Chapter 13
Climate Change Adaptation and Socio-Economic Resilience in Mexico's Grijalva-Usumacinta Watershed

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Abstract The Grijalva-Usumacinta watershed in Mexico's Tabasco and Chiapas states is home to six million people and a rich biodiversity. It is also the major source of Mexico's hydropower, as well as in-land and coastal hydrocarbons. However, the area's close proximity to the Gulf of Mexico makes it highly vulnerable to climate change effects: rising sea levels, destructive hurricanes, heightened rainfall and floods. These climate change impacts could be devastating, particularly for the 31 % of the population that live in extreme poverty and face food insecurity.

This paper presents an inter-disciplinary assessment of future climate change scenarios and associated impacts in the region, particularly for vulnerable populations living in rural areas. It focuses on the role of institutions in mediating interactions between climate change impacts and livelihoods, as well as in shaping adaptation responses. The assessment used can be broadly applied in comparable settings in developing states and emerging economies, with increasing climate change risks and threats. In so doing, it provides a reliable methodology that can be used to assess regional vulnerability and design climate change adaptation initiatives in rural areas.

The paper draws on experiences gained from the preparation of the "Plan de Adaptación, Ordenamiento y Manejo Integral de las Cuencas de los Ríos Grijalva y Usumacinta", project ATN/OC-12432—ME, funded by the Inter-American Development Bank and developed by Abt Associates, Inc. The views expressed in the paper are those of the authors and do not represent those of the Inter-American Development Bank or Abt Associates, Inc. For further information see: http://blogs.iadb.org/cambioclimatico/2014/05/08/adaptacion-ordenamiento-y-manejo-integral-el-caso-del-sur-de-mexico/.

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Introduction

The Grijalva and Usumacinta river watershed is a complex hydrological system expanding over 13.2 million hectares in the Mexico-Guatemala border. This paper focuses on the Mexican portion, which comprises 64 % of the system.[1] These rivers are the source of 34 % of the Mexico's runoff and are mainly located in the Mexican states of Chiapas and Tabasco (CONAGUA 2011).

According to the Mexican government, the Grijalva-Usumacinta watershed is highly vulnerable to climate change because it is frequently affected by extreme weather events and is at risk from sea level rise (Nicholls et al. 2007; INE-SEMARNAT 2006). During the first decade of the twenty-first century, 34 events associated with extreme precipitations affected the states of Tabasco and Chiapas, impacting close to 3 million people and resulting in losses of close to US 5 billion (Abt Associates 2013). The 2007 flood of the Grijalva River affected 75 % of Tabasco's population and resulted in damages equivalent to almost 30 % of the state's GDP. Based on available data, Mexican agencies have indicated that the watershed's hydrological behavior is characterized by increasingly frequent extreme trends (SEMARNAT 2009).

Recognizing the region's vulnerability to climate variability and change, the Government of Mexico requested the assistance of the Inter-American Development Bank (IDB) to develop a long-term adaptation plan for the Grijalva-Usumacinta watershed. The plan was to integrate the development of water infrastructure with ecosystem management and sustainable land use, in order to maximize the hydrological regulation services provided by ecosystems, as means to reduce the exposure of people and infrastructure to severe hydrometeorological phenomena. In response to this request, the IDB supported the development of the Adaptation, Land Use, and Integrated Watershed Management Plan for the Grijalva and Usumacinta Watersheds ("the Plan").

This paper focuses on the components of the Plan that assessed the vulnerability of rural populations in the watershed. In particular, it draws on the analytical work underpinning the Plan to discuss the role of institutions in shaping climate change risks and in facilitating interventions to support adaptation and enhancing social resilience to climate change. This paper will be relevant to individuals and organizations interested in inter-disciplinary approaches to climate change adaptation at a regional level, as well as to those working on the preparation of climate change adaptation projects in watersheds and rural areas.

[1]All the data, analysis and other information presented in this paper refer only to the Mexican portion of the watershed of the Grijalva and Usumacinta rivers.

The rest of this paper is structured as follows: Section "Literature Review" summarizes the literature review. Section "Methodological Approach" describes the methodology used to develop the Plan, particularly those aspects that were relevant to assess the vulnerability of rural populations to climate change and the adaptation actions that could be adopted. Section "Results" presents the Plan's main results and we conclude in section "Conclusions".

Literature Review

Füssel and Klein (2006) note that climate change vulnerability assessments have evolved from approaches that basically superimposed climate change events on a passive system to newer approaches that recognize the ability of people and systems to adapt to climate change. The adaptive capacity of such people and systems is stronger when they are able to adapt by developing strategies that are robust against uncertain future developments and integrating them into policies.

However, the capacity of social groups to develop adaptation strategies is significantly shaped by institutions, which mediate the interactions between climate risks and social groups (Agrawal 2008; Tyler and Moench 2012). For this reason, research on climate change adaptation has increasingly paid attention to the role of institutions in reducing vulnerability. Part of the research has found that, in many cases, institutions exclude vulnerable groups from decision-making processes. Marginalization caused by institutional factors is an underlying cause of vulnerability and also limits the participation of vulnerable groups in the development of adaptive actions (Adager 2005). These findings are consistent with those of the broader body of social science research that has assessed the role of institutions and governance in development (Acemoglu et al. 2001; Rodrik et al. 2004; Ostrom 2005; Slunge and Loazya 2012).

Other researchers have stressed the important role of institutions in promoting adaptation in the face of uncertain climate change impacts. According to this approach, climate change impacts cannot be accurately predicted because of the limited use of historical data and available climate change projections. Thus, institutions that support adaptive management by incorporating learning and promoting good governance are more likely to prepare communities and other groups for climate change's dynamic and complex impacts (Armitage et al. 2007). Instead of focusing on specific perceived climate hazards, institutions can help to build resilience to unpredictable stresses and shocks (Walker et al. 2002).

The potential contributions of institutions to climate change adaptation will vary from one context to another. According to Agrawal (2008), in rural areas, institutions mediate between climate hazards and livelihoods in three ways. First, they structure environmental risks and variability, thereby influencing the nature of climate impacts and vulnerability. Second, they create the incentive structure that defines the adaptation strategies that individuals and groups can adopt. Finally, they shape the extent to which external interventions can contribute or undermine local adaptation practices.

Building on Agrawal's framework, this paper presents the findings on the institutional factors that limit climate change adaptation rural areas in the Grijalva-Usumacinta watershed, as well as on the opportunities to reform them so they can contribute to enhance resilience to climate change.

Methodological Approach

The methodological approach that was adopted for the preparation of the Plan can be described as consisting of three main steps. First, we characterized the watershed, with the aim of understanding priority development challenges. As a second step, we estimated the likely climate change impacts on the watershed and how they would affect vulnerable populations and sectors, including the extent to which these impacts would exacerbate development challenges. Finally, we identified potential interventions to enhance the resilience of vulnerable populations, focusing on the areas that could yield short term benefits while also contributing to building longer term adaptation capacity. In this section, we discuss only the methodological aspects that are relevant to understand the role of institutions in climate change adaptation in rural areas of the watershed.

In order to characterize the watershed, it was sub-divided into six regions, defined by hydrographic units consisting on the main primary basins. This sub-division helped to identify predominantly rural areas and to tailor the vulnerability assessment to them. For each of the watershed's sub-regions, data from government and academic sources was used to elaborate a bio-physical characterization, including the composition of the natural environment, the hydric dynamic, predominant land uses and vegetation cover (CentroGeo 2010). A socio-economic characterization was also developed, focusing on factors associated with vulnerability to climate change, particularly poverty; inequality; access to basic services, resources and information; quality of housing and infrastructure; and livelihoods (Cutter et al. 2003; Brooks 2003; Wisner et al. 2004).

The approach to understand likely climate change effects was based on the downscaling of global climate change scenarios to the watershed level. The resulting regional climate change scenarios projected future temperature and precipitation trends. These scenarios were developed based on data from 15 Global Circulation Models, combined in a weighted ensemble using the Reliability Ensemble Averaging (REA) method developed by Giorgi and Mearns (2002) and implemented in Mexico by Montero and Pérez (2008), which estimates the uncertainty of each model. The scenarios were fed with historical data for 1961–2000 and the Representative Concentrations Pathways (RCPs) 4.5, 6.0, and 8.5 from the Intergovernmental Panel on Climate Change's (IPCC) Assessment Report number 5 (AR5) for the near future (2015–2039) and the distant future (2075–2099).

Econometric analysis was used to estimate the impacts of climate change on key agricultural activities. The analysis focused on the linkages between the production functions of these goods and climatic factors (Seo et al. 2008; Gay et al. 2006). The analysis was modeled as an optimization problem showing how the producer maximizes yields through a combination of labor and inputs selected by him, for a determined level of temperature and precipitation, and soil characteristics (Olivera-Villarroel 2012). To run the model, we used geographic variables (coordinates and soil quality); economic variables (labor, capital, and agricultural inputs), and climate variables (historical and projected precipitation and temperature). Data on agricultural yields and socio-economic indicators were obtained from the official agricultural production database (SIAP) of Mexico's Ministry of Agriculture, Livestock, Rural Development, Fisheries, and Food (SAGARPA). Hydrological data were obtained from the National Meteorological System's hydrometeorological stations, and the regional climate change scenarios described above provided projected temperature and precipitation data.

The econometric analysis was conducted for corn and coffee. Corn was selected because it is the staple food and its production is the main economic activity in rural areas in the region. Thus, impacts on corn yields have implications on both livelihood and food security. Beans are the second most widely cultivate crop and a key ingredient of the regional diet, but lack of sufficient data at the municipal level precluded an analysis on the impacts of climate change on this crop.

Shade-grown coffee is an economically important product, particularly in the Chiapas' portion of the watershed. It was selected as part of the analysis because coffee growing is one of the more widely adopted economic diversification activities in the watershed. Farmers can grow coffee while continuing with their other agricultural activities and sell it to complement their income. Shade-grown coffee has the additional advantage of being an agricultural activity that is compatible with forest conservation (Moguel and Toledo 2004). Thus, reductions in coffee yields as a result of climate change would seem to threaten both local livelihoods and forest areas, which would face a higher probability of being converted into agricultural uses.

Based on the results of the impact analysis, we assessed a first set of adaptation activities that are based on current practices in the region and that would aim to compensate the falls in crop yields associated with climate change. However, some of adaptive strategies we initially considered proved limited for natural and institutional reasons, as discussed below. Consequently, we assessed adaptive strategies that included improvements in knowledge, technologies or investments that could help to adapt to the changing climate. An institutional component was integrated into each of these interventions. This component aimed to assess whether proposed adaptive actions were feasible in the context of existing intuitions, as well as to propose institutional reforms that would support better governance and learning. Cost–benefit analyses helped to assess the feasibility of these interventions.

A multi-level stakeholder engagement process was launched from the beginning of the Plan's preparation. More than 200 people participated in the process, through three workshops with representatives from federal agencies, three additional workshops with representatives of the state governments of Chiapas and Tabasco, two workshops with research centers in the region, and a workshop with Civil Society Organizations and international donors. More than two dozen in-depth interviews were conducted with experts from different fields with significant experience in the watersheds. The participatory process bolstered the preparation of the Plan by providing guidance in three specific moments: (1) at inception, in defining the scope of the analytical work to be conducted; (2) at the completion of the diagnostic assessment that identified priority climate change threats in key areas; and (3) towards the end of the preparation of the Plan, to validate proposed interventions and ensure their alignment with ongoing efforts in the Grijalva and Usumacinta watersheds.

Results

Watershed Characterization

The Grijalva-Usumacinta watershed is different from the rest of Mexico in many ways, including its higher economic dependence on natural resources. Extraction and use of natural resources contribute with close to 70 % of Tabasco's Gross Domestic Product (GDP), compared with 10 % at the national level. Most of this wealth stems from the energy sector: 17.4 % of the country's oil and 19.6 % of its natural gas are produced in the lower basin (PEMEX 2014), and over 40 % of Mexico's hydropower is generated by the Grijalva River (CFE 2012). Benefits from these activities are captured mainly by the state-owned productive enterprises PEMEX, and the Federal Electricity Commission. However, there are no institutional mechanisms to share the extraction of this wealth with local communities. For example, in spite of hosting the most important hydropower complex in the country, Chiapas is one of the three states with lowest electricity coverage in Mexico (INEGI 2010). Local communities have benefited from specific investments in the past. For example, the development of dams has resulted in construction jobs and other benefits for neighboring communities. However, these temporary benefits are the result of ad hoc negotiations.

The watershed is also more rural than the rest of Mexico. More than 50 % of Chiapas's population and 43 % of Tabasco's lives in settlements of <2500 inhabitants, compared with a national average of 23 % (INEGI 2010). As a result of this dispersion, local populations tend to have less access to basic services and infrastructure. Natural resources sustain the livelihoods of the population living in those localities. In Chiapas, the primary sector occupies 36 % of the economically active population, compared with 13 % at the national level (INEGI 2016).

The economic structure and geographic dispersion of communities in Chiapas and Tabasco is associated with high poverty and marginalization. According to official data, the watershed is home to more than six million people, out of which

31 % live in extreme poverty and 32 % face food insecurity (CONEVAL 2010). Out of the 116 municipalities in the watershed, 66 % are considered highly or very highly marginalized by Mexico's government (CONAPO 2010).

Agriculture and livestock constitute the main livelihoods of rural communities. Corn is by far the most important crop in the watershed, occupying 52 % of agricultural lands; beans are a distant second, covering <10 % of agricultural lands. Practically all the corn produced by small rural communities is rain-fed and used for self-consumption (CentroGeo 2012). In addition to its cultural and nutritional value, the large area devoted to corn growing is associated with governmental subsidies. Primary data collection in three rural communities in Chiapas (Nuevo San Juan, Tierra Nueva, and Veinte Casas, in the municipality of Ocozocuautla) found that subsidies provide about 47 % of the income that would be generated from the sale of the corn produced in each hectare[2]. In fact, if households considered the economic value of their own labor, corn growing would not be economically viable in most cases in the absence of the subsidy (Olivera-Villarroel 2011).

Regional Climate Change Scenarios

The developed regional scenarios indicate that climate change is expected to result in higher mean temperatures of 1 °C in the near future (2015–2039) and, under the RCP 6 scenario, up to 3.2 °C in the distant future (2075–2099).[3] Both maximum and minimum temperatures are projected to increase in the near and distant future. Temperature increases are expected throughout the year, with the highest increases for average and minimum temperature between March and May, and the highest maximum temperature between June and August.

Precipitation in the watersheds is likely to fall as a result of climate change. In the near future, under the RCP 6 scenario, rainfall decreases would be relatively small, between 0.04 and 0.4 %, while distant future modeling showed reductions of between 1.9 and 2.9 %. An analysis of the probability distribution functions of precipitation by season showed that seasonal rainfall increases and decreases would become more significant over time, resulting in higher probability of extreme events in the distant future, including both heavy rainfall and droughts.

[2]Estimate includes two different subsidies: "PROCAMPO" and "Maíz Criollo".

[3]In this paper, we only discuss the results of the RCP 6 scenario. The results of the other scenarios can be consulted in the reports available at http://blogs.iadb.org/cambioclimatico/2014/05/08/adaptacion-ordenamiento-y-manejo-integral-el-caso-del-sur-de-mexico

Climate Change Impacts on Agricultural Yields

The analysis found that, under the RCP 6 scenario, climate change is estimated to reduce average corn productivity by up to 2.9 % in the near future, resulting in more than 13,000 families facing food insecurity. In the distant future, average productivity would fall by 5.8 %, threatening more than 28,000 families (Figs. 13.1 and 13.2).

In the case of coffee, temperature is the variable that has a more significant effect on productivity. Low temperatures are needed for the plant to flower, while extreme high temperatures might stress the plant (Granados Solís and Zamora Castro 2012). Based on the regional climate change scenarios, coffee yields are expected to fall by around 2.4 % in the near future, and 7.3 % in the distant future (Figs. 13.3 and 13.4). The impacts might be even more severe, as coffee production might not be economically viable under such conditions.

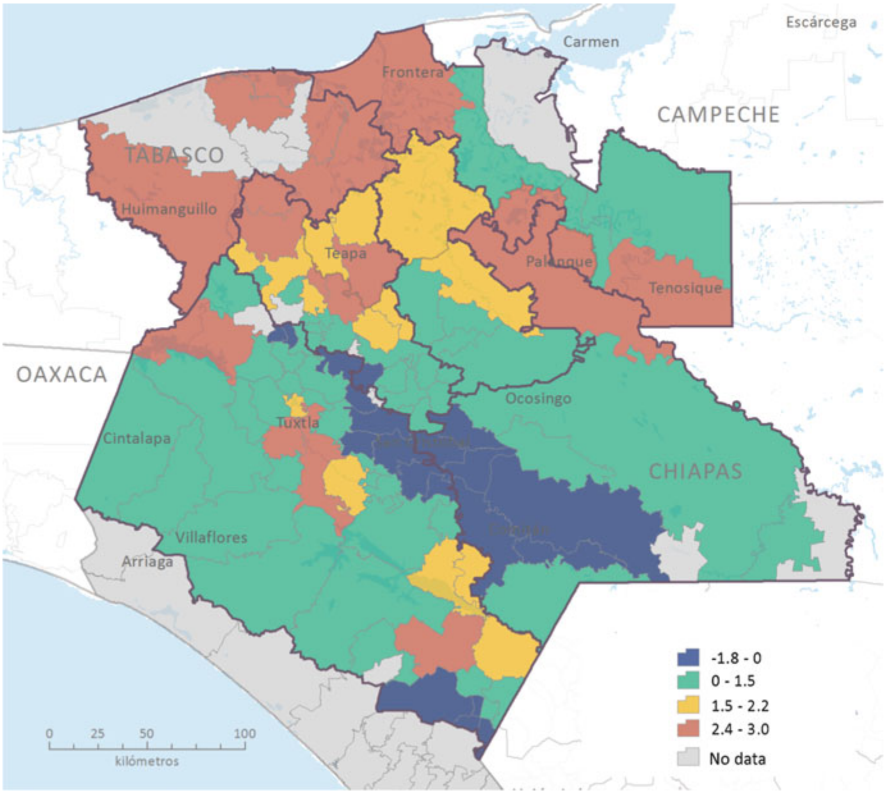

Fig. 13.1 Reductions in corn productivity (%), RCP 6 scenario, 2015–2039. *Source*: Abt Associates (2013)

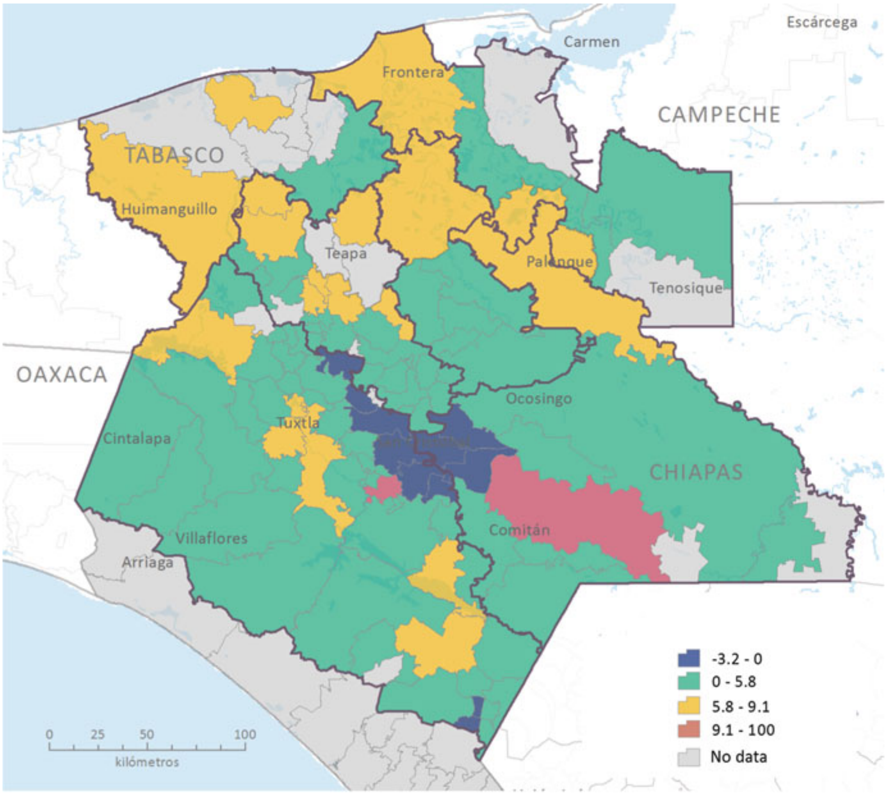

Fig. 13.2 Reductions in corn productivity (%), RCP 6 scenario, 2075–2099. *Source*: Abt Associates (2013)

Adaptation Options

A first type of adaptation response to the loss of corn productivity caused by climate change could consist of increasing inputs, labor, and other economic factors. However, given that corn is only economically viable because of government subsidies, most households would not be able to afford the additional inputs under current circumstances. Storage could be considered another adaptation alternative. However, the vast majority of rural farmers rarely have a production that is significantly above what they require to meet their self-consumption needs. Although market exchange is arguably one of the most effective adaptation strategies, it is constrained in the watershed's rural areas by institutional factors. These include: (1) the existence of monopolies and oligopolies that create gaps between seasonal sale and purchase prices; (2) lack of markets for other goods produced

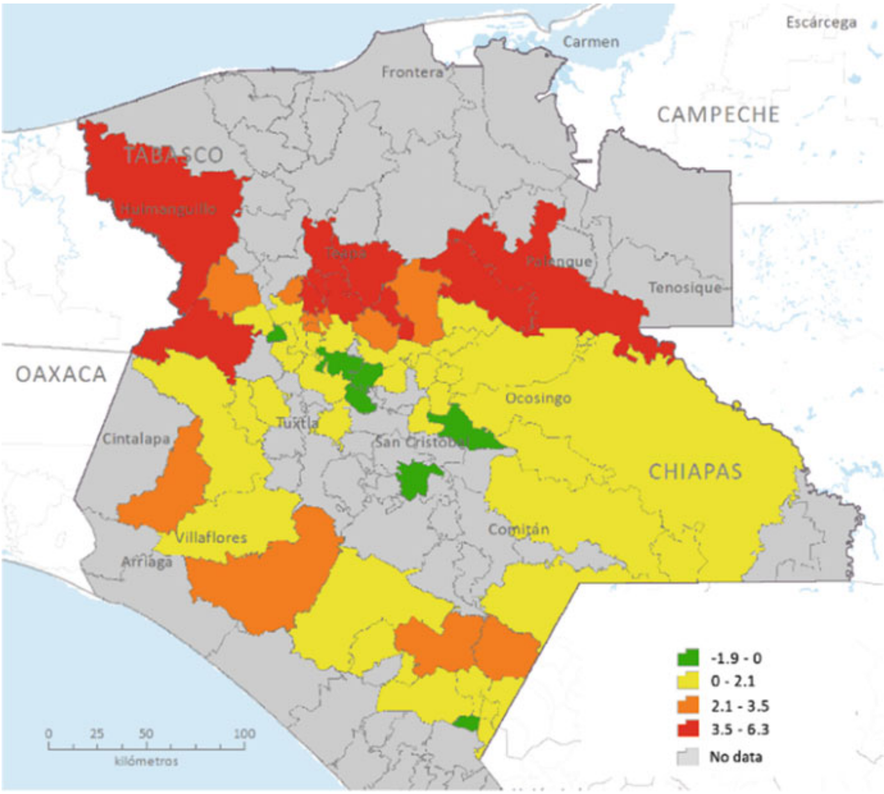

Fig. 13.3 Reductions in coffee productivity (%), RCP 6 scenario, 2015–2039. *Source*: Abt Associates (2013)

jointly with traditional corn; and (3) high transaction costs for participating in food markets (Olivera-Villarroel 2011).

In the case of coffee, mobility would seem the most likely adaptation action. Coffee plantations could be moved to higher altitude areas with colder temperatures. This alternative is constrained by geographic and institutional factors. In terms of geography, the region has only limited areas where such conditions are found. Institutionally, those areas have already been designated as national parks or are somebody else's property.

A different set of adaptation options would consist of developing the capacities of local communities to adopt climate resilient systems that integrate productive mosaics of forest, agriculture and livestock. The first of such options would consist of integrating corn and bean crops with fruit trees, such as peach and citrus. Experiences from the Mexican state of Oaxaca have shown that this type of activity can increase corn yields from between 0.5–3.9 and 21.2–24.9 t/ha because the trees provide organic matter and better nutrient recycling, and also reduce erosion. In Oaxaca, this intervention has also helped to increase and diversify households'

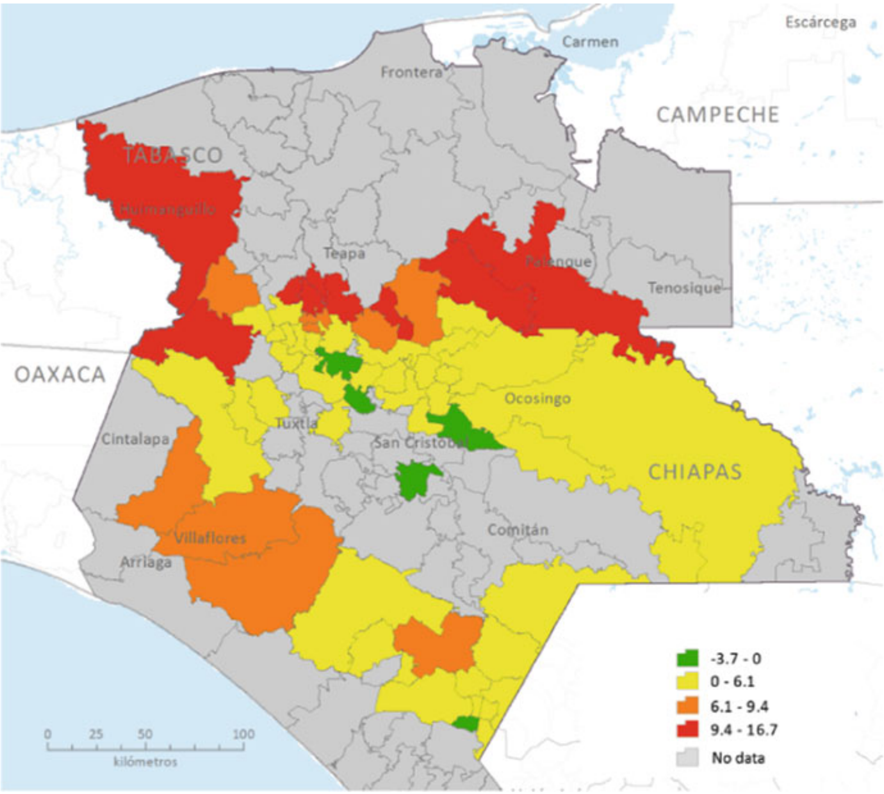

Fig. 13.4 Reductions in coffee productivity (%), RCP 6 scenario, 2075–2099. *Source*: Abt Associates (2013)

income, as well as to generate additional goods for self-consumption, such as fruits, wood and medicinal products (COLPOS 2008).

However, in order for this adaptation option to be feasible in the Grijalva-Usumacinta watershed, government programs would need to reduce their current focus on the intensive production of monocultures. In addition, technical guidelines would need to be developed, and continuously adjusted, to identify the tree species that could better adapt to climate change. We find that this program would have a benefit–cost ratio of 1.3.

A second adaptation option would be the promotion of silvopastoral systems that enable improved soil management and the diversification of livestock's feed. This intervention has been successfully implemented in Central and South America, where producers have been able to increase their incomes in US 70–1157 dollars/ha (Pagiola et al. 2009; Murgueitio 2009; Muhammad et al. 2009).

The main institutional barrier for the implementation of this intervention is the absence of programs in which silvicultural and agricultural activities can be integrated. The inclusion of fruit and fodder trees could also be used as a strategy to help livestock adapt to extreme weather events. This intervention would have a benefit–cost ratio of 2.9.

Another available adaptation option is diversification of livelihoods through the promotion of commercial forest plantations. Forestry activities are limited in the watershed and could be developed as a complementary activity by small rural communities. An institutional obstacle that would need to be overcome is the lack of consideration for climate change impacts in the selection of tree species that are currently eligible to receive governmental support. Overcoming such barrier would require dedicated research to better understand the impacts of climate change on the forest species that could be planted in the Grijalva-Usumacinta watershed without altering the area's ecological balance. This activity would need an implementation timeframe of 10–20 years, depending on the tree species. While this is significantly longer than the 4 years needed to implement the agro-forestry and silvopastoral activities mentioned above, the benefit–cost ratio for these activities are also significantly higher, at 7.6 for species such as teak and melina, and around 5 for cedar.

Importantly, these three adaptation options above would require a permanent technical assistance program, as they would entail the adoption of new practices by largely indigenous communities. Institutional reforms that would be needed to ensure the success of this program include providing technical assistance in indigenous languages, as well as developing multi-annual budgets to enable the continuity of the technical assistance program.

Conclusions

The findings of the analytical work underscore the Grijalva and Usumacinta watershed's vulnerability to climate change and advance a compelling argument to urgently initiate climate change adaptation actions targeting clearly defined geographic and sectoral climate change adaptation priorities. The case for supporting rural communities to adapt is particularly compelling.

Institutional factors have played an important role in shaping environmental risks and climate hazards in the Grijalva-Usumacinta watershed. The current institutional framework has favored the extraction of natural resources, particularly energy resources, without helping to translate natural resources wealth into other types of capital and sustained economic growth. As a result, an important portion of the region's population depends on low productivity agriculture to meet its needs. This dependence on primary activities, coupled with poverty and marginalization, results in high sensibility to climate change. As the results discussed in this paper show, projected climate change risks could result in more than 13,000 families facing food insecurity in the near future, and more than 28,000 families in the distant future.

Institutional factors also have an important role in enabling adaptation activities. As an example, the institutional factors that have constrained the development and integration of food markets in the watershed's rural areas have reduced the potential role of market exchanges as an adaptive strategy for rural households. This situation has also created incentives for farmers to focus almost exclusively on producing corn for self-consumption, which in turn limits the potential of storage as an adaptation activity. Coffee growing has worked as an economic diversification strategy, but it is highly vulnerable to climate change.

In this context, more effective adaptation activities will be those that can simultaneously help to improve agricultural yields and diversify households' incomes. The integration of forest, agricultural, and livestock productive mosaics has produced positive results in other parts of Mexico and other countries in the Latin American region. With dedicated research, these interventions could be continuously improved by incorporating scientific findings and community experiences. However, institutional reforms would be needed to enable such adaptation opportunities. In particular, technical assistance programs will be needed to create continuous learning opportunities and enhance the capacities of local communities to develop adaptation options.

References

Abt Associates (2013) Plan de Adaptación, Ordenamiento y Manejo Integral de las Cuencas de los Ríos Grijalva y Usumacinta. Programa de adaptación a las consecuencias de cambio climático en la provisión de servicios de la cuenca del Grijalva. Report commissioned by the Inter-American Development Bank, Washington, DC

Acemoglu D, Johnson S, Robinson JA (2001) The colonial origins of comparative development: an empirical investigation. Am Econ Rev 91(5):1369–1401

Adager WN (2005) Vulnerability. Glob Environ Chang 16:268–281

Agrawal A (2008) The role of local institutions in adaptation to climate change. Paper prepared for the social dimensions of climate change. Social Development Department, The World Bank, Washington, DC

Armitage D, Berkes F, Doubleday N (2007) Introduction: moving beyond co-management. In: Armitage D, Berkes F, Doubleday N (eds) Adaptive co-management: collaboration, learning and multi-level governance. UBC Press, Vancouver

Brooks N (2003) Vulnerability, risk and adaptation: a conceptual framework. Working Paper 38, Tyndall Centre for Climate Change Research

CentroGeo (2010) La Región del Usumacinta en México desde la perspectiva de la gestión del agua. En: Propuesta para una gestión territorial integrada de la cuenca Usumacinta en México. Report commissioned by the USAID Mexico Competitiveness Program, Mexico City, Mexico

CentroGeo (2012) Insumos para la Formulación del Plan de Adaptación, Ordenamiento y Manejo Integral de las Cuencas de los Ríos Grijalva y Usumacinta. Report commissioned by Abt Associates, Mexico City, Mexico

Colegio de Posgraduados (COLPOS) (2008) Investigación Agronómica y Transferencia de Tecnología en la Fase de Escalamiento del Proyecto Manejo Sustentable de Laderas en el Estado de Oaxaca Informe Anual 2007. Colegio de Posgraduados, Texcoco

Comisión Federal de Electricidad (CFE) (2012) Programa de Obras e Inversiones del Sector Eléctrico (POISE) 2012–2026. México, DF

Comisión Nacional del Agua (CONAGUA) (2011) Agenda del Agua, 2030. Programa Hídrico por Organismo de Cuenca, Visión 2030. Frontera Sur, México

Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL) (2010) Informe de Pobreza en México. El país, los estados y sus municipios 2010, México, DF
Consejo Nacional de Población (CONAPO) (2010) Indicadores. http://www.conapo.gob.mx/en/CONAPO/2010
Cutter S, Boruff BJ, Shirley WL (2003) Social vulnerability to environmental hazards. Soc Sci Q 84(2):242–261
Füssel HM, Klein RJT (2006) Climate change vulnerability assessments: an evolution of conceptual thinking. Clim Change 75(3):301–329
Gay C, Estrada F et al (2006) Potential impacts of climate change on agriculture: a case of study of coffee production in Veracruz, Mexico. Climate Change 79(3):259–288
Giorgi F, Mearns LO (2002) Calculation of average, uncertain range and reliability of regional climate changes from AOGCM simulations via reliability ensemble averaging (REA) method. J Climate 15(10):1141–1158
Granados Solís A, Zamora Castro MV (2012) Impactos del Cambio Climático y la Gestación del Modelo Alternativo de Economía Verde en América Central. Fundación Friedrich Ebert, Costa Rica
INEGI (2010) Censo de Población y Vivienda 2010, Principales resultados por localidad (ITER). Instituto Nacional de Estadística y Geografía, Aguascalientes
INEGI (2016) Encuesta Nacional de Ocupación y Empleo. Instituto Nacional de Estadística y Geografía, Aguascalientes
Instituto Nacional de Ecología (INE)—Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) (2006) México, Tercera Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático. Instituto Nacional de Ecología, Secretaría de Medio Ambiente y Recursos Naturales, Programa de las Naciones Unidas para el Desarrollo México, Environmental Protection Agency, Global Environment Facility, México DF
Moguel P, Toledo VM (2004) Conservar Produciendo: Biodiversidad, Café Orgánico y Jardines Productivos. Biodiversitas 55:1–7
Montero MJ, Pérez JL (2008) Regionalización de proyecciones climáticas en México de precipitación y temperatura en superficie usando el método REA para el siglo XXI. In: Martínez P, Aguilar A (eds) Efectos del cambio climático en los recursos hídricos de México. Instituto Mexicano de Tecnología del Agua, Jiutepec, pp 11–21
Muhammad I, Velásquez-Vélez R, Pezo D, Skarpe C, Mora J, Benjamín T (2009) Selectividad animal de forrajes herbáceos y leñosos en pasturas seminaturales en Muy Muy, Nicaragua. Agroforestería en las Américas 47:51–60
Murgueitio E (2009) Incentivos para los Sistemas Silvopastoriles en América Latina. Avances en Investigación Agropecuaria 13(1):3–19
Nicholls RJ, Wong PP, Burkett VR et al (2007) Coastal systems and low-lying areas. In: Canziani OF, Parry ML, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Cambridge University Press, Cambridge
Olivera-Villarroel SM (2011) Aplicando programas de reducción de emisiones por Deforestación y Degradación: Costos de oportunidad en actividades productivas el Ocote, Chiapas. Consultoría desarrollada como parte de la propuesta Formulación de un proyecto piloto REDD (Reducción de Emisiones por Deforestación y Degradación Forestal) usando el Sistema Plan Vivo en la Reserva de la Biosfera Selva El Ocote, Fase 3. Cooperativa Ambio, Chiapas
Olivera-Villarroel SM (2012) La productividad del maíz de temporal en México: repercusiones del cambio climático. EUROCLIMA—CEPAL, Chile
Ostrom E (2005) Understanding institutional diversity. Princeton University Press, New Jersey
Pagiola S, Ríos AR, Arcenas A (2009) Poor household participation in payments for environmental services: lessons from the silvopastoral project in Quindío, Colombia. MPRA Paper No. 4794, World Bank, Washington, DC
Petro´leos Mexicanos (PEMEX) (2014) Anuario estad´ıstico de PEMEX. Petróleos Mexicanos, Mexico City

Rodrik D, Subramanian A, Trebbi F (2004) Institutions rule: the primacy of institutions over geography and integration in economic development. J Econ Growth 9(2):131–165
Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) (2009) Programa Especial de Cambio Climático 2009–2012. Diario Oficial de la Federación, Viernes 28 de agosto de 2009, México, DF
Seo S, Niggol Dinar A, Kurukulasuriya Pradeep A (2008) Ricardian analysis of the distribution of climate change impacts on agriculture across agro-ecological zones in Africa. World Bank Policy Research Working Paper No. 4599, Washington, DC
Slunge D, Loazya F (2012) Greening growth through strategic environmental assessment of sector reforms. Public Adm Dev 32(3):245–261
Tyler S, Moench M (2012) A framework for urban climate resilience. Clim Dev 4(4):311–326
Walker B, Carpenter S, Anderies JM, Abel N, Cumming GS, Janssen M, Pritchard R (2002) Resilience management in social-ecological systems: a working hypothesis for a participatory approach. Ecol Soc 6(1), Art. 14
Wisner B, Blaikie P, Cannon T, Davis I (2004) At risk: natural hazards, people's vulnerability and disasters, 2nd edn. Routledge, London