NSF-PIRE) with a focus on addressing the socioecological sustainability of bioenergy development across six countries in the Americas (Argentina, Brazil, Canada, Mexico, the United States and Uruguay). To address this research topic, our team included more than 100 social, natural, physical and engineering scientists and students from six

countries actively working together over five years. Thus, we believe our team is uniquely qualified to identify and address the challenges and opportunities of interdisciplinary, international research.

To accomplish our research agenda, our project was organized in two ways: by country in which the researchers work and by discipline. First, each country, or case study, had a leader whose primary role was to assist and coordinate research within the country for a joint team of social and natural scientists. Second, we developed sub-teams based on disciplinary expertise, including a social science and policy team, an ecosystem team and a metrics team (see Table 2.1). Disciplinary teams also had a leader or co-leader. Much of the coordination efforts were accomplished remotely via email or video conferences, but each year of the project there were also researchers conducting fieldwork in each of the case study countries and meeting at annual in-person team meetings that rotated among case study countries.

Table 2.1. Number of NSF-PIRE project participants by sub-team and country.

Disciplinary Team	Argentina	Brazil	Canada	Mexico	United States	Uruguay	Total
Ecological	6	5	6	11	15	1	44
Metrics and Indicators	0	6	1	4	20	2	33
Socioeconomic/ Policy	0	0	0	7	12	0	19
Total	6	11	7	22	47	3	

2.3.1 Country Context

Our NSF-PIRE researchers started working in the field in 2014 in Argentina, Brazil and Mexico. Researchers worked in Argentina's northeastern province of Entre Ríos, near the town of Concordia. This rural area is developing large-scale eucalyptus plantations, replacing the dominant agriculture activities, grazing and annual crops. In Brazil, where oil palm has been grown since the 1970s, our research teams worked in Para State where large industrial plantations and smallholders participate in feedstock production (Raswant et al. 2008). We conducted research in the municipalities of Jalapa, Tacotalpa and Teapa of Tabasco State, Mexico, beginning in 2015. This region was selected for this research because of the presence of oil palm plantations. The primary economic activities in the rural communities in which we worked involve farming.

The sociopolitical context in Argentina during the fieldwork period of the NSF-PIRE project was mainly determined by three factors: the reemergence of the scarcity of foreign exchange, or an external restriction in the economy (Furtado 1959; Prebish 1971); a tense relationship between the farming sector and the government whereby higher and higher taxes were imposed on farmers, especially those who grew soybeans, maize and wheat grains (Barsky and Davila 2009; Rodriguez and Arceo 2006); and the extended tax evasion, particularly in the commercial and agricultural sectors. The lack of a consistent taxing policy, together with frequent tax amnesties and the existence of irregular markets (e.g., bread flour), resulted in a flexible attitude towards receipts or, more importantly, on sharing production metrics such as farmers' yields. In the perspective of the national economic and political situation during the fieldwork of the NSF PIRE project in Brazil, the Brazilian economy began to experience an economic recession that continues. This

economic recession is occurring along with a political crisis in the country that culminated in 2016 with the impeachment of former President Dilma Rousseff, re-elected President by the Workers' Party in 2014, on promises to carry out profound social transformation processes, maintaining the political path initiated by her predecessor's mandates.

The beginning of the NSF PIRE project roughly coincided with the first years of Mexican President Peña Nieto's tenure in office. A brief moment of optimism accompanied his rise to power due to high oil prices, a strong and relatively stable Mexican peso and his promise to reform the country's antiquated energy sector, opening it up to private and foreign investment for the first time since the nationalization of the country's oil assets in 1938 (Diario Oficial de la Federación, 2013; Williams et al. 2013). However, when oil prices dropped below $50 per barrel in 2014, initial enthusiasm for expensive offshore exploration rapidly declined, leaving Mexico without much of its badly needed oil revenues and the additional foreign investment it had expected (Webber 2016). Moreover, recent increases in drug-related violence and economic uncertainty together have undermined the government's legitimacy and further weakened the Mexican peso (Rapoza 2016).

2.4 Methods

Stemming from personal experience working on the large, interdisciplinary, international NSF-PIRE research project spanning six countries, we developed a structured survey (presented as a self-administered questionnaire) about the challenges that project members face while both working outside their home country and interdisciplinarally.

We administered the survey in person to all NSF PIRE team members at an annual meeting in June 2015 (~65 people attended). Attendees were surveyed at the beginning of a morning meeting when all meeting attendees were present and we collected completed surveys at lunchtime. A total of 29 surveys were returned, for a response rate of 45% from people who conduct research in NSF PIRE countries. Responses from researchers who work only in the United States, Canada and Uruguay were not included in the analysis because the respondents did not live or conduct fieldwork outside their home countries or the research had not advanced sufficiently for researchers to have faced challenges yet; therefore, 15 total surveys, from five natural scientists and 10 social scientists, were included in our analysis.

Two authors independently reviewed and inductively coded the returned surveys by reading through all responses and highlighting general patterns of barriers that were directly or indirectly mentioned (Bernard 2006). They then created a common list of themes (e.g. a coding scheme) based on the two respective lists, whereby they agreed on a shorter, more specific list, resulting in 11 common themes (Bernard 2006). They recoded each other's survey responses with the common themes and then discussed their decisions as a way to come to an agreement on themes that emerged to ensure intercoder reliability (Bernard 2006). Afterward, they collated the results based on patterns that emerged across all data and then calculated descriptive statistics and percentages of responses by pattern and by country.

2.5 Results

Our results are unique in that we present findings regarding the experiences of the research team when conducting interdisciplinary research in multiple countries outside the United States. In our six-country, NSF PIRE research project, many of the researchers worked in more than one foreign country (outside their home country) and had to shift into new contexts for each new field season in a different country. Scientists who conduct research outside their home countries in Argentina, Brazil and (or) Mexico completed the questionnaire. Eight respondents worked in Argentina, six in Brazil and thirteen in Mexico (each researcher may work in more than one country). These respondents gave a total of 37 responses about barriers to their interdisciplinary work in Argentina, 22 responses about barriers to their interdisciplinary work in Brazil and 47 responses about barriers to their interdisciplinary work in Mexico. Based on our coding results we determined that 11 different types of barriers were discussed in the survey responses: budget, bureaucracy, communication, consistency, danger and safety, different research and cultural traditions, integration, language, fieldwork logistics, personnel and relationships and time commitment (Table 2.2). In Argentina, barriers listed in more than 50% of responses were integration, fieldwork logistics, personnel and relationships and time commitment (Table 2.2).

Table 2.2. Percentages and total numbers (in parentheses) of responses to survey questions about the barriers of working in interdisciplinary teams internationally, by barrier and country. Bold font signifies responses that are equal to or greater than 50% of total responses.

Barrier	Description	Argentina % (N=8)	Brazil % (N=6)	Mexico % (N=13)
Budget	Concerns over money	25 (2)	33 (2)	0 (0)
Bureaucracy	Issues with government or industry, paperwork, permits	38 (3)	17 (1)	8 (1)
Communication	Difficulty understanding others and coordinating effectively	13 (1)	33 (2)	31 (4)
Consistency	Challenges in coordinating across time zones, temporal seasons	25 (2)	17 (1)	31 (4)
Danger and safety	Concerns over personal safety	0 (0)	17 (1)	15 (2)
Different research and cultural traditions	Misunderstandings due to cultural differences	13 (1)	17 (1)	15 (2)
Integration	Barriers to collaboration and understanding between disciplinary groups	**63 (5)**	**50 (3)**	38 (5)
Language	Inability or difficulty communicating in another language	25 (2)	**50 (3)**	31 (4)
Fieldwork logistics	Frustration with coordinating complex housing, transportation, time in field	**50 (4)**	17 (1)	**77 (10)**
Personnel and relationships	Complex interpersonal relationships and working with and depending on many people	**50 (4)**	**50 (3)**	46 (6)
Time commitment	Fieldwork and interdisciplinary time commitment is great and progress slow	**50 (4)**	17 (1)	23 (3)

In Brazil, barriers listed in more than 50% of responses were integration, language, personnel and relationships (Table 2.2). In Mexico, the only barrier listed in more than 50% of total responses was fieldwork logistics (Table 2.2). See Table 2.2 for country-specific results.

Budget was mentioned as a barrier to conducting interdisciplinary, international research twice (25%) by respondents who conduct research in Argentina and in two responses (33%) referring to research conducted in Brazil. There were no responses about budgetary challenges from people who conduct research in Mexico. The most responses that related to bureaucracy challenges were from Argentina (three, or 38%), with Brazil and Mexico each having only one response (17%) relating to this barrier. Communication challenges were mentioned four times (31%) by people who conduct research in Mexico, followed by those who work in Brazil (two responses, or 33%) and Argentina (one response, or 13%). Challenges in finding consistency and coordination when conducting fieldwork in Argentina, Brazil and Mexico were mentioned by respondents working in Mexico the most frequently (four responses, or 31%), followed by two responses (25%) regarding conducting research in Argentina and one (17%) in Brazil.

Only three responses (11%) about danger and safety were mentioned in all the responses from the three countries. There were no responses in regard to conducting research in Argentina, only one response (17%) from researchers working in Brazil and two responses (15%) from Mexico. In relation to different research and cultural traditions being a barrier to interdisciplinary, international research, there was one response in Argentina (13% of this country's responses) and Brazil (17% of this country's responses) and two responses (15%) in relation to research conducted in Mexico. Compared to the

total responses in Argentina and Brazil's relating to integration as a barrier, which had five (63%) and three (50%) responses, respectively, there were fewer responses (five, or 35%) in Mexico. Language was mentioned as a barrier faced by researchers working in Argentina (two responses, or 25%) and Mexico (four responses, or 31%), but was mentioned more frequently in Brazil (three responses, or 50%).

The fieldwork logistics barrier was in the top three most commonly listed by respondents and was mentioned by 50% or more of respondents for Argentina (four responses) and Mexico (10 responses, or 77%). This was the only theme in Mexico that more than half of the respondents mentioned. Personnel and relationships were listed as barriers to conducting interdisciplinary, international research nearly equally in all three countries. There were four responses regarding research in Argentina (50%), three from Brazil (50%) and six from Mexico (46%). The time commitment barrier was listed four times (50%) relating to conducting research in Argentina, there was one response (50%) about Brazil and three responses (23%) about Mexico.

2.6 Discussion

In this section, we discuss in detail five of the major barriers identified in our survey (responses equal to or greater than 50% of total responses), their causes in relation to the NSF-PIRE project and, finally, share general recommendations for overcoming all the identified barriers.

2.6.1 Integration

Integration in interdisciplinary and/or international research teams is perhaps the greatest challenge researchers face, as has been discussed extensively in the literature (Barrett and Cason 1997; Gardner et al. 2013; Knowlton et al. 2014; Morse et al. 2007; Palmer et al. 2016; Romero-Lankao et al. 2013; Strober 2006). Accordingly, integration was seen as one of the greatest challenges in each of the NSF PIRE case study countries. Respondents stated that they needed more time for discussion about specific research issues and field sites, which was not possible in part because the social and natural scientists completed their fieldwork at different times. Other respondents identified integration of data as a difficult barrier and pointed to the need to identify software that is capable of integrating data from multiple disciplines. Many respondents wished that the team had had more detailed plans of exactly how the information from different disciplines and countries would be integrated from the very beginning, before the fieldwork started, as found in Barlow et al. (2011) and Morse et al. (2007). Respondents said that there were not enough meetings to specifically address how to integrate socioeconomic and ecosystem teams' research, and that, due to the long distances and lack of face-to-face time, many researchers just ended up working on their own disciplinary questions since they were most comfortable with those methods.

Integration was likely ranked by respondents as a significant barrier in Argentina because there were some problems integrating across broad disciplinary categories (social sciences, engineering and natural sciences) as well as across finer disciplinary divisions (e.g., soil, water, biodiversity). Beyond the literature about the difficulty of integrating methods (Gardner et al. 2013; Strober 2006; Romero-Lankao et al. 2013), we also found

other challenges to integration in our survey results. The social and natural science teams had trouble lining up their field seasons temporally, and so working together closely to integrate questions, communities and methods was difficult. Within the natural sciences it was difficult to integrate field sampling, since each sub-team had different needs and schedules (e.g., birds' breeding season vs. yearly variation for water data) and scales of study (e.g., landscape vs. local sites). Further, the variables affecting the sub-teams' studies were different—the biodiversity team did not need to factor in soil type or past land use, for instance, whereas water and soil teams did—making overlapping experimental designs challenging. Respondents also identified integration as a significant barrier in Brazil because of language difficulties as well as issues similar to those in Argentina in trying to line up field sites, important variables and timelines between disciplines.

In Mexico, the local coordinators were very responsive to the needs of each visiting research group, helping to provide local resources to the teams and fostering a feeling of shared responsibility and teamwork in the country. Nevertheless, the integration theme was still the third most frequently mentioned issue from all responses in Mexico. This demonstrates the almost inescapable problem facing researchers working interdisciplinarally across multiple countries.

2.6.2 Language

Understanding the language of collaborators is obviously fundamental to successfully working together. Language barriers are often present in international teams (Barrett and Cason 1997; Ross 1984) and the NSF PIRE project, with researchers whose native

languages ranged from Portuguese to Spanish to English, was no exception. The differences in the prevalence of language as a barrier in the three case study countries perhaps points to the differences in the initial level of Spanish or Portuguese language skills that researchers possessed when beginning fieldwork in each country. However, in Mexico there was the added problem for alike of over 60 ethnic languages being spoken throughout the country.

2.6.3 Fieldwork logistics

Working on the ground in a foreign country is bound to present logistical difficulties, which are inherently related to not knowing how the local system works. For instance, respondents stated that conducting social science interviews in the US and Mexico was very different—in the US one cannot simply turn up at a doorstep and expect the inhabitants to sit and talk to you for an hour, as they would in rural Mexico. In the US, appointments for interviews are necessary, and keeping questions short and concise is essential so as not to be perceived as wasting someone's time.

The challenges of working on an interdisciplinary, international research project are made very apparent in the responses about fieldwork logistic challenges in Mexico, which encompassed most of the other barriers mentioned. Not only is it difficult to fully plan for changes in weather or the political climate of a country, but one must also coordinate multiple field seasons and when, where and how to share resources across disciplinary researchers, as noted by Freshwater et al. (2006) and Ross (1984). As Barrett and Cason (1997) and Ross (1984) found, our survey respondents also mentioned logistical challenges in securing housing and transportation, travelling long distances on

rough roads and seasonal concerns such as who would be available to be interviewed or surveyed or what biophysical measurements could be taken while researchers were in the field.

Fieldwork logistics were a barrier to conducting research in Argentina because of cumbersome bureaucracy, the need to pay for everything in cash and because the fieldwork was perceived as expensive. In addition, the natural and social science teams shared housing, which proved difficult to coordinate since everyone wanted to be closer to their particular study site. Rental cars were also shared, which was challenging due to the different schedules and locations of the researchers in the field. Bureaucracy was dealt with on both ends of the research, when researchers were in the field abroad, and again when they were at their home institutions. These types of challenges were not found in the existing literature. In Brazil, fieldwork logistics were minimal since research was undertaken within a large oil palm plantation and the company provided housing and assistance in getting around. This finding is surprising, since in the literature, several researchers found it more difficult for outsiders to gain access to essential stakeholders because of local suspicions about researchers from other countries (Barrett and Cason 1997; Di Castri 1976; Ross 1984).

2.6.4 Personnel and relationships

Challenges to conducting interdisciplinary, international fieldwork included having too many people in the field at a time, finding local contacts, and dealing with personal isolation and dependency on local hosts, as discussed in the literature (Dieguez et al. 2015; Halvorsen et al. 2015; Ross 1984). In Mexico, the problems associated with

personnel and relationships related to concerns about not recognizing the hard work being done by the local researchers as well as the problems in finding appropriate interviewees and survey respondents, as cited in Dieguez et al. (2015) and Ross (1984). Other respondents commented that there was not enough cross-disciplinary collaboration on the ground and that they were concerned that research participants were not being compensated or recognized for their time, as discussed by the National Research Council (2008) and Palmer et al. (2016). When the team members do not trust each other and there is a lack of clarity about the fieldwork being done (e.g., methods), relationships are bound to become tense.

Personnel and relationships were ranked as barriers in Argentina for many of the same reasons as in Mexico, and because of conflicts in personality types among team members, just as Romero-Lankao et al. (2013) found in their international, interdisciplinary research. Respondents also mentioned differing expectations about roles, authorship, and what would be provided (e.g., monetarily and in terms of field help). In Brazil, personnel and relationships were ranked as barriers due to different expectations of timelines, constantly changing plans and language difficulties, as well as the added complexities of working with NGOs and agribusiness personnel, as found by National Research Council (2008) and Palmer et al. (2016).

2.6.5 Time commitment

The barriers identified by our survey respondents that were associated with the time commitment of conducting interdisciplinary, international research mainly stemmed from individual researchers having difficulty planning to spend weeks doing fieldwork while

being full-time students. Many foreign researchers spent significant time in the field in Argentina, as opposed to having local collaborators conduct most of the field data collection as was the case in the other countries. The extra time that it takes to conduct interdisciplinary, international research was found to be a barrier not only in our research, but also in the literature (Morse et al. 2007; Ross 1984).

2.6.6 Recommended Solutions for Overcoming Barriers to International, Interdisciplinary Research

In this section, we recommend solutions for overcoming barriers to international, interdisciplinary research based on the literature and our experiences with our NSF-PIRE project (see Table 2.2). Our solutions can be grouped into three broad categories: 1) preparing and training team members in advance of conducting research and fieldwork; 2) conducting trust-building activities; and 3) granting international research partners more autonomy.

Preparation in advance of conducting research and fieldwork can include setting realistic yet flexible expectations (Gardner et al. 2013); conducting a thorough investigation regarding which permits are required well before starting the research (Ross 1984); and learning about both written and unwritten rules and norms (Ross 1984). From our experience, we recommend thoroughly training researchers before fieldwork occurs and creating agreed-upon guidelines for team members; getting to know the local context where research is conducted; and always being accompanied by local people who have local knowledge of the situation and can telephone to ask for appointments before the fieldwork starts. This type of preparation can promote integration across both countries

and disciplines; resolve timing and budgetary problems; minimize cultural and personal misunderstandings; mitigate personal safety issues and language difficulties in the field; and solve consistency and communication barriers.

Our experiences strongly suggest that fostering trust among researchers on interdisciplinary and international teams can help mitigate or solve communication, time, integration, logistical and personal relationship barriers to conducting fieldwork. Trust can be built by designing interactive experiences for the team members, getting researchers out of their seats at meetings and into team- and trust-building exercises and establishing trusting and cooperative relationships with local partners is essential for overcoming logistical barriers, as is a flexible and adaptive attitude to problems that arise. Beginning an interdisciplinary, international research project using existing interpersonal relationships among researchers who have already worked together is one way to ensure a strong sense of ownership and a democratic and trusting network of researchers (Gardner et al. 2013). Flexibility, patience, creativity and shared responsibility and involvement of all researchers should be encouraged, especially in teams composed of diverse groups of people from different disciplinary and cultural backgrounds (Cheruvelil et al. 2014; Di Castri 1976; Morse et al. 2007).

We recommend giving international colleagues more autonomy in interdisciplinary, international research projects. Cheruvelil et al. (2014) point out that having a philosophy that stresses that international partners are integral members of the team and should therefore share in the responsibilities, decision-making and communications is essential to overcoming cultural barriers. While some of the budget-related barriers to international research are unavoidable, a possible solution would be to

give foreign institutions subcontracts and lump sums of money for them to administer for the research in their own country. Castri (1976) suggest that promoting the exchange of information and researchers between countries can facilitate training and cultural understanding; in our experience, we found that it can also overcome communication and budgetary barriers.

In Table 2.3, we present our recommended solutions for overcoming barriers to international, interdisciplinary research based on our experience. We give recommendations for the major barriers identified by our survey respondents.

Table 2.3. Recommended solutions for overcoming barriers to international, interdisciplinary research.

Barrier	Description of barrier	Recommended Solutions
Integration	Barriers to collaboration and understanding between disciplinary groups	Define focal themes, research questions and spatial and temporal scales jointly before starting research (Di Castri 1976; Morse et al. 2007).
		Prioritize face-to-face meetings that focus on interdisciplinary and intercultural training (Goddard et al. 2006; Morse et al. 2007).
		Identify outside mentors who can help the team learn integration skills (Morse et al. 2007).
		Promote flexibility, patience, creativity and shared responsibility and involvement in the research project (Di Castri 1976; Morse et al. 2007).
Language	Inability or difficulty communicating in another language	Require researchers to be at least bilingual, as well as familiar with more than one discipline and different cultural settings.
Fieldwork logistics	Frustration with coordinating complex housing, transportation, time in field	Establish trusting and cooperative relationships with local partners to overcome logistical barriers in international field sites.

		Promote flexible and adaptive attitudes for problem solving (Gardner et al. 2013).
Personnel and relationships	Complex interpersonal relationships and working with and depending on many people	Take advantage of existing interpersonal relationships among researchers who have already worked together (Gardner et al. 2013).
		Select team members thoughtfully and carefully foster team member diversity (gender, ethnicity, religious beliefs, career stage, personality, socioeconomic class, life experiences, viewpoints, skills, problem solving methods) (Cheruvelil et al. 2014; Morse et al. 2007).
		Teach researchers interpersonal skills, including social sensitivity and emotional engagement (Pentland 2012; Parker and Hackett 2012; Stokols et al. 2008; Woolley et al. 2010).
		Build excitement about research goals and personal commitment to team members (Cheruvelil et al. 2014).
Time commitment	Fieldwork and interdisciplinary time commitment is great and progress slow	Build trust by discussing issues at length in order to get agreement and mutual understanding between all countries and disciplines.
		Write memorandums of understanding in which commitments and deadlines are clearly specified.
		Recognize and respect timing issues among disparate research groups (Morse et al. 2007).

2.7 Conclusions

We found five major barriers to conducting interdisciplinary, international research in our NSF-PIRE project countries (Argentina, Brazil and Mexico): integration; language; fieldwork logistics; personnel and relationships; and time commitment. The types of barriers and the strategies for addressing them differ from country to country and

between disciplines, but we developed a list of recommendations for preventing or overcoming each barrier based on our experiences and those found in the literature (Table 2.3). Although it is important to be aware of all the potential barriers, good interdisciplinary, international research should concentrate on getting an adequate mix of cultures, disciplines and languages in order to help the flow of communication and therefore make it easier to overcome the difficulties when they arise. Informal team outings and formal teamwork exercises that build interpersonal skills can also help teams foster strong relationships, establish shared research goals and standards of behavior and create a shared vision for project management. Our discussion of this case study and results of our survey and literature review can help other interdisciplinary, international research teams anticipate and address challenges in this type of work. Despite the hurdles in conducting interdisciplinary, international research, we have found it to be a rewarding, worthwhile experience. Many of the world's most pressing problems require an international team of experts with the skills to work together, and incorporating our recommendations can assist other teams in their planning, executing and publishing their research. International authorship and interdisciplinary research often leads to highly cited and impactful papers that may help solve the "wicked" problems that trouble society.

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Chapter 3: Public Perceptions Toward Bioenergy Development in Tabasco, Mexico[2]

Biodiesel from oil palm is an increasingly popular renewable energy option around the world, particularly in global southern countries like Mexico. Mexico's support for commercial scale bioenergy production began in 2008 with the Bioenergy Promotion and Development Law. However, few studies investigate the perceived impacts of national biofuel policies on local Latin American communities. This is a critical gap because many Latin American governments are promoting biofuel development as the best alternative to reduce reliance on fossil fuels, increase energy independence and stimulate rural development. This gap also has global implications because oil palm can only be grown in specific geographical locations in the tropics, so Latin America is expected to become one of the primary global biofuel suppliers. Our study attempts to fill this gap by providing a voice to those whose views are often overlooked in these larger national or international energy policy discussions where energy is produced in one location and consumed in another. We present results from our 2015 quantitative survey of 130 community members in Tabasco, Mexico, living close to areas of increased oil palm cultivation. Our findings indicate that perceptions about the future impacts of oil palm expansion are positively associated with attitudes toward support for current oil palm

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plantations, oil palm production used to produce biofuels for export, as well as attitudes toward the oil palm's provisioning of ecosystem services.

3.1 Introduction

In advance of the COP21 climate change talks in Paris in December 2015, Mexico pledged a 25% reduction in greenhouse gas (GHG) emissions and other climate pollutants by 2030 and offered to increase this amount to 40% if a global climate change deal were reached (UNFCCC, 2016). This pledge stems from the country's strategy to combat climate change through a competitive, sustainable economy that emits fewer GHG emissions, as outlined in the 2008 Law to Promote and Develop Bioenergy (Diario Oficial de la Federación, 2008) and the 2012 national General Law on Climate Change (LGCC, 2012). Mexico hopes to achieve the country's climate change goals through various reforms, the introduction of a carbon tax, energy efficiency measures and increased development of alternative fuels such as biodiesel (UNFCCC, 2016). Although each of these strategies is important to GHG emissions reductions, the current paper focuses specifically on Mexico's efforts to increase biofuel development to achieve climate change mitigation. Our goal is to investigate the extent to which public perceptions align with the government's vision to mitigate climate change.

Do communities proximate to oil palm plantations support or oppose bioenergy production? We consider this an important component of public perception in Mexico because these are the communities that will face the most direct local impacts of biofuel development. The answer to this question has implications for long-term growth in the country. To determine if biofuel development has localized support in these regions, we conducted a quantitative survey in the Tabasco State, Mexico, where climatic conditions

are highly favorable to palm plantations for biofuel development. Our survey asked about the level of support for an increase in oil palm plantations to be used for biofuel production in Tabasco.

3.2 Background

Mexico's interest in biofuel development was first formalized in a 2008 national law known as Ley de Promocion y Desarrollo de los Bioenergeticos, which initiated the writing of Mexico's first bioenergy plan (Romero-Hernández et al., 2011). This law was premised on the expectation that biofuels could stimulate Mexico's agricultural sector making it possible to achieve energy independence without endangering domestic food security (Diario Oficial de la Federación, 2008). Policy makers also expected that the domestic commercialization of biofuel would contribute to increased rural social wellbeing and community development through the expanded employment of marginalized populations (Camara de Diputados, 2008). Thus, not only were biofuels considered an important substitute for carbon emitting fossil fuels, but biofuels were also expected to drive the sustainable development of Mexico's rural economy (Creutzig et al., 2012; Dauvergne & Neville, 2010; German et al., 2011; Skutsch et al., 2011). In places like Tabasco, this meant increased utilization and expansion of existing oil palm plantations for biodiesel production.

The Mexican government also created the Agricultural Alliance in 1998, whose goal was to promote agricultural technologies, diversify cropping systems, increase the production of export crops and stimulate rural development through the establishment of plantations to grow cotton, soybeans, oil palm, coconut palm, citrus and ornamental

plants (Diario Oficial de la Federación, 1998). As part of the Agricultural Alliance's activities, oil palm plantations were established in six states, including Tabasco, with the specific intent of securing a domestic source of energy while helping to improve rural farmer wellbeing (Diario Oficial de la Federación, 1998). Our research studies the Tabasco region because it has a lengthy history of oil palm plantation activity as well as federal government support for bioenergy development (Diario Oficial de la Federación, 1998). As the geographic locations where oil palm is able to grow are limited to the tropics and the majority of countries that consume it are located elsewhere, exportation of oil palm can be expected (Byerlee et al., 2017). This is especially the case in the near future considering that the growing economies of China and India will likely spur more demand for oil palm as a cooking oil (Byerlee et al., 2017). We believe that the length of exposure to oil palm development in places like Tabasco is important for the coalescing of public perceptions because it provides sufficient time for issue saliency to stabilize within the general public.

3.3 Literature review

Public support for biofuels is not uniform within countries or regions. Literature suggests that support depends on demographics, past experience with alternative energy systems, media exposure and culturally specific worldviews (Bechtel et al., 2006; Corral-Verdugo & Armendariz, 2000; German et al., 2011). Perceptions hinge on differences in regional appeal or relevance. For example, the public is more likely to support a biofuel project if it is expected to have positive economic impacts, if it appears unlikely to harm the environment and if it can be incorporated into the local community with minimal lifestyle

disruption (Radics, 2015). Public perceptions toward biofuel are not guaranteed to align with the views of policy makers and technicians who may be more likely to focus on the scientific or technical merits of a given energy development program. It is necessary that the people who live in communities where feedstocks are grown and processed also view biofuels as an acceptable renewable alternative (Ellis, 2000). Knowing how the public and landowner-producers perceive biofuel feedstock development projects—which trade-offs people are willing to make and which are deemed unacceptable—is an important way to gauge social acceptance. Given that public support is often critical to the success of an energy development project (McAdam & Boudet, 2012), assessing the social acceptance of biofuel is an important step toward understanding the sustainability of biofuel systems in general, evaluating Mexico's approach to mitigating climate change in particular and gaining a broader appreciation for the potential impacts of biofuel development in Latin America with insights for the developing world as a whole.

Public perceptions of biofuel can be classified into three overlapping but somewhat distinct categories, which align with the standard three-pillars concept of sustainability, including perceptions of: 1) environmental, 2) economic, and 3) social impacts. In the remainder of this section, we review the biofuels literature with respect to these three dimensions, as well as to demographic impacts, to identify potential causes for the development of either positive or negative public perceptions. We also pay particular attention to the use of palm oil as a potential biofuel feedstock given the importance of this resource to the Tabasco region of Mexico.

3.3.1 Environmental Impacts

Oil palm's usage as a biofuel feedstock provides potential environmental benefits likely to positively impact public perceptions (German et al., 2011; Islas et al., 2007; Lozada et al., 2010). First, it can put marginal lands to productive use. Second, it can increase a region's carbon sequestration capacity. Finally, biodiesel production from oil palm can reduce a region's GHG emissions. Of course, perceptions regarding its negative environmental impacts can also raise opposition. These include potential biodiversity losses due to deforestation, land-use changes that reduce traditional land uses, reductions in water quality and availability, as well as the temporary carbon stock reductions that occur when new oil palm plots are cleared (Alemán-Nava et al., 2014; Bailis, 2014; Dauvergne & Neville, 2010; Fargione et al., 2010; German et al., 2011; Martinez-Alier, 2011; Rist et al., 2010; Rodríguez et al., 2014; Selfa et al., 2014; Skutsch et al., 2011; Solomon et al., 2015).

3.3.2 Social Impacts

Positive perceptions about the social impacts of biofuel feedstock development can also increase public support. These include additional wage increases and new employment opportunities created when biofuel industries expand, especially when smallholder farmers are involved in the production process (Dauvergne & Neville, 2010; German et al., 2011; Islas et al., 2007; Radics, 2015; Rist et al., 2010). Biofuel feedstock development can also be a major driver of critical infrastructure improvements that rural underdeveloped regions often lack in the absence of a local industry. Nevertheless, perceptions of negative social impacts could result in increased opposition to biofuel

development. These include concerns about poor working conditions in plantations, the inability to sustain traditional livelihoods or food production systems, increased food prices, rising rates of social conflict and the possibility of increased dispossession of farmers from the land (German et al., 2011; Halder et al., 2011; Skutsch et al., 2011).

3.3.3 Economic Impacts

Finally, biofuel production can have both positive and negative local economic impacts that affect support. In addition to the increased job opportunities mentioned above, biofuels can also provide increased energy independence for regions seeking to gain greater control over fluctuating or unpredictable energy costs (Andrade & Miccolis, 2010; Creutzig et al., 2013; Radics, 2015; Rodríguez et al., 2014; Skutsch et al., 2011). Although biofuel development can increase local economic growth, the distribution of economic benefits is not always equal. One reason is that oil palm plantation managers may discriminate against older workers, creating unequal employment opportunities (Hunsberger et al., 2014). The shift from locally valued agricultural products (e.g. fruits and vegetables) toward export-oriented production can also make it difficult for local communities to meet subsistence needs, which has a greater impact on the already impoverished. Thus, a legacy of growing export crops can generate significant public opposition (Dauvergne & Neville, 2010; USTR, 2014). Although it may not be possible to predict in advance which of the above issues will be most salient to the citizens of a biofuel development region, we believe these are the factors that are most likely to affect public perceptions of biofuel development in Tabasco.

3.3.4 Demographic Impacts

Aside from public perceptions regarding the expected impacts of biofuel development, a number of important demographic characteristics can also affect support. For example, men are more likely than women to perceive oil palm expansion positively since men are more likely to be employed in newly created biofuel jobs and their daily lives are less likely to be disrupted by this industry (German et al., 2011; Tandon, 2009). Private property owners are also more likely to support oil palm production than those who live on *ejidal* or communal lands due to the recent history of Latin American biofuel production regions, which experienced a series of unpopular land grabs and encroachments on *ejidal* lands (Dauvergne & Neville, 2010; German et al., 2011; Hunsberger et al., 2014; Moser et al., 2014; Rist et al., 2010; Selfa et al., 2014; Skutsch et al., 2011). Finally, age is also likely to impact bioenergy support with the highest levels of support expected from those of early working age. Young people are more likely to benefit from new plantation jobs because this group faces the highest unemployment rate in the region (Halder et al., 2010; Mingorria and Gamboa, 2010; Zarnikau, 2003). Therefore, as age increases, perceptions of the impacts of oil palm expansion are likely to become less positive resulting in lower support for oil palm.

3.5 Gaps in the Extant Literature

After having outlined the general mechanisms of biofuel support in the existing literature, it is now important to highlight how our study contributes to advancing our understanding of this topic. First, we believe that geographically embedded research is key to understanding how people respond to bioenergy production in different contexts

(German et al., 2011; Zimmerer, 2011). Yet, few studies investigate the perceived impacts of national biofuel policies on local Latin American communities. For example, none of the 44 articles on biofuel perceptions reviewed in Radics (2015) addressed Latin American perceptions. This is a critical gap because many Latin American governments are promoting biofuel development as the best alternative to reduce reliance on fossil fuels, increase energy independence and stimulate rural development (Sullivan et al., 2010). This gap also has global implications because Latin America is expected to become one of the primary biofuel suppliers to China and India, helping these regions to fulfill the demand for oil palm (Byerlee et al., 2017). Our study attempts to fill this gap by providing a voice to those whose views are often overlooked in these larger national or international energy policy discussions.

Another limitation of the extant literature is that much biofuel sustainability scholarship focuses strictly on either the short-term economic or environmental impacts of biofuel production, overlooking the social dimension entirely (Creutzig et al., 2012). Lacking research on biofuel-related public perceptions and beliefs about the impacts of biofuel production, we believe it is impossible to assess the full sustainability consequences of these production systems. Knowing how the public and landowner-producers perceive bioenergy development projects—which trade-offs people are willing to make and which they deem unacceptable—is critical to gauging social acceptance. This information is necessary if future policies are to be designed in a way that takes advantage of existing support without amplifying opposition. Therefore, studies like ours provide the background information necessary to increase the sustainability of any bioenergy system while enriching the literature on the sustainability of renewable energy

production systems overall (Dale et al., 2011; Howe & Boyer, 2016; West et al., 2010). In this way, our study adds to existing literature on the social acceptance of renewable energy development (Devine-Wright, 2007, 2009, 2013), gaining a deeper understanding of the drivers of biofuel support or opposition while bearing in mind perceived impacts across the environment, society and the economy.

3.6 Methods

In July 2015, we surveyed households in the municipalities of Jalapa, Tacotalpa and Teapa, which are the areas of Tabasco State with the highest concentration of oil palm plantations. The population of the rural communities included in our survey ranged from 400 to 2,000 residents. Our target population was adults over the age of 18. Given low literacy rates and poor mail and telephone service, our survey was administered orally and face to face. We attempted a systematic random sample of the region, which meant that after selecting an oil palm-growing region in Tabasco and randomly selecting communities within that region, we visited every other house and administered surveys with every willing participant. We completed a total of 130 household surveys out of 156 attempts, over a span of two weeks, resulting in a response rate of 83.3%.

Our survey questionnaire was divided into seven sections, including: demographic questions, ecosystem service values, knowledge about biofuels, anticipated community impacts of oil palm production, environmental values, attitudes about climate change and questions about public policies. The goal of each themed section was to develop an additive index using Likert-based questioning on a series of items pertaining to various aspects of the same topic. These indices were then used in descriptive statistical analysis

to describe existing attitudes toward biofuel feedstock production in the region and in inferential statistics to explain differences in support levels across respondents based on observed differences in perceived oil palm impacts and personal value systems.

To assess the level of existing support for biofuel in the region, we first created a four-item *oil palm support* index, including: 1) general support for oil palm, 2) support for oil palm if used for food, 3) support for oil palm if used for non-food products and 4) support for oil palm if used to produce domestic biofuel. Each item on this index was assigned a score from 1 (strongly disagree or oppose) to 5 (strongly agree or support) where the minimum index score was 5 and the maximum index score was 20 (see Table 2 for question wording). We also constructed a 14-item *oil palm impacts* index to measure perceptions toward the anticipated effects of oil palm expansion on the local environment, economy and society. This index was composed of 14 total items (see Table 3 for question wording) with five items designed to assess environmental impacts (air quality, water quality, bird habitat, flood prevention capacity and aesthetics), four items designed to assess economic impacts (local economy, employment stability, employment opportunities for women and worker security) and five items designed to assess societal impacts (desire to stay in community, ability to stay on one's land, youth retention, food availability and food production). Each item used a five-point scale that ranged from -2 (very negative impact) to 2 (very positive impact) with neutral being 0. The total index score had values ranging from -28 to 28. Finally, to assess the beliefs of respondents regarding oil palm's ability to provide valuable ecosystem services, we constructed a nine-item *oil palm ecosystem services* index to determine how respondents interpret oil palm's current impact on existing ecosystem services as opposed to future

impacts due to oil palm expansion (items in the index included aesthetics, tourism and recreation opportunities, bird habitat, clean air, clean water, sufficient water levels, food, productive soils and economic opportunities). Responses were recorded using a simple binary "yes/no" option regarding whether or not respondents believed oil palm provided the ecosystem service in question, with index scores ranging from 0 to 9. The higher the index score, the more ecosystem services the respondent believed oil palm provides and the higher the respondent score on this index.

Table 3.1 summarizes the demographic characteristics of our sample and compares them to the most recent census data for Tabasco. We see that female respondents outnumbered males 55% to 44% in our sample, resulting in a slight but insignificant overrepresentation of women who represent only 51% of the region (INEGI, 2016). The slightly higher number of women in our sample suggests that care should be taken when interpreting the aggregate statistics of our study, which we do below, but is not expected to impact our inferential statistics. In terms of age, our sample was heavily skewed toward the two working-age categories of 18-39 (40%) and 40-59 (44%) with nearly even representation from both. Although our sample includes responses from individuals 60 years and older (17%), the low sample size of this age category meant that it was necessary to collapse this group into the 40-59 category in our analysis. With that said, our sample does at least provide adequate coverage of the two critical working-age groups the literature expects should differ in their level of biofuel support.

Table 3.1. Sample Demographics (N=130)

Gender	**Frequency (N)**
Male	44% (57)
Female	55% (72)
Education	
No basic education	5% (6)
Some or completed primary school	40% (52)
Some or completed secondary school	32% (41)
Some or completed high school	12% (16)
Some or completed college	10% (13)

Ownership Type	**Frequency (N)**
Private	15% (20)
Ejidal	28% (36)
Uncertain	50% (65)
Age	
18-39	40% (52)
40-59	44% (57)
60-79	15% (19)
80+	2% (2)

Land Tenure	
> 10 years	7% (9)
10-20 years	19% (24)
> 20 years	74% (96)

In terms of education, our sample had a mean education level of some middle school (between six and nine years of school) (see Table 3.1). This is quite comparable to educational attainment rates from the Mexican census data in that the average educational level of the Mexican population aged 15 and older was 8.6 years of schooling (INEGI, 2016). Also, a significant majority of our respondents (74%) reported having lived in their community for more than 20 years with much of the remainder having lived at least

10 years in the community (19%) and even fewer having lived in the community for less than 10 years (7%). This meant that most respondents had adequate exposure to recent biofuel development activity in the region and many had a memory of traditional land uses prior to oil palm expansion.

The majority of our sample fell into the "uncertain" land ownership category (50%) with the remainder representing both *ejidal* (communal) (28%) and private (15%) landowners. Many of the "uncertain" respondents fell into this category due to their inability to classify their own ownership status as a consequence of complex property ownership structures in the region. This makes it difficult to verify the exact balance of private versus *ejidal* owners in our sample but, based on the responses of those who could self-identify, it is clear that the views of both ownership structures are well represented.

Finally, in terms of occupation, 17% of our sample worked as oil palm producers while 15% worked on oil palm plantations or smallholder plots for the industry. The remaining respondents worked in other areas of the agricultural sector (31%), ranching (15%), the public sector (18%, primarily school teachers) or in a mixture (32%) of other non-oil palm industry occupations (e.g. retirees, homemakers, etc.). The broad representation of occupations in our sample ensures that the public perceptions we report below were not biased toward the oil palm industry or those working outside the industry. Given these sample demographics, we believe our sample is sufficiently representative of the average adult residing in the Tabasco biofuel production region.

3.7 Results

The goal of our study was to first determine the level of support for an increase in oil palm plantations within Tabasco, and then to determine why differences in support exist within the region. In terms of the level of support for oil palm, the sample mean for our *oil palm support* index was 14.5 out of 20 (see Table 3.2). However, reliability analysis indicated that our index could be improved with the removal of the *biofuel for export* item (raising Chronbach's alpha from .732 to .807 with this item removed). The removal of this item from our index resulted in a new adjusted support level of 15.48 out of 20. These results tell us that the current level of support for oil palm in the region is quite high. However, it is also important to note that respondents as a whole expressed much more support for expanding oil palm production specifically for biofuel than expanding oil palm production in general.

Table 3.2. Descriptive Statistics for Oil Palm Support Index

Each item on this index was assigned a score from 1 (strongly disagree) to 5 (strongly agree) where the minimum index score was 5 and the maximum index score was 20. The support for oil palm if it is used to produce biofuel for export variable was removed from the index.

Oil Palm Support Index	**Mean**	**Median**	**Chronbach's Alpha if Item Removed**	**N**
Q: Considering everything, I support an increase in oil palm plantations.				
General support for oil palm plantations	3.49	4.00	0.644	128
Q: What would your opinion be about an increase in oil palm plantations if the oil was used for the following?				
Support for oil palm if it is used to produced food	3.99	4.00	0.643	128
Support for oil palm if it is used to produced non-food products (cosmetics, pharmaceutics)	3.91	4.00	0.658	128
Support for oil palm if it is used to produce biofuel for the community	4.09	4.00	0.663	128
Support for oil palm if it is used to produce biofuel for export	3.03	3.00	0.807	128
Chronbach's Alpha for 5 items	**0.732**			**128**

In addition to assessing the current level of support for oil palm, our questionnaire also used an index to assess the perceived impacts of future oil palm expansion on the region. The sample mean for our *oil palm impacts* index was 7.9 (with the total index score ranging from -28 to 28) with a high Chronbach's alpha of 0.88 (see Table 3.3). This index tells us that respondents as a whole foresee oil palm expansion having only a

slightly positive impact on the region despite reported support for biofuels. We can also see that this positive orientation primarily stems from anticipated benefits to the local economy in general and employment stability while local food production, flood prevention and water quality are expected to benefit the least.

Table 3.3. Descriptive Statistics for Oil Palm Impacts Index

Each item used a five-point scale that ranged from -2 (very negative impact) to 2 (very positive impact) with neutral being 0. The total index score had values ranging from -28 to 28.

Perceptions of Future Oil Palm Impacts	**Mean**	**Median**	**Chronbach's Alpha if Item Removed**	**N**
Q: In your opinion, if there were an increase in oil palm plantations, how would this impact the following?				
Clean air	0.55	1.00	0.871	127
Bird habitat	0.66	1.00	0.873	125
Flood prevention	0.05	0.00	0.885	125
Clean drinking water	0.10	0.00	0.872	125
Beautiful landscape	0.58	1.00	0.864	127
Desire to stay in the community	0.48	1.00	0.864	128
Capacity to retain youth	0.59	1.00	0.865	128
Local economy	1.07	1.00	0.870	127
Number of stable employees	0.99	1.00	0.871	126
Employment opportunities for women	0.47	1.00	0.873	126
Workers' security	0.52	1.00	0.865	124
Ability to stay on one's land	0.79	1.00	0.869	128
Availability of local food in the community	0.65	1.00	0.869	127
Local food production	0.06	0.00	0.871	124
Index	**7.90**	**8.50**		**112**
Chronbach's Alpha for Index	**0.879**			

The final index we created in our survey was used to assess the ecosystem service beliefs of our respondents. A higher score on this index indicated that respondents believed oil palm provides more ecosystem service benefits. The sample mean for this *oil*

palm ecosystem services index was 5.33 out of 9, with a reasonable Chronbach's alpha of 0.70 (see Table 3.4). This indicates that respondents believed oil palm provides a moderate but important number of valuable ecosystem services. Taking a closer look at the index item means, we see that economic opportunities provided by oil palm achieved the highest ranking followed by aesthetics and bird habitat provided by the plant. The clean water and sufficient water level items received the lowest mean scores with some mild reservations about food provisioning as well.

Table 3.4. Descriptive Statistics for Oil Palm Ecosystem Service Provision Index

Simple binary "yes/no" responses (Yes = 1, No = 0) were given regarding whether or not respondents believed oil palm provided the ecosystem service in question, with index scores ranging from 0 to 9.

Oil Palm Ecosystem Service Provision	**Mean**	**Median**	**Chronbach's Alpha if Item Removed**	**N**
Do you believe that oil palm plantations provide the following?				
Beautiful landscape	0.80	1.00	0.68	130
Tourism and recreational opportunities	0.56	1.00	0.66	128
Clean air provision	0.66	1.00	0.65	130
Clean drinking water provision	0.22	0.00	0.66	130
Food provision	0.46	0.00	0.69	128
Economic opportunities	0.97	1.00	0.70	130
Bird habitat provision	0.74	1.00	0.66	130
Provision of sufficient water resources	0.35	0.00	0.65	130
Provisions of productive soils	0.54	1.00	0.67	130
Index	**5.33**	**5.00**		**126**
Chronbach's Alpha for Index	**0.70**			

After establishing the fact that there is support for biofuels in our region, while perceptions about the future impacts of oil palm expansion and the ecosystem service benefits of oil palm are only moderately positive, we then conducted regression analysis

to determine factors shaping variation in support for biofuels within our region to gain a sense of the social barriers and opportunities to future biofuel expansion. The results of this work are presented in Table 3.5 with our *oil palm support* index serving as the dependent variable in two separate but overlapping models. The independent variables of Model 1 all come directly from our literature review whereas Model 2 includes additional control variables chosen based on having achieved statistical significance in a simple correlational analysis with our dependent variable (see Table 3.5). We chose this approach to demonstrate the merits of existing literature on biofuel support when controlling for other reasonable explanations overlooked in the literature.

Table 3.5 shows us that the only variable to achieve statistical significance in our "literature-review" model (Model 1) was our *oil palm impacts index*, which had a positive relationship with oil palm support and resulted in an adjusted R-squared of 0.50. In this moderately strong but sparse model, oil palm support increases a quarter point on our 16-point scale as perceptions about the future impacts of oil palm expansion become more positive, as expected. Model 2 shows us that this relationship continues to hold when controlling for other reasonable explanations while the adjusted R-squared of this saturated model increases only slightly to 0.57. Age also becomes statistically significant as well as beliefs about government promotion of biofuels. Both variables show a positive relationships with support for oil palm but perceptions about the future impacts of oil palm remain most impactful on oil palm support, as indicated by the Beta values of our coefficients.

Table 3.5. Nested regression results for *Oil Palm Support Index* as the dependent variable

Independent variable	**Model 1: Slope (Beta)**	**Model 2: Slope (Beta)**
Oil palm impacts index	.221(.714)*	.207(.674)*
Gender	.209(.041)	.307(.059)
Perceptions of oil palm biofuel exports	.202(.039)	.368(.071)
Importance of local energy production	.339(.921)	.600(.111)
Landownership	-.011(-.002)	-.070(-.014)
Age	.461(.089)	.791(.150)*
Oil palm ecosystem services index	--	-.105(-1.015)
Beliefs about countries' responsibility for environment	--	.261(.093)
Belief about government promotion of oil palm	--	.665(.240)*
Belief about government enforcement of environmental laws	--	.040(.016)
Perceptions of government response to community needs	--	.208(.096)
Constant	**13.041**	**9.016**
Adjusted R-square	**0.504**	**0.567**
N	**112**	**107**

*p<.05

Given the rather intuitive outcome that perceptions about the future impacts of oil palm expansion impact oil palm support from our first regression results, we decided to explore this issue further to explain differences with respect to their perceptions about the future impacts of oil palm expansion. To do this, we reran our regressions with the *oil palm impacts* index as the new dependent variable and repeated our two-step modeling approach from above to select independent variables (see Table 3.6). The goal here was to elaborate on the causal pathway that leads from perceptions about the future impacts of oil palm expansion to eventual oil palm support or opposition.

In this second stage of our regression analysis, three of the literature-based independent variables achieved statistical significance in Model 1 with an adjusted R-squared of 0.45: *Perceptions of oil palm when used to produce biofuels for export*, *importance of local energy production* and the *oil palm ecosystem services index*. Each variable showed a positive relationship with perceptions about the future impacts of oil palm expansion, as expected. In our saturated model (Model 2), the adjusted R-square value increased to .68 (but N dropped from 108 to 105), the *perceptions of oil palm when used to produce biofuels for export* variable and *oil palm ecosystem services index* variable both remained statistically significant from model 1 to model 2, but the *importance of local energy production* variable was no longer statistically significant. The general *support for oil palm plantations* variable was the only variable that was added in model 2 to be statistically significant.

Table 3.6. Nested regression results for *Oil Palm Impacts Index* as the dependent variable

Independent variable	**Model 1: Slope (Beta)**	**Model 2: Slope (Beta)**
Gender	-.750(-.046)	-1.157(-.069)
Perceptions of oil palm biofuel exports	**4.104(.249)***	**1.032(.150)***
Importance of local energy production	**2.999(.176)***	1.287(.078)
Landownership	.041(.002)	.063(.004)
Age	-.833(-.050)	-1.236(-.073)
Environmental values	-.467(-.091)	.514(-.100)
Perceptions of oil palm ecosystem service provision	**2.124(.548)***	**1.206(.308)***
Support for oil palm plantations	--	**3.470(.401)***
Perceptions of oil palm to produce various products (e.g. cosmetics)	--	1.371(.131)
Perceptions of oil palm to produce biofuels for domestic use	--	1.335(.109)
Belief about government promotion of oil palm	--	-.217(-.024)
Belief about government enforcement of environmental laws	--	.727(.091)
Perceptions of government response to community needs	--	-.529(-.076)
Constant	**-5.645**	**-28.77**
Adjusted R-square	**0.449**	**0.682**
N	**108**	**105**

*p<.05

3.8 Discussion

3.8.1 Overview of findings

The goal of our study was to investigate the social acceptability of increased biofuel development from oil palm in Tabasco, Mexico, and describe what type of spatial relationships are being created. In the previous section, we presented survey findings pertaining to the following research questions: 1) "What is the current level of support for oil palm within Tabasco's oil palm communities?"; 2) "What ecosystem services do the general public believe oil palm provides to these communities?"; and 3) "What perceived impact is oil palm expansion likely to have on the environment, economy and society of these communities?" We found that age, attitudes toward government support for oil palm and perceptions about the future impacts of oil palm expansion all had statistically significant and positive relationships with oil palm support. We also found that attitudes toward the development of biofuel for export purposes, ecosystem service provision and support for oil palm plantations all had statistically significant and positive relationships with perceptions about the future impacts of oil palm plantation expansion. In the remainder of this paper, we discuss the significance of these findings as they pertain to both the existing literature and the current energy policy landscape in Mexico.

Our descriptive statistics tells us that oil palm support is moderate in the region, oil palm is believed to provide a moderate number of ecosystem services and the impact of future oil palm expansion is perceived to be relatively positive. These results align with findings in the extant literature (German et al., 2011; Islas et al., 2007; Lozada et al., 2010). These are all good signs for biofuel development based upon oil palm expansion. However, oil palm support is clearly not unanimous within the region. This is why it is

important to investigate differences in oil palm support levels among our respondents as a way to uncover potential barriers to or opportunities for future oil palm expansion for biofuel development.

Moving beyond simply describing oil palm support, our regression analysis showed us that few of the variables hypothesized in the literature had a statistically significant relationship with oil palm support or perceptions about the future impacts of oil palm expansion in our study. There are two plausible explanations for this. It is entirely possible that no relationship actually exists in reality but it is also reasonable to assume that our study lacked statistical power due to an insufficient sample size to detect existing fine-grain relationships. Despite the second possibility, it is important to note that our exploratory study was still able to uncover a few important statistically significant relationships worth elaborating on in more detail. For example, the hypothesized relationship between age and oil palm support was confirmed but opposite of what was expected from the literature (Halder et al., 2010; Mingorria and Gamboa, 2010; Zarnikau, 2003). In other words, the older working age group was more supportive of oil palm than the younger working age group, which could be due to the fact that they are the ones currently benefitting the most from existing oil palm jobs. Unlike other studies, we did not find that gender (German et al., 2011; Tandon, 2009) or land tenure (Dauvergne & Neville, 2010; German et al., 2011; Hunsberger et al., 2014; Moser et al., 2014; Rist et al., 2010; Selfa et al., 2014; Skutsch et al., 2011) are positively associated with perceived future benefits of oil palm in Tabasco.

One of the major findings in our study relevant to oil palm policy in Mexico is the confirmed positive relationship between attitudes toward oil palm export production and

perceptions toward the future impacts of oil palm expansion. This finding is likely due to the fact that communities in our study region have already experienced the effects of exporting oil palm for use in food products and cosmetics (Diario Oficial de la Federación, 1998) as well as exporting other agricultural goods, like beef, as Dauvergne and Neville (2010) found. Our results suggest that those who had a positive experience with export production are also likely to develop positive perceptions toward the future impact of oil palm expansion and vice-versa. Programs like the Agricultural Alliance likely played a role in fostering these positive public perceptions in the Tabasco region over time. These rural development and poverty alleviation programs sought to promote export production as a means to generate employment in marginalized communities.

Our data support similar findings from the literature regarding the potential of bioenergy development to provide opportunities for rural communities (Dauvergne & Neville, 2010; German et al., 2011; Islas et al., 2007; Radics, 2015; Rist et al., 2010). Oil palm eventually became incorporated into an export-led growth strategy as a way to expand beyond the region's limited domestic market. This is likely why attitudes toward oil palm development for export purposes play such a large role in positively shaping perceptions of future impacts (Eastmond et al., 2014; Hall, 2011; Rodríguez et al., 2014). Given that there was overall positive support for oil palm's impacts, including social impacts, in our data, we did not find negative relationships between perceptions of oil palm's impacts and support for oil palm as German et al. (2011), Halder et al. (2011), Skutsch et al. (2011) did.

Our findings also indicate that perceptions about the future impacts of oil palm become more positive when respondents believe oil palm provides more ecosystem

services. Therefore, we cannot confirm findings from the literature regarding impacts on ecosystem services where oil palm is grown (Alemán-Nava et al., 2014; Bailis, 2014; Dauvergne & Neville, 2010; Fargione et al., 2010; German et al., 2011; Martinez-Alier, 2011; Rist et al., 2010; Rodríguez et al., 2014; Selfa et al., 2014; Skutsch et al., 2011; Solomon et al., 2015). This means that informing the public about the ecosystem service benefits of oil palm can have a significant positive impact on oil palm support down the line.

In our most robust, saturated regression model, perceptions of local energy production were not significant in explaining oil palm support of future oil palm production, a finding that is somewhat surprising considering that the media continues to stress this connection when reporting on Mexico's dwindling oil reserves or the government's action that amended the constitution to allow private investment in the country's oil industry, signaling the importance of energy independence (US EIA, 2014). Unlike some research that has shown that emphasizing increased energy independence through growing bioenergy feedstocks would generate local support for this such projects (Andrade & Miccolis, 2010; Creutzig et al., 2013; Radics, 2015; Rodríguez et al., 2014; Skutsch et al., 2011), we contradict these findings in our research.

3.8.2 Contributions to the Literature

Our research on public perceptions of oil palm production as a potential future bioenergy feedstock fills a gap in the literature by presenting public perceptions of bioenergy development in Latin America. It can inform decision makers of the public acceptability of exporting biofuels from Mexico to other markets. These issues can be

used as framing devices when creating acceptable policies that benefit both the environment and citizen's livelihoods. Policymakers should emphasize the future benefits of using a flexible crop like oil palm as both a potential domestic energy provider and opportunity for smallholders to enter the international export market. This is especially pertinent and relevant to the growth of the oil palm industry in Mexico since expanding markets globally will create demand that Mexico will help fulfill (Byerlee et al., 2017). Our work also lends clues on how bioenergy policies in Mexico, such as its climate change mitigation policy framework, will be received by the public. Although the literature continues to stress the importance of assessing sustainability across all three of these pillars simultaneously (Solomon et al., 2014; Stattman & Mol, 2014), our study is one of the first to approach this issue from the social acceptance dimension in Latin America.

It may be too early to say what the long-term impacts of growing oil palm will be. The spatial relations within Mexico, between various social actors have long been strained. However, unlike researchers who have found opposition to a new bioenergy crop (Skutsch, 2011) that is grown in one place but consumed in another, our results offer an alternative perspective: we reveal positive public perceptions of an existing feedstock with the potential for producing bioenergy for export. There is a lack of coherence and coordination between national and subnational governments, so there are no comprehensive linkages between initiatives across governments (Valenzuela, 2014). In the past, the Mexican federal government has contracted its governance mechanisms to international organizations like the World Bank, which then work directly with subnational governments to meet its various goals (Valenzuela, 2014, World Bank,

2014). If Mexico had stronger and more transparent governance structures, the benefits of growing oil palm in tropical countries may be distributed more equally. Several researchers suggest that Mexico adopt mandatory sustainability standards that include socioeconomic and environmental criteria (Hunsberger et al., 2014; Stattman & Mol, 2014) that incorporate the needs and desires of local producers (Moser et al., 2014). Our study provides a framework for informing this discussion. Without such measures, there may be more contested relationships at the landscape level as oil palm production expands.

3.9 Conclusion

In this paper we reviewed the public perceptions surrounding oil palm production and its potential expansion in Tabasco, Mexico. Few studies investigate the perceived impacts of national biofuel policies on local Latin American communities. This is a critical gap because many Latin American governments are promoting biofuel development as the best alternative to reduce reliance on fossil fuels and stimulate rural development. This gap also has global implications because Latin America is expected to become one of the primary biofuel suppliers to developing countries whose expanding populations rely on oil palm for cooking but which are unable to grow the crop. Our study attempted to fill this gap by providing a voice to those whose views are often overlooked in these larger national or international energy policy discussions.

We used descriptive and inferential statistics to analyze the results from our quantitative survey of 130 community members in Tabasco. This research shows that the social acceptance of oil palm is a complicated issue. We first demonstrated that support for oil palm could be high even when perceptions about the future expansion of oil palm

are moderate. We then showed that perceptions about the future impacts of oil palm, which had the greatest impact on oil palm support, hinged on perceptions about interrelated issues that ranged across the two of the three pillars of sustainability: perceived ecosystem service benefits (the environmental pillar) and perceptions about oil palm to produce biofuel for export (the economic pillar).

Policymakers, scientists and researchers who are interested in the sustainability and spatial relations surrounding bioenergy production should emphasize the future benefits of using a flexible crop like oil palm as both way to produce local ecosystem services and opportunity for smallholders to enter the international export market. In doing so, Mexico can also move forward in achieving their climate change mitigation goals.

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Chapter 4: Community Perceptions of Environmental Change and Adaptation Strategies in Two Communities in Tabasco, Mexico[3]

Rural inhabitants in many parts of the world face multiple stressors associated with global economic pressures, national-level neoliberal reforms, and patterns of environmental change. Using a political ecology lens, this research examines historical Mexican structural adjustment policies to better understand current public perceptions of environmental change among members of five *ejido* communities, with a focus on understanding the options local people have for adapting to such change in the future. Our results show that societal responses to environmental change in Mexico are determined by past political processes and, in part, by geographical location and landscape features as well as the resources (including social, political, and economic capital) perceived to be available to communities to adapt to these changes.

4.1 Introduction

Rural communities face numerous socioecological stressors. The concentration of political and economic power in urban centers, along with economic restructuring from local to global scales, has increased the vulnerability of many already-marginal rural places (Álvarez Gordillo & Tuñón Pablos 2016). This marginality has been exacerbated in many instances by national-scale adoption of neoliberal policies that expose rural places to global market forces (McMichael 2006). Increasing human populations, global

[3] The material contained in this chapter is in preparation for submission to *Society and Natural Resources* as Pischke, E. C., Mesa-Jurado, M. A., Eastmond, A., Abrams, J. and Halvorsen, K. E. Community Perceptions of Environmental Change and Adaptation Strategies in Two Communities in Tabasco, Mexico.

climate change dynamics, and various demands on natural resources all contribute to biodiversity loss and rural environmental degradation (Escobar 1995; INEGI 2016; Jiménez-García 2014).

Tabasco State serves as a microcosm of current Mexican social and ecological dynamics. With its dependence on petroleum extraction and processing, Tabasco is very responsive to global oil prices. With its extensive low-lying marsh and riverine ecosystems, it is particularly susceptible to hydrologic and climatic change (US EIA 2015; Rugeley 2014). These dynamics take place within a longer-term context of globalization, land use change, and shifts in outside intervention (Rugeley 2014). Given this history, we seek to understand how residents of five Tabascan *ejidos* perceive recent changes in their natural and social environments and their ability to maintain or improve their livelihoods in the face of these changes. Using a political ecology approach, we combine qualitative research with historical accounts to make connections between long-term changes in rural Mexico and current perceptions of community, environment, and livelihood prospects.

4.2 Literature Review

4.2.1 Political Ecology

The heterogeneous analytic framework of political ecology situates human-environment interactions within a broader political economic context (Blaikie and Brookfield 1987; Steward 1972; Wolf 1972). This perspective starts from an understanding that power and domination pervade social relationships and impact the ways that people use, manage, conserve, and otherwise interact with nonhuman nature (Robbins 2012; Peet and Watts

2004). Key themes in this diverse literature include: state control of natural resources and conflicts with local livelihoods (Bryant and Bailey 1997; Peluso 1992); local livelihood strategies and land uses as reflective of national and global relations of capital exchange (Escobar 1995); conservation as a form of enclosure (Neumann 2004); the organization of resistance among smallholders, the landless, and others affected by relations of domination (Peet and Watts 2004; Scott 1985); power relations underpinning claims of environmental knowledge and expertise (Gerber 2011; Rocheleau et al. 1996); and visibly and invisibly gendered dimensions of social resistance, environmental management, and environmental conservation (Rocheleau 2008).

Political ecologists recognize that environmental change, including land use change, often results from economic and political power dynamics, and decisions made outside the locations where such changes occur (Robbins 2009). The concept of chains of explanation (Blaikie and Brookfield 1987) has been used to connect social and ecological outcomes in particular places with economic structures, environmental protection, development discourses, and state actions. Political ecologists recognize that politics influence the environment, and poor environmental conditions can lead to community resistance toward public policies (Robbins 2009).

4.2.2 Government Impacts on Socioecological Systems

In developing countries, decisions made at the global, national, and local levels cause environmental change and can result in problematic social conditions. Global causes of social and environmental change include patterns and practices of colonization (Tudela 1989; Rugeley 2014); structural adjustment policies (Bryant and Bailey 1997; Escobar

1995; Kurtz, 2004); and international trade agreements that advantage state, and corporate interests and disadvantage rural people (e.g. North American Free Trade Agreement [NAFTA]) (Gravel 2007; Zimmerer 2006).

State governments wield natural resource policies as a form of political control, often in partnership with powerful private actors (Peluso 1992). Developing rural landscapes to gain access and control of natural resources and people (e.g. modernization schemes) is an example of this (Escobar 1995; Peluso 1992; Rugeley 2014; Uribe Iniesta 2009). Other national level causes of environmental change include: lack of rural governmental investment and corrupt, unaccountable officials (Christie et al. 2003); low governmental capacity to effectively implement and monitor programs (Dauvergne and Neville 2010); and top-down governmental natural resource management with limited local participation or decision-making (Bryant and Bailey 1997; Christie et al. 2002; Christie and White 2000). Environmental problems that results can include over-use and over-consumption of natural resources due to dwindling local availability and lack of alternative livelihood options (Klooster 2000), and local land use change and crop production spurred by government subsidies (Reynolds and Stafford Smith 2002).

When governments impose policies from the outside and local communities respond, environments are often modified in unexpected ways. Bryant and Bailey (1997) therefore see landscapes as "politicized environments," (p. 17) where politics and power lead to positive or negative environmental change (Robbins 2009). Resultant environmental problems can include, over-use and over-consumption of natural resources due to dwindling local availability and lack of alternative livelihood options through deforestation and biodiversity reductions (Klooster 2000), and change in the type of crops

are produced (Reynolds and Stafford Smith 2002). Environmental impacts from monocrop plantations such as jatropha and oil palm can affect biodiversity, but can also have unexpected consequences on human populations (Banerjee et al. 2017; Eastmond et al. 2014).

4.2.3 Community Impacts on the Environment

Peet and Watts (2004) discuss the importance of understanding local community members' perceptions of their community because that is where their everyday lived experiences play out and where they make sense of their lives. At the community level, causes of social and environmental change include poverty (Christie et al. 2003) and a lack of awareness of impacts of personal and collective choices and low capacity for managing natural resources (Wilbanks and Kates 1999). Local government corruption and broken promises by elected officials (Christie et al. 2003) and poor community organization and conflict resulting from power imbalances can lead to environmental neglect (Klooster 2000). Furthermore, poor community organization and conflict (Hardin 1968) can result from power imbalances (Christie et al. 2003; Klooster 2000). While many political ecologists broadly share Ostrom's (1990) critique of "tragedy of the commons" discourses (Hardin 1968), they tend to depart from much of the common pool resource literature by emphasizing the distorting influences of higher-scale political and economic systems (Saunders 2014) and patterns of heterogeneity and struggle within communities themselves (Agrawal and Gibson 1999).

4.2.4 Adaptive Capacity

Climatic and environmental change exacerbate socioecological impacts of institutional and political actions, spurring groups and individuals to find ways to adapt (Paulson et al. 2005; Pelling 2010). These actions include strategies to adapt to environmental change in the Global South, such as community organizing and increasing institutional capacity (Agarwal and Gibson 1999; Berkes and Ross 2013; Binford 1985; Christie et al. 2003; Magis 2010) as seen in coastal Vietnam (Adger 1999) and India (Sharma and Tomar 2010); community involvement in local problem solving (Agarwal and Gibson 1999; Christie et al. 2003), specifically in Mexico (Klooster 2000; Pelling 2010); and building grassroots social movements in response to a lack of government action (Peet and Watts 2004). Establishing partnerships between local governments and community members to co-manage natural resources has been successful in the Philippines (Christie et al. 2003), as have formal and informal education programs that train people to prepare for and prevent loss from natural disasters (Carmin et al. 2015; Christie et al. 2003).

Migration to places with more livelihood options, such as tourism infrastructure, is common (Álvarez Gordillo and Tuñón Pablos 2016). Migration is one response to lost harvests and lost livelihoods, but is often not an option for the poorest and most vulnerable and can negatively affect community social and economic wellbeing (Carmin et al. 2015). An example of domestic migration destinations is in Mexico's Yucatan Peninsula (Pelling 2010). For those who cannot move to find work, adaptation to changing conditions is necessary. In India, national plans for adapting to sea level rise have been made (Dubash 2012), while diversifying incomes was a successful strategy for adapting to local environmental change in Africa, Asia (Agrawal 2010), and in Latin

America (Eakin 2000). Requesting funds or infrastructure development from international donors (Wood 2011) has been successful in Kenya and Tanzania (Eriksen et al. 2005). Finally, in Mexico, farmers often try to mitigate loss from severe weather events by adjusting when they sow seeds and protecting crops using natural crop cover and barrier fences (Eakin 2000).

Various crops, including oil palm and teak, have been able to provide income for certain villages in Tabasco since the *La Alianza Para El Campo* subsidies were established in 1998 (Diario Oficial de la Federación 1998). The experience and familiarity with the crop on large scale plantations that were able to receive the government's oil palm subsidies enabled small-scale farmers to use their acquired knowledge to establish their own small household oil palm plants and begin to participate in the commodity trade (Dauvergne and Neville 2010). Structuring oil palm production on farmers' plots allows them the flexibility to grow other subsistence crops or cash crops like coffee as a supplemental income if the price of oil palm on the international market drops (Dauvergne and Neville 2010). In the case of small- and medium-sized farmers, domestic subsidies for crops like oil palm were not available to them, so they were more likely to work on the large-scale plantations that the government, large landholders and industry created (Diario Oficial de la Federación 1998).

4.2.5 Ecological and Climate Change in Tabasco

Salazar Conde et al. (2004) analyzed aerial photographs in the Sierra Madrigal (in the Teapa region) for three time periods between 1973 until 2003 and detected an 80% loss of rain forest during that period. They determined that the forest loss was due to fire and

the land was subsequently turned into cattle ranches or grew into to secondary forests (Salazar Conde et al. 2004). Regional climate change observations in North America since the mid-20th century show that there have been an overall increase in the number of warm days and nights, number of heat waves and extreme precipitation, with some spatial variations (Hartmann et al. 2013). Observations for this region also show a decrease in cold days and dryness or drought (Hartmann et al. 2013). Scientists have high to medium confidence in these data (Hartmann et al. 2013). In Enríquez et al.'s (2016) analysis, Tabasco's rainfall is predicted to decrease overall, but extreme events (e.g. flooding and droughts) may increase due to climate change. As a result, the state's corn productivity is expected to decrease (Enríquez et al. 2016). Climatic changes can also lead to changes in the amount of water available in bodies of water, movement of species across landscapes as temperatures rise and phenology (timing of seasonal variations in species) which will further impact how people cope with or adapt to their environments (Lawler 2009).

4.2.6 Literature Gaps

Globally there are many rural areas that lack resources to cope or adapt to the many stressors caused by social and environmental changes. Local adaptation responses to specific socioecological changes depend on a variety of variables. The extant literature on adaptation capacity does not contain comparative studies between communities within the same region, making our study unique. We contribute to this gap by showing that despite similar local sociopolitical contexts, variation at smaller scales leads to diverse adaptation strategies.

The climate change projections for the future will impact already-vulnerable rural communities, threatening them with more extreme weather and rising sea levels in Tabasco (Enríquez et al. 2016). There is a national climate change plan (see Gobierno de la Republica de Mexico 2013) and several state plans[4]; however, there is no plan for the state itself nor one for the smaller geographic regions where our research takes place. The World Bank (2017) acknowledges as much on their website, citing that because the large size of Mexico and various levels at which adaptation occur, which their adaptation plan does not address, there is a research gap in their work. In the absence of a local environmental change mitigation or adaptation plans in Tabasco, Mexico, we can contribute to the literature that helps identify public perceptions of their adaptation capacity and what actions people are already taking, which could potentially be incorporated into such mitigation and adaptation plans.

4.3 Background

At the beginning of the 20th century, because of its climatic and geographical conditions, Tabasco was still relatively isolated from the rest of Mexico and the outside world (Tudela 1989). Population density was low (5 inhabitants per km^2, on average), its economy was almost exclusively oriented toward agriculture and a large proportion of the rural population practiced shifting slash and burn subsistence agriculture, growing mostly maize, beans, and rice (Tudela 1989). Expectations led many to believe that an economic

[4] See the Inter-American Development Bank-funded "Adaptation, Land Use, and Integrated Watershed Management Plan for the Grijalva and-Usumacinta Watersheds" that covers parts of Tabasco State (Enríquez et al. 2016) and a World Bank "Adaptation To Climate Change Impacts On The Coastal Wetlands In The Gulf Of Mexico" project (World Bank Group 2017).

boom would follow the opening up and incorporation of Tabasco's tropical forests into the national and international economies (Tudela 1989).

Due to past economic crises and unpayable debt, Tabasco's social and environmental landscapes have been modified by several projects from different spheres and levels of government and economic processes (Bryant and Bailey 1997; Uribe Iniesta 2009). Various agricultural and industrial projects were reorganized and subjected to economic, social, and territorial organization in order to promote monoculture crops (e.g. banana, 1920-1930), industrial land use (cattle, 1960-1988), and natural resource extraction (oil and gas, 1973-1994) both to supply the domestic and foreign markets (Uribe Iniesta 2009). A 1970s petroleum boom brought new extraction and related commercial activities, increasing state economic dependence on the petroleum industry (Capdepont Ballina 2010). Petroleum industry development was used to modernize the region (Uribe Iniesta 2009). Petroleum extraction still continues in the Tabasqueño Grijalva River region, but is in decline (US EIA 2015).

The rise of neoliberalism in the "Third World" in the 1980s, allowed the International Monetary Fund to privatize government services and open up untapped markets to the world economy (Escobar 1995). In Tabasco, this resulted in clearcutting large areas of tropical forest, wetland drainage, road construction, increased cattle ranching, and increased industrial agricultural production (Tudela 1989). These strategies were chosen to colonize and incorporate the region into Mexicam development policies (Tudela 1989; Uribe Iniesta 2009).

In addition to international policies, land tenure and reform is an important aspect of Mexican history and land management processes. The 1917 agrarian reform in Article

27 of the Mexican Constitution gave ownership of agricultural and forestlands to the rural poor; approximately 80% of communal lands are owned by *ejidos* (groups of people who received land to cultivate) and *comunidades agrarias,* or agrarian communities (groups of people whose ancestral lands were returned to them) (Klooster 2003; Mexican Constitution, Article 27 1917; Ponette-González and Fry 2014). This constitutional provision aimed to reduce the concentration of land in the large haciendas that characterized the pre-revolutionary landscape, and instituted a system of communal ownership, resulting in the establishment of 29,000 *ejidos* nationwide (Muñoz-Piña et al. 2003). The 1993 national land reform, with its *Programa de Certificación de Derechos Ejidales y Titulación de Solares* (Program for Certification of Ejido Rights and Titling of Plots or PROCEDE) certification program, enabled *ejidos* to survey and certify their land, granting them a title of ownership, and allowing *ejidatarios* to vote whether to divide and privatize their land (Vásquez-León and Liverman 2004). Unless *ejdatarios* certified their lands under the PROCEDE process, there was no way for them to title their land or access loans and credit from local banks (German et al. 2011; Moser et al. 2014; Vásquez-León and Liverman 2004).

As a consequence of rural restructuring, the agricultural sector was left without full access to credit, insurance, or technical assistance (Escobar 1995). Market exposure associated with the North American Free Trade Agreement (NAFTA) drove down the market value of many staple crops, creating hardships for small-scale farmers and triggering outmigration, and proletarianization (Zimmerer 2006). To help rural farmers transition after the NAFTA policies began in 1994, Mexico gave them subsidies through the *Programa de Apoyos Directos al Campo* (PROCAMPO) and Oportunidades

programs to address income losses through subsidies of staple crops like corn, beans, and wheat (Assies 2008; Gravel 2007; Lozada et al. 2010). The end of government subsidization of agriculture shifted such funds toward corporate and industrial production instead (Bryant and Bailey 1997). Much of the past growth has failed to make an impact on poverty in rural areas and instead created increasingly unequal access to the tools and resources that would facilitate self-sufficiency (Tudela 1989; Gravel 2007).

4.3.1 Site Context

We conducted interviews in two *municipios* in Tabasco State, Mexico: Emiliano Zapata and Teapa. The primary economic activities in Tabasco involve farming, which accounted for 226,263 ha of 2,473,781 ha total in 2011 (INEGI 2016). Most of Tabasco is covered by networks of water and is flood-prone, except west of the Grijalva River in the Chontalpa area where land is elevated enough to enable farming and cattle ranching to occur there (Rugeley 2014). Farther south in the state near the Chiapas state border it is mountainous and less humid; this area is known as La Sierra, is defined by mountains and caves, and historically is where people in the region lived (Rugeley 2014).

We worked in three villages in the Emiliano Zapata area: Jobal, Nuevo Pochote and Pochote. We also worked in two communities in the Teapa *municpio,* San Pablo Tamborel and Arcadio Zentella (see Table 4.1). These five rural *ejidal* communities were chosen as part of a larger study in order to understand how land use changes are affecting socioeconomic conditions in each region and assess their socioecological sustainability. We chose comparative sites where land use change was occurring—from secondary forests and cattle ranching to large, monocrop plantations. Our current paper fits within

this context of land use and environmental change, as we are examining how rural *ejido* communities perceive these changes and how they might adapt to future changes.

Table 4.1. Research site context

State	County	Ejido/ town	Population	Level of Marginalization*	Geography
Tabasco State			2,238,603		
	Emiliano Zapata		29,518		River (rios) zone
		Pochote	350	Medium	Flat, flood-prone land along Usumacinta River
		Nuevo Pochote	200	High	Flat fields
		Jobal	344	High	Flat, flood-prone land
	Teapa		53,555		Mountain (sierra) zone
		San Pablo Tamborel	218	High	Hilly land
		Arcadio Zantella	667	High	Steep, hilly land

*The marginalization rating as defined by the National Population Council (Consejo Nacional de Población) is understood as the disadvantages that groups of people in a community face (CONAPO 2010).

4.4 Methods and Data Analysis

Our qualitative interview data was collected in January 2015. Five researchers conducted the interviews. In each community, we met with the *delegado*, the town representative, to

ask for permission to talk with people and spend a few days in town. In one town we were asked to hold a public meeting with residents to respond to questions in advance of conducting interviews there. We used purposive and snowball sampling methods to contact interviewees (Bernard 2011). We approached adult residents at their homes or in public places (e.g. on the street or in local businesses) to request interviews, and asked each one if they could refer us to others in the community who might be able to respond to our questions. We recorded and transcribed verbatim 87 in-depth, semi-structured Spanish-language interviews.

We interviewed 54 people in the Emiliano Zapata *municipio* and 33 in Teapa. Key interview themes included: interviewees' perceptions of their community and current and past employment opportunities; the land and primary activities within the community; perceptions of the state of the environment, perceived changes within it and its effects on the community; oil palm production; and community oil palm production systems' sustainability (an analysis of oil palm perceptions and impacts will be published separately). Interviews generally lasted between 40 and 60 minutes. Each interview was recorded and transcribed verbatim. We read and coded each transcript to identify emergent patterns, then re-read the interview transcripts to identify new patterns based on initial ones.

4.5 Results

In the responses to questions about current perceptions of community, environment, and changes occurring there, as well as livelihood prospects in the rural Mexican countryside, three main concerns emerged: economic, environmental, and governmental. People also

discussed how they have adapted or might adapt in the future to such changes. This results section presents major patterns in their responses.

We present these major patterns represented by the percentage of people who mentioned any particular theme. While we interviewed 87 people, different numbers of interviewees responded to each question because not all interviewers asked all of the questions of each interviewee. Demographic information is summarized in Table 4.2. We interviewed slightly more women than men and more people who were born outside of the community where they currently live than those born within it. Interviewee's most-common occupations were housewife and agricultural work. Fifty-nine percent of people had access to parcels of land for their personal use, with an average of approximately 7 hectares of land per person. Of the 56 people who grew crops, half consumed everything they grew, rather than selling it. Fewer than half raised cattle, with an average of three heads per cattle-owning household.

Table 4.2. Demographic information

Variables	**Categories**	Emiliano Zapata	Teapa	Total N
Average age		47	45	--
Gender	Female	28	18	46
	Male	26	15	41
Born in the community?	Yes	23	10	33
	No	29	19	48
	No response	2	4	6
Primary Occupation	Housewife	18	6	24
	Agriculture	16	8	24
	Fisher	5	0	5
	Work on a ranch	0	3	3
	Work on oil palm	4	3	7

	Government employee	3	3	6
	Other	5	1	6
	No response	3	9	12
Access to land, land use practices	People with access to land (parcels of land)	39	12	51
	Average land size	6.8 ha	8.5 ha	--
	People who grow crops (including in *traspatios*)	45	11	56
	People who only consume their crops	25	3	28
	People who only sell their crops	6	6	12
	People who consume and sell their crops	15	4	19
	People who have cattle	22	4	26
	Average number of heads of cattle	2	4	--

4.5.1 Economic Concerns

About half (47%) of the respondents regarding community problems in both *municipios* focused on the lack of jobs in both communities, the increased difficulty in being able to make a living for oneself, and the rising cost of consumer goods. These same themes emerged in response to perceptions of community changes over time, with seven people (14%) from Emiliano Zapata and nine interviewees (35%) in Teapa related to the issue, as well as three people or 12% from Teapa who discussed changes in economic opportunities in the environment. However, in response to questions about community changes, there was also discussion about an increase in off-farm jobs on plantations (specifically oil palm) in both regions which is helping to off-set economic worry (50

from Emiliano Zapata, or 66%, and 26 from Teapa, or 34%). However, many insisted that wage work on these plantations did not pay well and came with few benefits.

4.5.2 Experience with Environmental Problems

Community changes. Interviewees described environmental problems in terms of a decrease in land and resource availability and negative human impacts on the environment. One man from Teapa who works in the oil palm plantations lamented land privatization and the loss of access to natural resources, saying, "It had been common land, but it's already been divided and, as a non-*ejido* member…we don't have rights to anything" (*Jorge*,[5] Interviewee 33). Similarly, people discussed changes in the availability of natural resources in Teapa (18 interviewees or 67%), including local decreases in the amount of firewood, animals, wilderness, an increase in local erosion, and a sub-theme about how, despite deforestation in some places, afforestation is occurring, leading to more plantations of teak, mahogany and oil palm locally. Ten interviewees (or 37%) from Teapa also lamented that people were not taking care of their land (i.e. they cut down trees, hunted animals) or had contaminated the environment. To illustrate the former change, a middle-aged farmer said, "It's hard because you see now, well, no one is doing anything good. Now almost everyone's destroying the timber, animals; these [things] are always affected by humans" (*Lucía*, Interviewee 67).

[5] Names of interviewees have been changed to protect their identity.

Community problems. In regard to community problems, the environment was discussed by about a third of interviewees (27%) in both *municipios* and included responses about extreme weather events (e.g. floods, drought). Environmental problems in Emiliano Zapata (17 interviewees, 21%) included lost harvests and human illness associated with flooding, diminishing natural resources (e.g. fish), and an increase in invasive fish species.

Changes in the environment. In responding to a question about changes in the environment, 22 people (48%) in Emiliano Zapata described perceived changes in climate, such as the length of time that weather events last, prolonged wet or dry periods, and a change in when seasons begin. Eleven of those respondents (24%) perceived an increase in extreme weather events including flooding and drought. A female cattle rancher who depends on the land for sustenance described the changes in their ability to farm because of weather as such:

> *Before, people grew more corn, the sustenance of a family is corn. The seeds—either beans, corn, chili—would provide. Not anymore. The flood and inclement weather, the rains and everything they do […]. When the rainy season ends sometimes the sun, or dry periods when it doesn't rain for a majority of the year, the land here is parched, land that is broken and the crop simply dies.* (*Isabel,* Interviewee 22)

Twelve people (26%) talked about perceived changes in the harvest, specifically higher frequency of lost harvests, in Emiliano Zapata because of unpredictable or severe weather. Related to those comments were those referring to changes in the ability to produce food locally, as described by a young teacher: “There had been the best corn harvests and everything here, but because we live in the lowlands, no: the water has really affected everything” (*María*, Interviewee 7). The impacts of such extreme weather were discussed in terms of loss of land area to put animals out to pasture, living with the uncertainty about when disaster might hit, and families having to escape their homes to find dry land. In Teapa, in response to questions about changes in the environment, people also mentioned problematic changes in weather (four interviewees or 15%), referring to unpredictable weather, such as an early arrival of the rainy season or prolonged drought, and how the changes in weather affect daily life. Also in response to a question about changes in the environment, in Emiliano Zapata, 24 interviewees (52%) talked about changes in the quantity of trees, fish, and other animals locally and, of the total responses, five (11%) regarded a perceived increase in the abundance of an invasive fish (“*el pez diablo*” or “*peje-sapo*,” *Pterygoplichthys pardales*). The difficulty the community has had with invasive fish is widely acknowledged by citizens, some of whom presumeably do not work as a fisherman, as illustrated here by Eugenia who works in the private sector: “It hadn’t been here before, but in other areas, the ‘devil fish’ had been there and they caught it and it left. But here, it’s affected the fishing zone a lot and it’s diminished that industry” (*Eugenia*, Interviewee 50).

4.5.3 Concerns About Local Government

The government, what it provided for communities and what problems it is blamed for, was the third major type of response that people gave in response to questions about perceptions of community changes over time and perceptions of community problems. In response to a question about how the community has changed over time and what caused these changes, one of the major patterns that interviewees from both *municipios* discussed involved changes to their town (21 from Emiliano Zapata, 42%, and 14 from Teapa, 54%), including improved infrastructure and general progress in terms of better living conditions or more services being offered by the government compared to the past. Discussions in both *municipios* (45 interviewees, 56%) about community problems were related to infrastructure (i.e. lack of services, including transportation and communication services and lack of or poor water wells or drainage). Twenty-six people (53%) from Emiliano Zapata and 19 people (61%) from Teapa responded this way. Beyond the environmental and landscape differences between our two *municipios*, the government was also cited as a cause of positive environmental change because of programs, subsidies, or infrastructure that it provided (i.e. improved infrastructure to manage environmental problems like flooding).

4.5.4 Adaptation Strategies

In response to questions about future changes in the environment and future community changes, the three most common patterns of adaptation strategies people mentioned include governmental, collective, and individual responses. Since the government enabled privatization of *ejidos*, people felt that they have been left with few options for

making a living other than asking the government to provide them with resources. Despite politicians breaking campaign promises to support rural residents (which residents acknowledge), people in Emiliano Zapata still thought future changes in their local communities depended on government support or incentives to solve community or environmental problems (i.e. more federal or municipal government programs, incentives, and infrastructure projects). The 20 responses (38%) about the government stepping in to respond to community needs suggested that more non-monetary resources, governmental programs and subsidies are needed, that raising the minimum wage is necessary, and that foreign investment can also help solve local problems. This idea was expressed by an older farmer who spent his life working in the fields: "We need a government that in reality wants to help the countryside; in order to do this, they have to promise to help the countryside so that things get better" (*Pablo,* Interviewee 4).

Regarding future community changes**,** in Teapa, 15 people (71%) also pointed out that the government has failed them in the past and say that they have come to realize that they cannot trust or rely on politicians anymore; however, people still talked about what politicians, especially local *municipio* presidents, should be doing (i.e. following through on their promises to the communities) to help their communities. The importance of a government program in supplementing a family's income is described by an older wife and mother as such:

> *It's been a year or so that they've given me support from [the government program] Prospera….it supports us in the way that every other month they give us our support for children and for ourselves. From that, we help*

> *ourselves. We really help each other out. Because at least for me, the first thing that I think of is in my amount [of government support]. I invest it in the most useful things for our daily cleaning, such as soap, toothpaste and all that….And apart from this, I have a part left that's for the education of my child….Sometimes my husband's salary doesn't cover it. No, it doesn't. I can make things work with the funds that we're given.* (*Rosalva*, Interviewee 72)

In Teapa, in response to questions about future changes in the environment, ten people (40%) said that government needs to provide incentives for conserving or protecting nature, as suggested by Ana, whose family members are cattle ranchers: "Well, it's only possible if they make a reforestation program in which the government gives us plants. Then we'd be able to reforest the bare parts" (Interviewee 76).

The second strategy that people identified as a possible way to adapt to environmental changes and community problems was through a collective, communal response. While interviewees in both *municipios* mentioned how people need to organize themselves to create change in the future there were differences between how communities would do it. Fifteen people (28%) in Emiliano Zapata mentioned social organizing (28%) as a possible response to future community changes, but did not give many examples or details on how this would happen. Regarding future changes in the environment, 15 people (29%) said that they will receive environmental benefits if they organize themselves to ensure the benefits exist. In Teapa, six people (29%) mentioned community organizing to assuage future community changes. One farmer described the

changes she hoped to see coming from within the community: “The future will change when people organize themselves better and say, ‘let's work this way,’ or when there is a project…to excel, to change the town. If not, we’ll continue to live in poverty" (*Rosa,* Interviewee 19).

Almost paradoxically, when people described the two community organizations that exist in each *municipio*, El Malayo and the River Fishermen’s Association, they often mentioned them in terms of what they do now (i.e. grow and sell crops and sell the fish they catch, respectively, in each place) rather than the potential for expanding the groups to include other foci, such as for communicating their problems to the local or regional government, holding politicians and local authorities accountable for following through with their promises or policing illegal logging or polluting the environment, which would all be ways to change the institutional and political systems to reduce community vulnerabilities.

Finally, the third avenue that people identified as a way to adapt to current and future social and environmental conditions included actions that they as individuals could do. In response to questions about future community changes, 15 interviewees (30%) in Emiliano Zapata said educating their children and working harder to make improvements in their own livelihoods would solve their problems and in Teapa, six people (23%) discussed taking advantage of government projects in order to find off-farm work to supplement lost farming income. Out of 23 community members from Teapa who were asked about future changes in the environment, 10 people (43%) said that the environmental benefits will accrue if the community intervenes to educate people. In Emiliano Zapata, there is also a sense of powerlessness and inability to change one’s

situation since migration is not an option, as represented by Homero, who lived half his life in the community:

> *Sometimes even the authorities don't support us. No, no, no; we go, we talk and everything, they do not listen to us, they do not do anything for us. No, here we are. Anyway, the person who has his house, their way of living, well, it's hard to say, 'well, then I'm leaving' and leave everything here. No way, not after living here so long, to not live here, to move elsewhere because it is difficult.* (*Homero*, Interviewee 2)

They were more likely to deal with flooding when it occurs, rather than take preventative measures to avoid it, as one farmer said, "I'm going to wait out the flood here, with my mother-in-law, here on her land on the edge of the river because a little water reaches here, a little there. We've waited out the flood here before" (*Alberto*, Interviewee 17). In Teapa, people talked more about taking control of their livelihoods by migrating to find work or better opportunities if necessary.

4.6 Discussion

In our results section we reviewed the three major patterns that emerged from our data: concerns about the economy, environmental problems, and what the government was doing and should do. Economic concerns included responses relating to environmental problems including problematic weather, diminishing natural resources, and reduced access to land was another pattern that emerged, as were people's criticisms of and praise

for the government's actions. We focus here on three political ecology dimensions: government, community, and environment. In this section we discuss these findings in relation to the literature.

4.6.1 Perceptions of Economic Conditions

A major theme that emerged from the interview data related to people's preoccupation with the economy, which is understandable if we consider past structural readjustment policies that led to high unemployment rates, stagnant wages, and related hardships. Economic conditions were discussed by many people and they tended to talk about it in the same way (i.e., economic problems, lack of jobs). This is a common finding in Latin American research (Kurtz 2004). Economic problems interrelate with the environmental and community concerns that emerged in our data.

Almost all of the towns in the two *municipios* where we conducted interviews had high levels of marginalization (only Pochote did not) (CONAPO 2010; SEDESOL 2016). Similar to cases described by Christie et al. (2003), from the perspective of community marginalization and isolation, the mountainous communities in Teapa might face more social and environmental change than the riverside communities in Emiliano Zapata, which are located across the Usumacinta River from the municipal capital. Emiliano Zapata communities should be more likely to have access to infrastructure and public services that would help them endure such changes. However, the levels of poverty in each *municipio* or the distance from a larger city did not seem to preoccupy people as much as landscape features and employment opportunities.

4.6.2 Perceptions of Environmental Problems

"First World" structural adjustment policies after the Mexican economic crisis in the 1980s allowed outsiders to dictate how land would be used (Bryant and Bailey 1997; Escobar 1995). Several scholars (Escobar 1995; Peluso 1992; Rugeley 2014; Uribe Iniesta 2009) have shown that modernization schemes, like PROCEDE, allowed the government to privatize rural landscapes in order to gain access and control of natural resources and people, inhibiting their ability to subsist off the land; our results show that the privatization of land and natural resources has hurt the people who relied on it most: *ejidatarios*. Unlike in India, where national plans were made for adapting to sea level rise (Dubash 2012), in Emiliano Zapata, they said they were more likely to deal with flooding when it occurs, rather than take preventative measures to avoid it. For example, they discussed how they move to higher ground temporarily when the rainy season arrives and perform off-farm work rather than relying wholly on fishing to make a living (Berkes and Ross 2013).

The discussions of increased local flooding and drought that people in both regions experienced matches the IPPC scientists' observed climatic changes over the past six decades (Hartmann et al. 2013). Lawler (2009) and Enríquez et al.'s (2016) projections for the mean that people will continue to respond to more frequent floods and droughts, with an increase in crop loss, particularly losses in corn, a staple crop.

As Gravel (2007) discussed, the poorest people find it very difficult to live off the land because they have such small plots that they are unable to rely on them for their family's subsistence needs, which is similar to our findings. Interview respondents in our study own seven hectares of land on average (see Table 4.2). People who have small

amounts of land said that they are unable to access local markets because they do not grow enough to sell; however, Buechler (2016) showed that it is often women's home gardens that are able to provide for their family when environmental change negatively impacts their husband's parcels.

The structure of Mexican *ejidos* would seem to be well-suited for reducing risk to environmental change. Communally-managed land can spread the benefits of shared natural resource management efforts to all *ejidatarios* and their families and also helps the *ejido* reduce vulnerabilities caused by political decisions or natural weather events by sharing workloads and burdens felt by the *ejido* (Berkes and Ross 2013; Binford 1985; Klooster 2000; Robbins 2009). However, through the PROCEDE process the state enabled the striping-away of *ejidos'* ability to collectively manage natural resources. The long-term, collective management of natural resources that Ostrom (1999) saw as a way to ensure sustainability was slowly dismantled in the Mexican countryside through land reform in the 1990s. If an *ejido* voted to certify their land and allow privatization of their land, including common areas, each *ejidatario* would be granted the right to manage their land in any way they chose, without the approval of the *asamblea ejidal* (local assembly). Moreover, the loss of rain forest cover to fire in the Teapa region, as found by Salazar Conde et al. (2004), has limited the availability of natural resources (e.g. firewood, non-timber forest products) that people rely on.

4.6.3 Perceptions of Governmental Responsibility

A history of development policy and privatization in the 1980s and land use change from traditional agroforestry practices to large, monoculture plantations in Mexico have led to

environmental change in the countryside, as described by Escobar (1995) and Jiménez-García (2014). This began with European colonizers targeting Tabasco for agricultural development with the production of cocoa, Campeche wood, black pepper, and cinnamon during the colonial period (Capdepont Ballina 2010; Tudela 1989; Rugeley 2014). Currently, Tabascans continue to struggle to find a balance between growing food for their families and other ways of generating income from the land. We can see the extent to which governmental policies have impacted the environment by considering how rural farmers changed their practices from self-subsistence farming and livestock-raising to growing subsidized cash crops and participating in the world economy, as Reynolds and Stafford Smith (2002) describe. People cannot depend growing traditional corn and beans or only rely on fish for feeding their families anymore.

The people we interviewed recognized and welcomed the role that state and corporate interests play in changing economic conditions in the countryside (e.g. through the PROCEDE process and the various governmental programs like Oportunidades); however, they did not always link those programs to an increase in their dependence on the government, as Dauvergne and Neville (2010) found. They often talked about the environmental problems and difficulties they face in accessing natural resources as being associated with privatization of land and the PROCEDE process, but talked about the necessity of government assistance programs and even saw them as being one of the only options for resolving their socioeconomic problems. Despite the request for more government assistance, such programs provide only small amount of money to recipients and thus do not provide robust safety nets for those who need more assistance (Buechler 2016).

People did not discuss outsider institutions' direct intervention in the countryside, as pointed out by Gravel (2007) and Zimmerer (2006). They also did not refer to Mexico's governmental structure that limits local participation in politics to one community representative (e.g. municipal president or *ejidal* representative), which Bryant and Bailey (1997), Christie et al. (2002) and Christie and White (2000) discuss in terms of government responsibility for environmental change. Nor did they notice how local government corruption and broken promises led to environmental problems, as discussed by Klooster (2000).

Results regarding the government failing to serve people are not surprising given the history of government intervention in the lives and landscapes of otherwise self-sufficient farmers in Tabasco and the high level of vulnerability that poor, rural people are exposed to in the wake of climate change described by Robbins (2009) and Rugeley (2014). Power imbalances that Christie et al. (2003) and Klooster (2000) discussed allowed outside interventions, such as the creation of the Parque Estatal Sierra de Tabasco in Teapa, which led to restricted access to natural resources and local responses to them. While locals lamented the fact that their forests were fenced off, they had little recourse to change the situation because of the political and economic systems that are in place (Saunders 2014). Moreover, people in both *municipios* felt that their local politicians had either abandoned them or broke their promises for helping them, confirming Christie et al.'s (2003) findings that environmental change is caused by a lack of government support in the countryside and unaccountable officials.

4.6.4 Adaptation Strategies

The academic literature acknowledges that despite the challenges the rural poor face living in the global south, those people have found ways to adapt to their environments. In our data, three types of adaptation responses within Emiliano Zapata and Teapa emerged: asking the government to take action to mitigate and solve community problems; collective, societal-level responses; and individual action that community members can take. We discuss these three adaptation strategies in turn here as they relate to the literature.

Governmental response. In order to adapt to government or *ejidal* policies, people mentioned needing government programs and subsidies, which Gravel (2007) showed as being a valuable response to local problems. People also mentioned that the government should raise the minimum wage and provide more non-monetary resources, which we did not find in the adaptation literature. Instead, a more common, perhaps long-term strategy, that is discussed by Agarwal and Gibson (1999), Berkes and Ross (2013), Binford (1985) and Magis (2010) and was successful in Vietnam (Adger 1999) and India (Sharma and Tomar 2010) in building institutional capacity locally.

Rather than working with citizens, local governmental authorities often constrain residents' abilities to adapt to difficult times because there is a lack of transparency within the government or local representation in government. Perhaps because people do not anticipate that the government will partner with them to create community change, they talked about what *municipio* presidents should be doing to follow through on their promises to the communities. To adapt to environmental and community problems,

interviewees also thought that government infrastructure projects would be beneficial and that foreign investment might help provide them, as Wood (2011) suggests and Eriksen et al. (2005) found in Kenya and Tanzania.

Collective response. There are major differences between each community and their ability to adapt to market price fluctuations through organizing groups of people to collectively support each other. The El Malayo cooperative in Teapa provides community members who farm a way to pool their resources, diversify their income and adapt to crop damages due to weather and disease, similar to strategies discussed by Berkes and Ross (2013), Binford (1985) and Magis (2010). Residents of San Pablo Tamborel were able to reimagine how they make a living and provide for their families by starting a cooperative, which gives them access to regional and international markets for their products and distributes risk throughout the *ejido*; such community organizing is discussed in the literature by Berkes and Folke (1998), Christie et al. (2003) and Magis (2010). In Teapa, people recognized the importance of community involvement in local problem solving, as Agarwal and Gibson (1999), Christie et al. (2003), Klooster (2000) and Pelling (2010) discuss as strategies for adapting to environmental change.

In contrast, from the community members' perspective, the River Fishermen's Association in Emiliano Zapata was a way for the most powerful fishermen to capture the market and edge out competitors, resulting in conflict within the community (Agarwal and Gibson 1999). People also mentioned the corruption they saw among the leaders of the River Fishermen's Association and discussed conflicts that that created within the community. None of the interviewees in this research discussed current opposition to the

government, nor the possibility of building a grassroots social movement in response to their problems, which Peet and Watts (2004) discuss as a viable response to a lack of government responsibility.

Individual Responses. The Tabasco area has always been a challenging environment to live in, but over time people have found ways to live there and adapt to changes. Interviewees from Teapan communities more often described individual-level strategies for adapting to landscape changes than those in Emiliano Zapata, perhaps because they do not experience the severe weather events in the same way.

Migration to places with more livelihood options, as discussed by Álvarez Gordillo and Tuñón Pablos (2016) and Pelling (2010), was an adaptation strategy in Teapa as a response to lost harvests and lost livelihoods; they also supplement their income with remittances from family members who migrated. However, as Carmin et al. (2015) found, migration was not seen as an option for the poorest and most vulnerable, especially in Emiliano Zapata. Interviewees mentioned that educating their children would also be a way to adapt to future community changes in Emiliano Zapata and to adapt to future environmental changes in Teapa, which Carmin et al. (2015) also found. People also acknowledged that they think working harder to make improvements in their own lives will benefit them in the future despite changes. As Eakin (2000) also found in other parts of Mexico, in Teapa people said they had adjusted when they sow seeds in order to accommodate changing seasonal weather patterns.

Teapans saw plantation forests as an improvement on the landscape and growing precious timber and commodities like oil palm have given people and the environment, in

their words, “a future.” Like Agrawal (2010) and Eakin (2000) found in Africa, Asia and Latin America, Teapans adapted to local environmental change through diversifying their income. Finding off-farm work and relying less on farming in Teapa was one such individual-level action, as Magis (2010) found. In Teapa, smallholder farmers participate in alternatives to traditional subsistence farming (e.g. growing ornamental flowers and oil palm for international and regional markets) order to create a supplemental income, as Dauvergne and Neville (2010) and Klooster (2006) discuss.

As Rugeley (2014) described and we show in Emiliano Zapata, many people rely on the Usumacinta River for their livelihoods since farming is nearly impossible because of frequent and seasonal flooding and an increase in the amount of invasive fish, yet they lack other alternative sources of income. Furthermore, many people do not have the option to work in or grow oil palm because they lack land that is not flood prone or lack the necessary resources in order to participate. In other respects, oil palm expansion in the region may lead to more jobs and productive programs in Teapa and perhaps closer to Emiliano Zapata, which would fulfill Gravel’s (2007) stipulation that government intervention in the countryside move away from cash handouts. However, interventions like this should proceed with caution, as lessons from jatropha plantations in the Yucatan demonstrate a worst-case scenario, with negative social and environmental impacts (Banerjee et al. 2017; Eastmond et al. 2014; German et al. 2011; Rodríguez et al. 2014; Skutsch et al. 2011).

4.7 Conclusion

Agricultural modernization of rural Tabasco occurred in the second half of the 20th century through the implementation of a number of large scale international development projects meant to reduce rural poverty and gain access to the countryside (Escobar 1995). Such macroeconomic policies, contrary to their stated goals, resulted in the destruction of extensive areas of humid tropical forest, exportation of natural resources, and the impoverishment of much of the rural population (Bryant and Bailey 1997; Isaac-Marquez et al. 2005; Tudela 1989). We used a political ecology lens to show how the three main themes that emerged from our interview data with rural Tabascans—environmental problems, the economy, and the governmental responsibility—are related to these past political and economic actions. They impact current environmental conditions and created institutional and structural constraints in the region that people are finding ways to adapt to: people who live in the mountains of Teapa have found or created more options for adapting to changes in the communities (i.e. working in teak and oil palm plantations or migrating to find work), whereas in the river zone of Emiliano Zapata, invasive fish, natural weather events and environmental destruction in low-lying lands have further worsened their condition and ability to make a living.

The current research is limited to community members' perceptions of environmental and community change. We did not ask how the government is or plans to respond to such changes or local authorities' adaptation strategies, which might be different from those of community members. We also did not include biophysical data on how the environment has or will change, to know what types of challenges the community should be preparing for or expect. We plan to do so in future research.

Our research is of use to decision makers and local authorities in Tabasco because it shows what resource constraints community members face and what they expect the government to provide. The successful adaptation strategies that people discussed could be emphasized in future governmental mitigation or adaptation plans in the region. International policies created current socioeconomic conditions, but the local governments are now what control land use in a top-down manner, controlling *ejidatarios* and withholding resources from them and/ or ignoring their needs. Policymakers should focus on ways to create partnerships with and include *ejidatarios* and community members in decision making and strengthening the capacity of community organizations to adapt to environmental change. Unless they are able to strengthen community organizations to benefit more people or find other ways to change social and economic institutions, people will remain vulnerable to local environmental changes (Berkes and Ross 2013; Walker et al. 2004).

Rural communities not only have come to rely on employment opportunities with large companies, but are at their mercy because of the difficulty rural laborers have in finding stable employment that does not fluctuate with international market prices (Selfa et al. 2015). These companies offer Mexico and other countries in the Global South the chance to enter the global energy market while nominally improving worker and environmental conditions (Klooster 2006). Anticipated government subsidies in the form of oil palm or other crops should be considered as one option of many for adapting to new institutional and social systems. This will be a double-edged sword, contributing to continued dependence on the government to provide employment and resources locally,

but also potentially mitigating climate change through carbon sequestration and production of biofuels from oil palm (Lozada et al. 2010).

4.8 References

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Chapter 5: Conclusions and Future Research

My research focuses on what are often called “wicked” problems: local responses to environmental change and the challenges to studying such responses (Norris et al., 2016). Just as there are multiple perspective, from which a problem—like climate change—can be managed or solved, multiple perspectives are needed in scientific research on these problems and processes. Climate change occurs on an international scale: anthropogenic causes and physical impacts can cross borders. Thus, it is necessary to conduct international research to solve such problems by integrating multiple disciplinary approaches to studying wicked problems. Successful interdisciplinary and transdisciplinary teamwork is, however, in and of itself also a wicked problem (Norris et al., 2016). Identifying and understanding the challenges that interdisciplinary research teams face when conducting research abroad can suggest ways to overcome such barriers.

International problems like climate change have no one cause and no single solution. Solutions must come from many angles and sources and perspectives. Our PIRE team uses natural, social and engineering sciences to study the impacts of bioenergy development projects to assess the sustainability of them. A multi-pronged approach tackles problems from various angles to, in a sense, make the problem smaller. We also study the barriers to conducting such research so that future research can be more successful.

In chapter 1, we found the major barriers to conducting interdisciplinary, international research in Argentina, Brazil and Mexico—integration, language, fieldwork logistics, personnel and relationships and time commitment—can be overcome with a

concerted team effort. Generally, we recommend interdisciplinary teams spend time getting to know each other as well as the context and language of the countries they will be working in, establishing trust among researchers as well as host country nationals and anticipating problems, but being flexible when they arise so they can be lessened.

Perceptions of the environmental, social and economic impacts of bioenergy feedstock development, like oil palm plantations, will affect levels of public support for the plantations and the success of climate change mitigation policies. People are responsible for using and changing the land, no matter if prompted by current conditions or forced to because of past political decisions (Dunlap & Brulle, 2015). Many of the repercussions of such land use practices—using agricultural inputs, overfishing, deforestation—have, over time, contributed to environmental change and exacerbated the effects of climate change. Other human activities, like reliance on fossil fuels as an energy source, have led directly to climate change. Therefore, in order to begin to solve the problem of climate change, we must focus on human activities and understand how and why people are interacting with their environments (Dunlap & Brulle, 2015). In chapter 3, I focus only on local perceptions of oil palm plantations and the potential for them to be a sustainable solution to global climate change. Our findings show that perceptions about the future impacts of oil palm are positively correlated with perceptions about perceived ecosystem service benefits of oil palm plantations and perceptions about oil palm if used to produce biofuel for export.

Individual-level human actions that can mitigate future environmental change and lesson the effects of climate change include personal actions (e.g. reforestation efforts, sustainably using natural resources), acceptance of local projects that take similar actions,

voting for pro-environmental and pro-community politicians and supporting or creating local civil society adaptation projects that promote resiliency and reduce vulnerability in communities. Just as organizations must find incentives (i.e. payment for work) to get people to do their required tasks or use punishment (i.e. firing someone) for not doing what is required of them, nations and smaller political entities must use similar tactics to compel people to behave a certain way (Babbie, 1994). Values and norms can change, albeit slowly, over time into less consumptive, environmentally-conscious practices (Spaargaren, 2003). This can be facilitated by structural changes; it is easier for people to choose environmentally-friendly choices if there is a structural option (Spaargaren, 2003; Warde, 2005). This is where climate change mitigation policy comes into play: regulations and other mandated laws are used to push people toward desired results. Due to the diffuse nature of climate change causes and the reluctance or ignorance to change destructive personal habits and actions, national and sub-national climate-related policies are needed to make society-wide structural changes to slow climate change (Gardner & Stern, 2008; Selin & VanDeveer, 2009).

Beyond policies requiring people to behave in a certain way, socioecological responses to environmental change depend on local environmental conditions, social power dynamics, land tenure and resource availability. Past international structural adjustment policies and the effects of anthropogenic climate change have led increasingly vulnerable rural populations in Tabasco, Mexico, to find ways to making a living under difficult circumstances (i.e. fluctuating employment opportunities, more severe weather events) (Cardona, 2001; Eakin & Luers, 2006; Robbins, 2009). To address this, in chapter 4, I found that communities' responses to environmental change were greatly influenced

by the resources people had available to them as well as past political processes and, in part, by geographical location and landscape features. As our findings show, climate change adaptation strategies can go hand-in-hand with finding ways to deal with social and economic problems. Adaptive capacity depends on social and political transformations in order to both respond to impacts and prevent future vulnerabilities (Pelling, 2010).

Structural changes made at the institutional (e.g. governmental, industrial) level, such as requiring that a total percentage of national GHG emissions, is a more effective way to incentivize or mandate large-scale pro-environmental changes than relying on individual's actions (Gardner & Stern, 2008; Selin & VanDeveer, 2009). Structural changes should be permanent (and funded) to create lasting change; this can be especially difficult when governments or industry are not incentivized to do so (Unruh, 2000). Structural fixes need the expertise of policy experts who know how governance works in natural resource management (Heberlein, 2012).

However, Mexico is unlikely to produce *effective* federal climate policies that will result in GHG reductions for different reasons. Despite the enthusiasm with which the Presidents Felipe Calderon and Peña Nieto's administrations had drafted climate change policies, it may only be a superficial display of the country's eagerness to be grouped with developed countries (Torres Ramirez, 2014). Mexican politicians have done a poor job of governing transparently and of holding agencies accountable for achieving their goals (Hevia et al., 2011; Valenzuela, 2014). The inability of the president to legislate new policy is a major challenge to implementation of climate policy (Jordana, 2010).

Thus, although the country has the political will to enact climate and renewable energy policies, the governmental structure and lack of capacity to implement and enforce them is weak. As we found in chapter 4, rural Tabascans do not trust their local politicians to follow through on their promises and there is no evidence of partnerships between civil society and the government for solving problems. Furthermore, because of the mis-match in time scales between politicians' short term limits (and their quick fixes to problems) and the long-term solutions needed to tackle the problems caused by climate change, multiple strategies from every level of society are needed to begin to solve the problem (Dunlap & Brulle, 2015).

Despite this lack of accountability, in chapters 3 and 4 we found that people must still rely on government subsidies and depend on government corporate projects that provide local employment opportunities. Globally, biofuels have become a potential tactic for improving sustainable development in developing countries (Skutsch et al., 2011). While sustainable development has been criticized for not being the silver bullet solution to environmental problems (Escobar, 1995; Sovacool et al., 2016), it may be one possible solution of many. Oil palm sustainability certification has also improved the livelihoods of rural residents in Malaysia, and provided employment and infrastructure projects in Mexico, but has not eradicated rural poverty (Byerlee et al., 2017; Castellanos-Navarrete & Jansen, 2015). Bioenergy feedstocks can be a sustainable source for producing renewable fuels, but the feedstock, geographic region and socioeconomic conditions determine the level of sustainability. Public perceptions are also an important component of the long-term success of a bioenergy project. In findings from chapter 3, I

show that people who support oil palm feedstock projects do so when they perceive future environmental benefits and support producing biofuels for export.

In chapter 3 I also showed that there is a consensual spatial relationship between Mexico and importing countries, which bodes well in a globalized and interconnected world where products are produced in one location and consumed in another (Byerlee et al., 2017). However, as demand from oil palm products and biofuels rises as countries develop, the sustainability potential of the bioenergy feedstocks and spatial relations surrounding it (i.e. exported GHG emissions and pollution from the Global North to the Global South) may become contested, especially because oil palm only grows in a limited amount of tropical regions worldwide (Byerlee et al., 2017). Moreover, oil palm plantations may just be a continuation of business-as-usual development projects where multi-national companies direct growth and development projects where multi-national companies direct growth and development in partnership with the state (at the expense of farmers and poor citizens) (Bailis & Baka, 2011; German et al., 2011). The concept of sustainability will also be tested as more countries trade goods and natural resources are extracted in one place but consumed in another.

Climate change will exacerbate the challenges caused by environmental degradation combined with globalization processes (Newell, 2016). A multitude of approaches at many levels, from the individual, the societal level through policy changes and transnationally, need to be brought together to continue to understand environmental decision making and move toward new theories and approaches to solving problems (Gardner & Stern, 2008; Shove, 2004; Shwom & Lorenzen, 2012). We need action on all levels of government to solve global climate change and (local) environmental change as

well as a revolutionary new way forward (rethinking how society works and changing people's norms). Since there are environmental problems that cross national boundaries and socioeconomic inequalities that are difficult to solve by only relying on technical policy solutions, there needs to be another type of social and systemic restructuring.

5.1 Future Research

There are many feedback loops associated with socioecological systems because as humans use and manipulate land and natural resources, the quality and quantity of the resources changes, leading to different ways people use and manipulate them (Liu et al., 2007). My research, which uses a political ecology lens to describe environmental changes, admittedly does not draw on ecological data, which is a criticism that political ecologists have faced (Walker, 2004). In the future, I intend to integrate interview data presented in chapter 4 with biophysical data. The biophysical data I could draw on includes ecosystem service impacts, including carbon storage, water and soil quality and biodiversity, such as pollinators or birds, in three typical Tabascan landscapes: cattle pastures, oil palm plantations and secondary forests (*acahuales*). Through this research I would generate a place-based, Mexico-specific perspective of ecosystem services and biodiversity, which would lend importance to environmental knowledge in rural Mexico rather than imposing an American perspective on the creation of a natural worldview (Escobar, 1992) and will lend insights into what the best conservation policies might be in a particular region based on how people use and interact with the landscape. Results from the interview data related to biodiversity and ecosystem service provision in Mexico

could also advance knowledge relating to how individuals understand and interact with the natural world.

Building on the integrated research described above, in future research, I will also draw on other case studies from the NSF-PIRE project to make cross-country comparisons in how socioecological systems are impacted by bioenergy feedstock production in communities where they are grown. Similar to the research presented in this dissertation, the research will focus on public perceptions of such production sites, including eucalyptus plantations in Argentina, oil palm in Brazil or woody biomass collection in Canada and the United States. Such comparative studies can generate insights into how to make such systems more sustainable over the long-term by analyzing when and how humans benefit from them and the tradeoffs involved in choosing one type of system over another.

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