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# Adaptive Capacity to Climate Variability in Three Rural Communities at Sierra de San Pedro Martir

## Capacidad adaptativa ante variabilidad climática en tres comunidades rurales en Sierra De San Pedro Mártir

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ABSTRACT

Climate change adaptation has multiple definitions**,** to have a reference conceptual framework we understand it as the reduction of vulnerability to climate variability. This paper's objective was to assess the adaptive capacity and response to climate variability in three rural communities at Sierra de San Pedro Martir National Park. We applied discourse analysis and non-participatory observation. As for data collecting, we carried out structured interviews during community workshops and semi-structured ones to external stakeholders. Results show that communities recognized droughts as the most important climate phenomenon, given that it impacts their economic activities and daily life alike. But inhabitants did not associate water availability to environmental services provided by the National Park. Our main contribution was modifying the methodological tool. Conclusions indicate that adaptive responses are associated with social characteristics of the local population and their strategies diversity. The public institutions' role in rural adaptation was not addressed in-depth.

*Keywords*: 1. climate adaptive capacity, 2. cognitive and social skills, 3. interests and motivations, 4. Baja California, 5. Sierra de San Pedro Martir.

RESUMEN

La adaptación al cambio climático tiene múltiples acepciones, para tener un marco referencial se entiende como la reducción de vulnerabilidad a la variabilidad climática. Nuestro objetivo fue evaluar la capacidad adaptativa y respuesta a la variabilidad climática en tres comunidades rurales cercanas al Parque Nacional Sierra de San Pedro Mártir. Usamos análisis del discurso y observación no participante, colectando datos mediante entrevistas estructuradas a participantes en talleres comunitarios y entrevistas no estructuradas a informantes externos. Encontramos que para las comunidades las sequías son el fenómeno climático más importante porque limita la disposición de agua e impacta sus actividades; pero no asociaron el agua al servicio ambiental del parque. Nuestra contribución fue modificar la herramienta metodológica. Concluimos que las respuestas adaptativas están asociadas a características sociales de la población local y la diversidad de sus estrategias. No exploramos a profundidad el papel de las instituciones públicas en el proceso de adaptación.

*Palabras clave*: 1. capacidad adaptativa climática, 2. habilidades sociales y cognitivas, 3. intereses y motivaciones, 4. Baja California, 5. Sierra de San Pedro Mártir.

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## INTRODUCTION

Climate change is one of the biggest challenges 21st-century societies face (Dionisio & Ibarra, 2013) because the associated impacts could disrupt the stability of social and natural systems alike. Two main strategies to address climate change are recognized by international policy: mitigation and adaptation. The former refers to the human intervention aiming to reduce the sources of Greenhouse Gases (GHG) emissions as well as to increase carbon sinks and it is related to a country's capacity to cut down emissions by means of sustainable development, while the latter is recognized as the process to adjust usual and expected climate and its effects; adaptation is considered to be in function of the capacities of systems, institutions, humans and other organisms (Allwood, Bosetti, Dubash, Gómez-Echeverri, & Stechow, 2014).

Climate change models simulate different changes at regional levels among current conditions, under a 1.5 °C global temperature increase, and at 1.5 °C to 2 °C increment. For example, below a 2 °C global warming scenario, there are higher risks of droughts, and rainfall is projected to diminish except for precipitation associated with tropical cyclones. In that case, rainfall is estimated to increase leading to extreme events with higher frequency at higher latitudes of the northern hemisphere, East Asia, and North America. Heavy rainfall is likely to intensify flooding (IPCC, 2018).

In Mexico, climate change scenarios estimate rainfall reduction and rise of temperature, in the North and Northwest regions (Salinas et al., 1988 as cited in Esparza, 2014). Additionally, 20% of fir and oak forests, 46% of shrublands, and 77% of grasslands are expected to be lost between 2020 and 2050. Expected rainfall contractions are likely to affect the current hydric stress. This, in turn, will impact economic activities, in particular agriculture. Production losses are estimated to reach between $16 and $22 thousand million Mexican pesos (Martínez, Castillo, & García, 2010) or $1.295 to $1.781 billion U.S. dollars, respectively.

Baja California is particularly vulnerable to climate variability. According to the Climate Change Act for Baja California (PEACC-BC, for its acronym in Spanish), the total annual precipitation will abate 10 to 20%. While the average annual temperature will rise between 1.5 and 2.5 °C during the following 50 years, this temperature gain will exacerbate the hydric cycle, and possibly phenomena such as El Niño/La Niña will introduce a higher variability in the precipitation rate (SPA, 2012). Climate change is likely to boost the current hydric stress already classified as high (79.8%) in 2016; this magnified water scarcity will put pressure on the local agriculture, which already has a high consumptive use of water that amounts to 83% when the national average was 77% by 2016 (CONAGUA, 2016).

In the PEACC-BC, impact analysis includes urban settings and housing, this is understandable as 92.3% of the local population live in cities (INEGI, 2019). However, little is known of the impacts that 280,833 persons (7.7% of the total population in Baja

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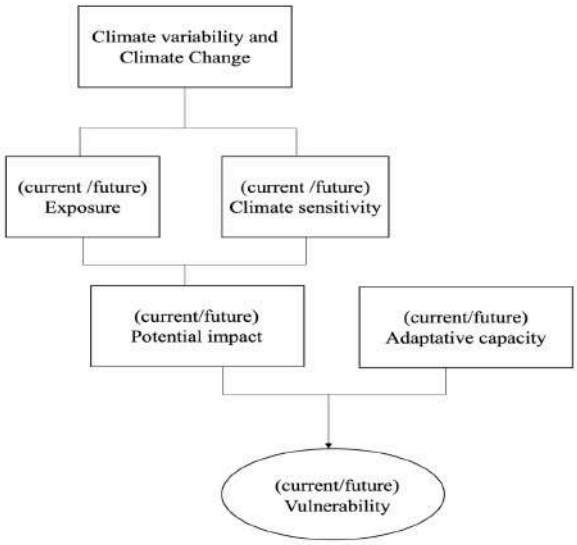
California) that inhabit rural communities will face due to climate variability. Given that the stability of the community structure in rural settings is based on natural resources' availability and environmental services, it is relevant to ask about the vulnerability of rural societies in Baja California under climate variability. To fill this information gap, this study aims to assess the adaptive capacity and response of rural communities facing vulnerability due to climate variabilities. To isolate the relationship between environmental services and climate variability impacts, the rural communities selected for this research were those living near a national park from where people get environmental services.

## THEORETICAL CONCEPTUAL FRAMEWORK

Adaptive capacity is closely related to climate variability, exposure, and sensitivity. In conjunction, these elements defined vulnerability, as shown in Figure 1. In this section, these concepts are reviewed, and the theoretical foundations for adaptive capacity are detailed in their analytical expressions. In such pursue, climate variability is understood here as the variations of climate conditions on the spatial and temporal scale due to natural or anthropogenic causes. Such climate variability could boost the exposure, which increases the likelihood of negative impacts on economic, social, cultural, and environmental systems that thrived under different climate conditions (IPCC, 2013). In turn, this exposure to climate variability gives rise to vulnerability or the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

Figure 1. Components of (Current and Future) Vulnerability




Source: Retrieved from "Vulnerabilidad al cambio climático" (INECC, 2016).

The concepts presented above are supported by a group of climate change expert members of the Intergovernmental Panel on Climate Change (IPCC). However, it must be said that there are additional definitions for these very same concepts that are comprehensive, scientifically rigorous, and internationally accepted; discrepancies between authors present difficulties when operationalizing concepts and their components to evaluate them. The same applies to the concept of "adaptive capacity under climate change," at present, there is no scientific consensus on the exact definition. Adaptive capacity is defined as "[…] the capacity of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2001, p. 987) facing climate variations.

Through adaptive capacity, systems, institutions, individuals, and other organisms conform adaptive responses, which enables them to be prepared, find solutions, or recruit resources, all of which are aimed at reducing expected risks and coping with potential problems (Borkovec, Robinson, Pruzinsky, & DePree, 1983). However, not all outcomes from climate-adaptive responses are necessarily successful. There is a real risk that climate funding may support initiatives that are harmful to the socio-ecological systems, i.e., that foster adaptation in the short-term but insidiously affect systems' long-term vulnerability and/or adaptive capacity to climate change (Magan, 2014), generally known as "maladaptation."

The multiplicity of the concepts' definitions leaves very little space for direct operationalization. Nonetheless, adaptive capacity studies from the perspective of social sciences have contributed with new analytical elements, highlighting that adaptive capacity endows social systems with elements to face and endure external strains coming from social, political, and environmental changes (Adger, 2000). And although decisions are taken at individual levels, adaptation is also dependent on available resources (Adger, 2003; Ribot, 2014).

Furthermore, it has been recognized that adaptive capacities under climate change conditions at individual levels depend on the cognitive process involved in decision making (Grothmann & Patt, 2003). On the other hand, under the framework for the governance and adaptive management of resources, the system's diversity and complexity determine both the flexibilities to change and capacity to react to climate variability (Huntjens et al., 2008; Pahl-Wostl, 2009). Also, the management of common resources requires flexible responses and collaborative interaction capacity among all those concerned in the adaptive management process (Challenger, Bocco, Equihua, Chavero, & Maass, 2014).

At this point, three preliminary conclusions could be drawn for adaptive capacity in social systems:

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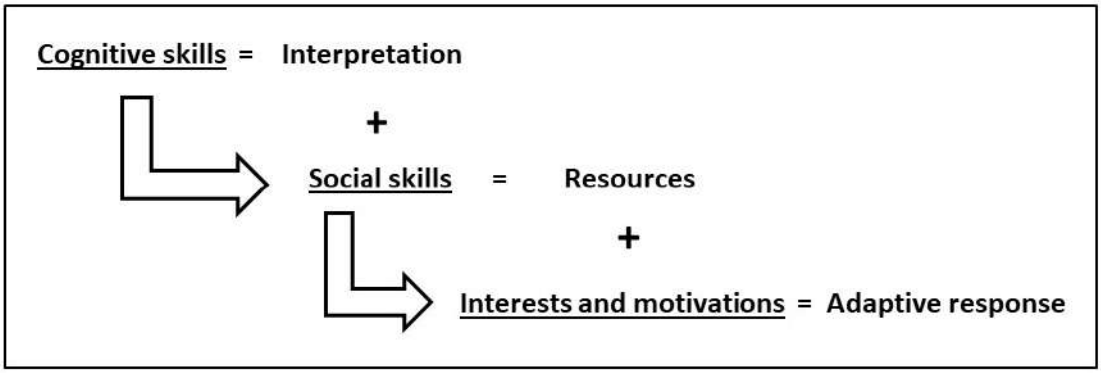
- It is present in the intrinsic characteristics of individuals, in particular those determining social vulnerability due to specific climate phenomena. Moreover, it could also be measured in the function of adaptive response.
- It is positively skewed to favorable adaptation responses that are defined by resources, means, and skills of the social system to face external pressures and avoid major changes to prevent maladaptation.
- It is a simultaneous and continuous process of the social adaptive response when facing changes due to dynamics in economic, political, and biophysical subsystems. Regardless that individual members of the group can relate the changes they are undergoing to climate change impacts.

In addition, two key elements in operative frameworks of the adaptive capacity had been identified: 1) non-climatic factors; for example, economic resources, technological level, available information, infrastructure, institutions, and equity; and 2) endogenous factors such as characteristics and behavior of the members of the community, global economic context, and geopolitics (Pérez Morales, Navarro Hervás, & Álvarez Rogel, 2016).

Figure 2 depicts a summary of concepts introduced in this section together with their relationships. As seen, adaptive capacity could be determined by three key factors: 1) cognitive skills, 2) social skills, and 3) motivations and interests. Furthermore, given that the adaptation process, when challenged by climate variability, requires endogenous support to help rural communities ease adaptive responses. In Mexico, public policies instruments such as government subsidies and support and programs have the potential to impact in two aspects: a) implementation of adaptive actions and strategies pre-designed in the governmental arena and b) capacity-building to improve the adaptation process.

Figure 2. Factors Influencing Adaptive Capacity




Source: Prepared by authors based on Adger et al. (2009) and Pahl-Wostl (2009).

## OPERATIONALIZATION AND DATA COLLECTION

The term **exposure** was considered to be operative through two elements: type and degree. The former refers to climate types and meteorological phenomenon that rural populations identify as the most relevant because of the impact climate phenomenon may have on their productive activities and daily life. This information was collected by asking primary sources: "What changes do you think have taken place in your region due to climate changes?" during fieldwork through structured interviews. Once main climate phenomena were identified, their degree of impact on their resources was established. This information was collected through the question: "What changes affected you the most?" Impacts, degrees, and targets were identified and listed for participants in workshops to discuss, prioritize, and vote.

The concept of **climate sensitivity** was considered operational from the status and level of impact reported by participants in community workshops as actual obstacles to main productive activities and daily lives due to climate variability. Data were collected by structured interview, such information was organized, and the full range of responses was presented as a voting list during community exercises.[3]

**Three key factors were determined to implement adaptive capacity**: a) cognitive skills, b) social skills; and c) interests and motivations (see Figure 2). In conjunction, these explain the type of adaptive response that community members at individual and collective levels take. **Cognitive skills** were expressed through the level and type of learning and information that subjects must understand and size changes in their lives because of perceived causes that participants may or may not associate in a conscious way to climate variability.

The level of learning was defined by the educational level that subjects possess and reported in the participation form fulfilled by the participants in the community workshop. With regards to type of learning, two indicators were proposed: 1) explicit knowledge (schooling level and career) and 2) tacit knowledge (inherited learning). These data were collected during community workshops using three sets of questions about residence time in the rural community, main productive activities in their town, and natural resources used daily.

On the other hand, **social skills** were considered attributes that allow individuals to work together giving rise to adaptation measures to face changes due to climate variability. This concept was expressed in three variables: a) stability of the rural community's internal social structures, b) the organizational capacity of the community members to establish common objectives and resolve conflicts, and c) the collective action for the management of common resources and goods. In addition, the ladder of participation of Geilfus (2009),

[3] For a detailed description of the interview script, refer to González Ornelas (2018).

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as modified by Jiménez (2015), was applied to determine the type of participation and involvement of workshop participants in community projects and to provide evidence of relationship types and degree of organization that members of the communities keep among themselves.

Finally, **interests and motivations** were analyzed through observation during community workshops of the behavior of groups and their responses to identify relationship type and common interests for workshop participants.

Incidentally, exogenous factors were surveyed through applications to the Conservation for Sustainable Development Program (PROCODES, for its acronym in Spanish) of the National Commission on Natural Protected Areas (CONANP, for its acronym in Spanish) that rural communities submitted during the period from 2010 to 2017. The examined applications were categorized into four classes: a) technical studies, b) conservation and ecosystem restoration projects, c) alternative production projects, and d) training courses. The analysis of community projects was used to identify the adaptive response orientation, this was associated with workshop participants' responses. Three types of orientation adaptive responses were found:

- Socio-environmental projects are submitted by an organized group of people interested in promoting ecosystem conservation as a strategy to preserve their productive activities and daily life to the long term, under the understanding that components from the biophysical and social spheres are dynamically linked.
- Socioeconomic projects are requested by communities keen on keeping their traditional productive activities going; people may be open to a certain degree of change in the way resources are managed. Measures to face climate variability are usually planned for the short term.
- Sociocultural projects are presented by community members whose interest or motivation is to safeguard their cultural heritage elements that have been affected by climate variability. Measures are outlined in the medium or long term.

**Adaptive response** as action or strategy is a component resulting from the adaptive capacity and is expressed operationally from three conceptual elements. The first depends on three variables: 1) actions' complexity, 2) actions' diversity, and 3) flexibility to change their way to develop main productive activities. The second criteria to list adaptive response rested on the willingness of community members to work together or act individually, and in case of collaboration, its degree according to the perception of three different stakeholders such as: 4) community members, 5) external informants, and 6) these researchers. The last categorization criteria considered the orientation of the adaptive response (as for exogenous factors): 7) socioenvironmental orientation, 8) socioeconomic orientation, and 9) sociocultural orientation; or the combination of these.

The main tool to collect data during community workshops captured the concepts detailed before as operational questions in a structured interview format with five sections, these were:

a) Social profile of the interviewees: gender, age, education level, hometown, residence time, and occupation.

b) Productive activities and primary resources of the rural communities that are exposed and sensitive to climate change.

c) Perception of 1) climate and meteorological conditions, 2) surrounding environment, and 3) productive and daily life activities.

d) Organizational structure: external support, alliances, and leadership.

e) Current and proposed adaptation measures.

The combination of variables in each of the three criteria of adaptive response resulted in 28 types of adaptive responses that were categorized in one of six categories of the adaptive response stairway (see Table 1):

Table 1. Categories of Adaptive Response to Classified Adaptive Capacity at Rural Communities

| id | Type of adaptive response in hierarchic order | Type and degree of adaptive capacity |
|---|---|---|
| 1 | Socioenvironmental, socioeconomic, and sociocultural Collective Strategy | High adaptive capacity at community level |
| 2 | Socioenvironmental and economic Collective Strategy | |
| 3 | Socioenvironmental and sociocultural Collective Strategy | |
| 4 | Environmental Collective Strategy | |
| 5 | Socioenvironmental, socioeconomic, and sociocultural Individual Strategy | High adaptive capacity at individual level but turning potentially communal |
| 6 | Socioenvironmental and economic Individual Strategy | |
| 7 | Socioenvironmental and sociocultural Individual Strategy | |
| 8 | Environmental Individual Strategy | |
| 9 | Socioenvironmental, socioeconomic, and sociocultural Collective Action | Medium adaptive capacity at community level |
| 10 | Socioenvironmental and economic Collective action | |
| 11 | Socioenvironmental and sociocultural Collective action | |
| 12 | Environmental Collective Action | |
| 13 | Socioenvironmental, socioeconomic, and sociocultural Individual Action | Medium adaptive capacity at individual |

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| | | |
|---|---|---|
| 14 | Socioenvironmental and economic Individual action | level but turning |
| 15 | Socioenvironmental and sociocultural Individual action | potentially communal |
| 16 | Environmental Individual Action | |
| 17 | Sociocultural collective Strategy | |
| 18 | Sociocultural and socioeconomic Collective Strategy | Low adaptive capacity |
| 19 | Sociocultural Collective Action | |
| 20 | Sociocultural and socioeconomic Collective Action | |
| 21 | Sociocultural Individual Strategy | |
| 22 | Sociocultural and socioeconomic Individual Strategy | |
| 23 | Sociocultural Individual Action | |
| 24 | Sociocultural and socioeconomic Individual Action | |
| 25 | Socioeconomic Collective Strategy | Maladaptation |
| 26 | Socioeconomic Individual Strategy | |
| 27 | Socioeconomic Collective Action | |
| 28 | Socioeconomic Individual Action | |

Source: prepared by authors based on community workshops and Geilfus (2009), as modified by Jiménez (2015).

The categorization of the adaptive response in conjunction with the participation form answered three main questions about the nature of the adaptive response, the condition of the adaptive capacity of the rural community, and the tendency of the adaptation process of the community determined from the typology of the proposed adaptation.

In relation to Table 1, collective strategy is understood as a set of adaptive strategies that most community members, as organized groups, opt for one or more actions from a series of proposals carefully analyzed to face climate variability. In general, adaptive responses are supported by a strong social structure with members with diversified and ample knowledge. On the other hand, individual strategies are characterized by adaptive responses implemented at an individual level by most community members. These responses take the form of actions of series of proposals to face changes associated with climate variability. In this type of adaptive response, collaboration among community members is limited, and individuals work independently in isolation from the existing groups.

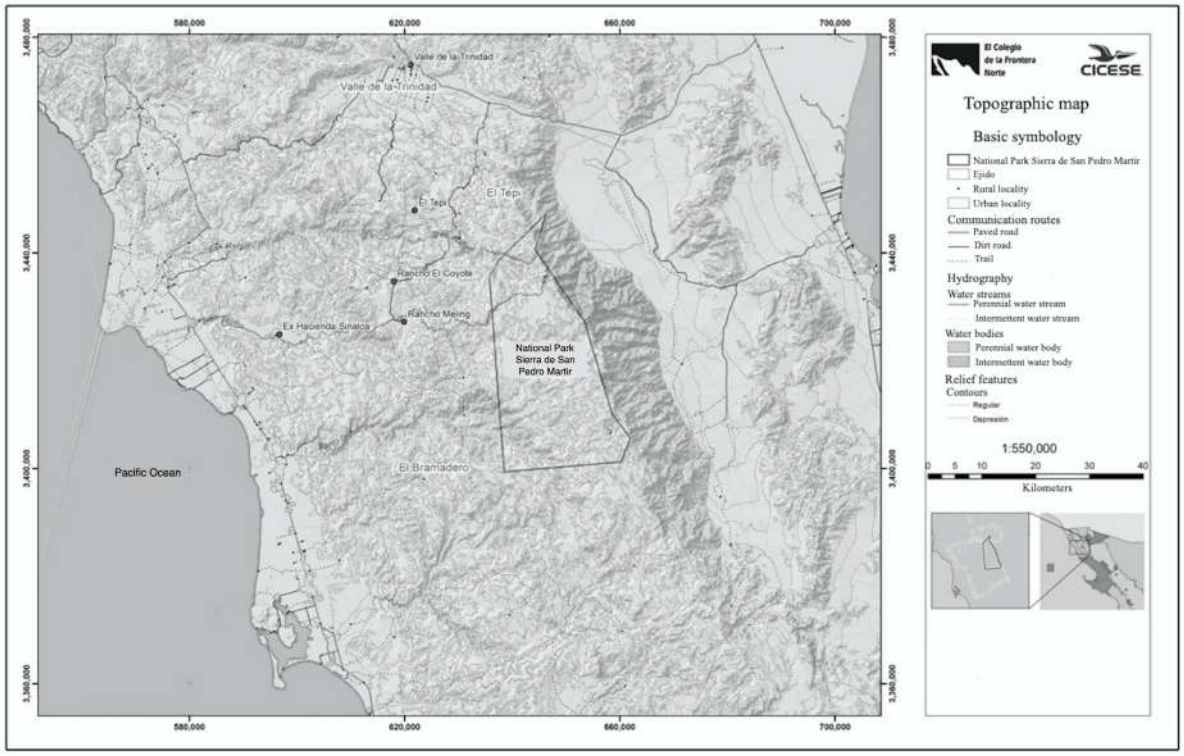
By comparison, collective actions are adaptive responses taken by most community members in organized groups. However, such actions come from simple reasoning on climate problems' sources and causes. Thus, actions are of common sense and picked instinctively to face climate variability. In this type of adaptive response, it is common to find that group members who take decisions have basic education. In contrast, individual actions represent adaptive responses as actions performed by community members on an individual basis to face climate variability impacts; but actions are generated from simple reasoning. This type of adaptive response is found on unstable social structures with

conflicts among people in the community, this limits to a large extent their capacity to act collectively.

## STUDY AREA

The study area is located in Ensenada, Baja California, Northwestern Mexico; this municipality is the largest in the state, covering its central and southern region. Ensenada municipality extends from the Pacific coast to the Sea of Cortez. In the region, weather consists of short, dry, and hot summers, while winters are long and cool. The warmest month of the year is August, with high temperatures around 26°C (79°F), whereas the coldest is January, where the average maximum temperature is 20°C (68°F). It also is the wettest month. In this land area of 52,482.4 km$^2$ (5,248,200 ha), the three rural communities —here studied— are located, specifically to the north and west of the national park Sierra de San Pedro Martir (see Map 1); this is part of the Baja California Mountain Range.

Map 1. Study Area




Source: Retrieved from "Capacidad adaptativa ante los efectos de la variabilidad climática en tres comunidades rurales en torno al Parque Nacional Sierra de San Pedro Mártir" (González Ornelas, 2018).

In the following paragraphs, the basic characteristics of the selected rural communities are presented:

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**1) Ex Hacienda Sinaloa** is located at 150m above sea level with an area of < 10,000 ha dominated by chaparral and desert scrubland. The town is in a region with water scarcity problems and annual precipitation of around 200 to 250 mm. Ex-Hacienda Sinaloa has a floating population of nearly 250 inhabitants, out of which 132 are men and 102 are women. As for their age, 46% are underage, and 54% are adults. Most inhabitants are either illiterate or have basic education and work as day laborerers generally in other's people land; for this reason, is common that laborers change residence frequently. Ex Hacienda inhabitants also made a living breeding small animals and growing vegetables on small family plots. Families live in scattered, small, and precarious dwellings with water supply limited to once per week. Most households (88%) have electricity supply but use firewood for cooking (INEGI, 2010). Services provided by the community are limited to selling food and drinks to the visitors on their way to the national park Sierra de San Pedro Martir.

**2) Bramadero Norte** is located at 100 m above sea level with an area of >> 10,000 ha covered with chaparral and pine forest. The region has a rainfall rate of 250 to 400 mm per year. The community does not suffer from water shortages, but this may be limited during droughts. Bramadero Norte has approximately 100 inhabitants, out of which 63% are men and 37% are women. Most adult age inhabitants have basic, medium, and higher education levels, with low poverty levels. 12% of households lack water supply, and 20% have no drainage. Economic activities are the sale of livestock and apiculture. Bramadero Norte's inhabitants also provide tourism services, including cinegenic and ecological tourism and accommodation to the national park visitors.

**3) El Tepi** is located at 30 m above sea level with an area of >> 10,000 ha covered with chaparral, pine forest, and desert scrubland. The region has a rainfall rate of 250 to 400 mm per year. This community does not have water scarcity problems, although water availability may vary during droughts. El Tepi has a population of fewer than 250 inhabitants, out of which 80% are men, and 20% are women, 28% are underage, and 72% are adults; they have basic, medium, and high educational levels with low poverty levels. The principal economic activities are the sale and purchase of agricultural goods and livestock. Inhabitants also grow yucca and offer ecotourism services to national park visitors.

## METHODS

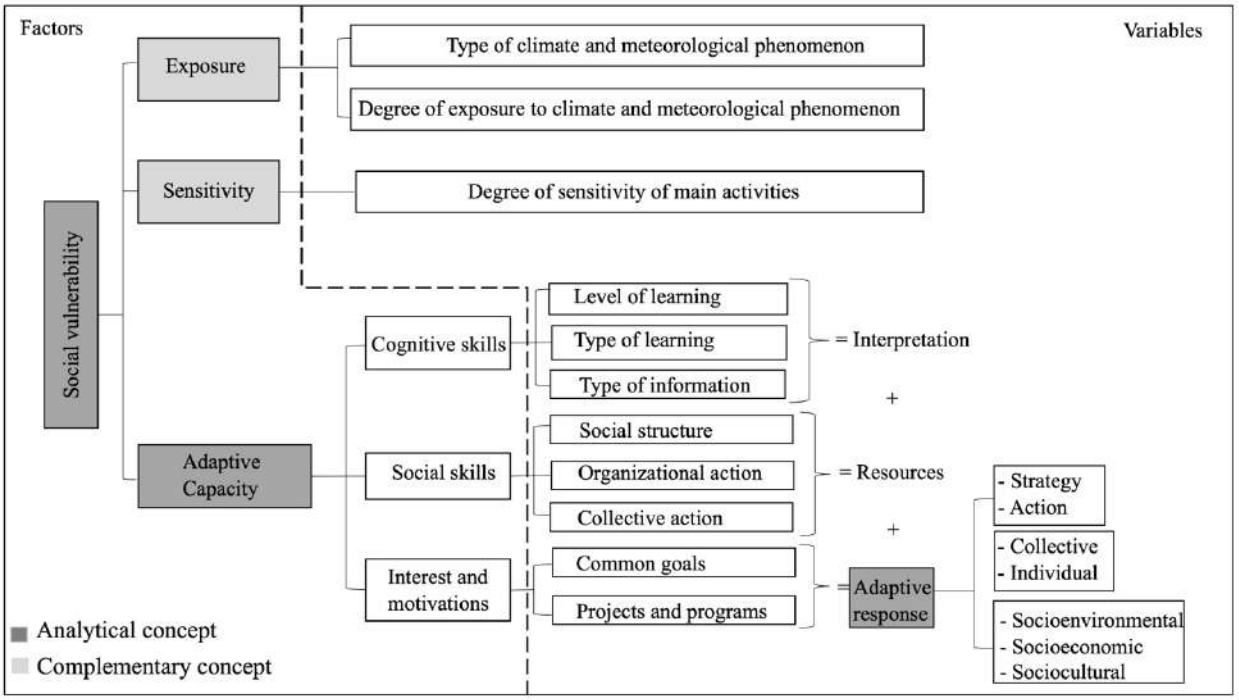
The method used for this investigation was discourse analysis. Data were collected using structured interviews with local stakeholders during the community workshops and semi-structured interviews with external informants. Both constituted main sources of information, while secondary sources were different documents and official databases to validate primary information. Data treatment, processing, and analysis were implemented using Excel (data capture and treatment), Transcribe (interview transcription), Atlas Ti (information analysis), and ArcGis (mapping). The design of data collecting tools started with the operationalization of the components associated with adaptive capacity and

response facing climate variability. It is shown in Figure 3 and is described in the operationalization section.

Maps were prepared using vector files from the Mexico drought monitor of the National Meteorological Service and annual precipitation data from the meteorological stations from the National Water Commission (CONAGUA, for its acronym in Spanish).

To complement the information collected from members of the rural communities that attended workshops, six semi-structured interviews with key stakeholders were carried out: two informants from academia, three government officials, and one representative from a civil association. This exercise pursued two objectives: the first, knowing the perspective of external actors regarding the social adaptation process in the rural communities under study, and the second, to report on the adaptive measures implemented by local agencies.

Figure 3. Methodological and Analytical Diagram




Source: Prepared by authors based on IPCC (2001), Pahl-Wostl (2009), and Poteete, Janseen, and Ostrom (2012).

## RESULTS

This study had as objective to assess the adaptative capacity and response of rural communities facing vulnerability due to climate variability. As such, results revealed first

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the risks perceived by inhabitants in the rural communities under study, their perceived impacts on their daily life and economic activities; then the adaptive responses are presented in Table 2.

Results indicated that members in the three rural communities perceived droughts as the most important climate phenomenon in their region; workshop participants listed as evidence the periods of dryness that lasted longer, occurred more frequently, and were more pronounced. The second most important climate phenomenon identified was water scarcity. However, the level of impact for each community was different; participants listed as evidence: the drying or reduction of water bodies such as watering holes and waterways and lowering water levels in wells or even depletion.

Participants in workshops developed in this study reported that water scarcity was associated with precipitation changing patterns such as intensity reduction, duration, and frequency of rain; people in rural communities recognized these two phenomena as climate variability. In the case of Ex Hacienda Sinaloa, people associated water scarcity only to natural causes of climate variability and never linked it to their management and use of surrounding resources in the socioecological system, including the poor management of the local water resources, neither to environmental services provided by the national park nearby.

While it is true that in general workshop participants reported that water scarcity was the main problem they faced, people from Ex Hacienda Sinaloa described the worst impacts at household levels. For example, water came from an agricultural well, and supply was limited to once per week. Water scarcity in this community has forced people to reduce their water consumption significantly per household and reconsider water use. Members from Ex Hacienda Sinaloa are increasing their water storage and implementing water reuse strategies, but mostly it is done at an individual level. People recognized a constant competition for water with the surrounding agricultural sector.

Bramadero Norte and Tepi communities develop agricultural economic activities, being livestock breeding the most important, in specific cattle for meat production; other activities are vegetable growing and forest harvesting. Given the strong dependency on livestock in the Bramadero Norte and Tepi communities, they may suffer climate change impacts estimated for local livestock in the PEACC-BC due to water scarcity and temperature increase. Water scarcity may affect animals, directly and indirectly, due to impacts on forage crops that usually have a high water demand. Temperature rise could affect directly as well as indirectly the livestock activity. The former could affect cattle productivity due to stress, while the latter could be seen in the accrual of animal pests and diseases due to high temperatures (SPA, 2012).

People's perceptions collected during community workshops in Bramadero Norte and Tepi revealed that ranchers are already experiencing the impacts delineated in the PEACC-BC. For example, cattle farmers reported problems due to the temperature increases and

precipitation reduction, phenomena they recognized as climate variability. Also, cattle breeders are adopting strategies such as reducing the number of animals due to water scarcity, losses of pastureland, increased pests and diseases, and changes in animals' reproductive cycle and growth.

In addition, for Bramadero Norte and Tepi communities, livestock has an important sociocultural component. Ranchers value livestock and are ready to defend and preserve it no matter how big the obstacles caused by climate variability are. People see themselves as being part of a community and value traditions associated with such activity. Farmers generate strategies to preserve such activity to pass it to new generations.

The perception of people dedicated to agriculture in the three rural communities is that there is a boost of pests and diseases in plants due to temperature surges. Farmers are using more pesticides, and this is polluting agricultural lands and nearby water bodies. Workshop participants also reported that arable lands and crop yield per hectare have shrinkage because the period of seasonal rains is shifting. In the case of Ex Hacienda Sinaloa, agricultural activities have undergone the worst impacts and have little opportunity to design strategies as most people work as day laborers in other' people land but are also vulnerable because people grow small vegetable allotments for self-consumption.

Besides perception on productive activities, workshop participants in the three rural communities identified the reduction of abundance and diversity of natural resources that were at their disposition in profusion before. However, few people related such resources to the environmental services provided by the national park Sierra de San Pedro Martir. Perceived changes comparing current versus previous conditions allow people to identify visible changes in water, soils, and vegetation used for production activities, loss of useful domestic species, to name but a few.

As well as productive activities and natural resources, the degree of climate sensitivity includes the influence of changing climate patterns. These affected, directly and indirectly, other social components such as daily life activities, health, and households. Together all these impact the way of life and wellbeing of rural communities. While dealing with these complications, people have been forced to diversify and complement traditional practices by alternatives such as hunting, ecotourism, beekeeping, and vermicomposting.

Adaptive capacity due to climate variability in the three rural communities living near the national park Sierra de San Pedro Martir is shown in Table 2. As can be seen, two of these three rural communities have an adaptive capacity that enables them to endure more or less successfully climate variability because they have inherited and tacit knowledge and common interest and are likely to work together. Only Ex Hacienda Sinaloa members are more likely to work individually, as shown under the "social skills" section in Table 2. However, they are also less equipped with knowledge as most of them have low schooling levels, and because of their character of newcomers to the region.

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It must be added that there are examples of people working together in the past in Ex Hacienda Sinaloa. For instance, during community workshops, a group of women joined and reported that they developed a productive project with international funds consisting in building a greenhouse used to grow native species for cosmetic use. This group reported that concluding the project meant the ending of the activity, and infrastructure was abandoned.

A historical review of projects developed there was carried out to check information and understand the low adaptive capacity of Ex Hacienda Sinaloa. It was found that several projects funded by PROCODES were implemented to build and strengthen capacity in this community. In such projects, people were likely to work together under the right conditions. However, such collaboration ended with the project; posterior lack of support disbanded the surviving group.

Table 2. Adaptive Response to Climate Variability of Three Rural Communities in Northern Mexico

| | ADAPTIVE CAPACITY | | |
|---|---|---|---|
| Community | (1)<br>Ex Hacienda Sinaloa | (2)<br>Ejido El Tepi | (3)<br>Bramadero Norte |
| Cognitive skills | Are low due to limited knowledge of their surroundings and basic educational level; these translate to a loss of capacity to understand, interpret, and seize their territory. | Are of medium to high degree derived from a deep knowledge of their environment from previous generations that have inhabited that region. The average educational level allows ranchers to improve practices; these aspects provide the community with a good capacity to interpret changes in their territory. | Are of medium to a high degree and highly influenced by a profound knowledge of their environment inherited from the experience of previous generations that have inhabited that region. In addition, their average educational level allows community members to incorporate new knowledge; all these aspects provide the community with a good capacity to interpret changes in their territory. |
| Social skills | Individual responses generate a low capacity to benefit from natural resources. | Collective capacities inherited from "*ejidos*" leading to a good organization capacity to exploit natural resources. | Collective capacities are due to strong family bonds resulting in an appropriate organization capacity to use natural resources. |
| Interests and motivations | External support is assigned to overcome short-term constraints. There is no long-term planning to use natural resources. | Yucca harvesting is identified as a short-term strategy. Infrastructure construction is aimed to store water and support incipient tourism services. Both actions are developed with a medium and long term in mind. | Infrastructure construction is aimed to store water and channel it to pastures; the change of productive activities is going from cattle farms to tourism. Productive activities diversification is a long-term strategy to use natural resources. |
| Adaptive response | Low | Medium to High | High |

Source: Elaborated by authors using data from interviews and community workshops.

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PROCODES reports on Ex Hacienda Sinaloa projects showed that this community has been benefited continuously from 2010 to 2017 except for 2013. As noted, CONANP has accompanied this community providing high-quality training of key local people to become "allies for conservation," the name given by public servants working in the national park of Sierra de San Pedro Martir.

In addition to subsidies provided by CONANP, Ex Hacienda Sinaloa has received support from other governmental institutions, some mentioned during community workshops were: The National Forestry Commission (CONAFOR, for its acronym in Spanish), the Secretariat of Agriculture, Livestock and Rural Development, Fisheries and Food of Mexico (SAGARPA, for its acronym in Spanish), and the National Institute for Social Economics (INAES, for its acronym in Spanish). As seen, there is a strong presence of public institutions acting on this community. However, their work does not seem likely to produce the expected results to foster and strengthen necessary capacities for the rural community to decide and design their development. Thus, the public policies model is of a welfare nature. On top of this, the various public funds seem not to be coordinated among the diverse governmental agencies neither international institutions; furthermore, there are no monitoring mechanisms to enhance the effective application of projects.

In addition to the limited amount of money, there is limited time to develop projects. Authorized proposals must be completed in no more than three months from the date on which the financial support agreement was signed; this is inconsistent with the adaptation process known to require time. Thus, public expending and conditions may not be measuring the full scale of the climate variability problem; more importantly, public support may not facilitate climate adaptation in social systems at local levels.

Previous results regarding external funds indicated that residents in Ex Hacienda Sinaloa have become dependent on receiving external support; members from this rural community are prepared to develop any type of project that could bring benefits preferably in the short term. Still, they are interested in remaining involved in the community and, for that reason, generate more adaptive responses, some culturally related —such as belonging— apart from the mere socioeconomic project, these few responses may indicate a developing community's identity. This could be explained if considered that Ex Hacienda Sinaloa is the most recent community, and its members had the shortest residence time in the region.

## DISCUSSION AND CONCLUSIONS

In the three rural communities studied here, changes in the local climate conditions —so far known— have driven community members to spontaneously modify their daily life activities in households and workplaces alike. Rural inhabitants may not give a name to the climate phenomenon impacting, but they are aware of its consequences. And as an

emerging adaptive response, rural inhabitants are already diversifying their activities and way of life and collaborating at different levels for the common good.

As seen in Table 2, adaptive capacity in rural communities depends greatly on their inhabitants' educational level, the understanding of their environment, and their capacity for self-organization to deal collectively with changes in the surroundings and diversify their productive activities with a common benefit in mind. These results agreed with some studies published by scholars such as Huntjens et al. (2008). Table 2 also shows that the Ex Hacienda Sinaloa community is the most vulnerable in part because its average annual precipitation is lower than the other two rural locations studied. But most importantly, because the location of Ex-Hacienda Sinaloa is at the end of the local sub-basin, where water availability is reduced due to use in up-stream areas.

But the vulnerability of Ex Hacienda Sinaloa not only comes from its access to natural resources, it is also largely influenced by social aspects. For example, not all community members own an agricultural plot, and those that do, have plots not established under a common regime in contrast to the *ejido* structure observed in the other two communities better adapted to climate variability. The fragmented land ownership in Ex Hacienda hinders the management of water resources in particular; this finding agrees with results revealing that access to resources is a limitation to the adaptive process (Lampis, 2013).

In relation to social vulnerability, it is important to emphasize that communities whose adaptive response was more strategic also demonstrated to be less dependent on governmental programs. Some community members even manifested that those bureaucratic affairs were too many to include them in their adaptation strategies. Thus, they tend to ignore public funds. Similarly, public institutions also ignore communities that do not claim support.

Nonetheless, community members with higher adaptive responses recognized that governmental intervention could benefit their hometowns. However, they demand control of the potential public intervention on their territory to consider their needs and prioritize their perceived actions, and guide strategies; thus, members of better adapted rural communities have a clearer vision of what they expect. On the contrary, members from the community with a lower adaptive capacity expect that actions and strategies towards climate variability from the public intervention may last. But given the discontinuity of governmental programs product of administration changes, this community's vulnerability to climate variability increases every political cycle.

Currently, rural communities under study face high uncertainty in relation to climate conditions that could be reduced if they have access to information on how to design and implement strategies and to guide the decision-making process. So far, access to information seems to be very much related to formal educational level; higher schooling means better access to information. Thus, even if a rural community has access to useful data, illiterate inhabitants will not make the best use of it; this does not mean that people

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with basic education will never make proper use of information. Results from this study indicated that help from public institutions and civil society organizations may help facilitate access and use of information, at least in the beginning. Once inhabitants are empowered, they may take better strategies to face climate variability. Though accompaniment, strengthening, and support must be continuous and at hand when required. Communities that entrusted initiatives and felt abandoned hardly confide again.

Many experiences from previous public interventions have not been exploited enough. For instance, the "allies for conservation" could be employed as connectors between local governments and rural populations, as well as agents for change to promote capacities and identify the right social context. Although it was not studied in better detail the role of public institutions on the adaptation process of rural communities, the review carried out in this study indicated that institutions and public policies on climate change adaptation in Mexico may have significant advances in legislation. Nonetheless, funds destined to facilitate the adaptation process in social systems are not significant compared to the challenges brought by climate change.

For example, the Climate Change Fund (*Fondo para el Cambio Climático*), one of the most important funds to facilitate mitigation and adaptation process, allocated 18,000,000.00 (Eighteen million Mexican pesos) in its national call for proposals No. 11/17 "Proyectos Operativos de Mitigación y Adaptación al Cambio Climático Listos Para Ser Instrumentados" (SEMARNAT, 2017). If this sum is divided equally into the 32 Mexican Federal States to develop at least one project, each approved proposal could get 562,500 Mexican pesos. Hardly enough money to develop a long-lasting intervention of climate adaptation.

Still, financial support from other public institutions such as CONANP has helped rural communities near the national park Sierra de San Pedro Martir indirectly ease the climate adaptation process generating adaptive capacities mainly through PROCODES projects. Yet, an important limitation is the dependency on limited public funds. Nevertheless, the strategy implemented by CONANP to optimize scarce resources has an unexpected but positive effect on adaptation, pushing communities to collaborate. This mechanism has opened an opportunity to better social skills that at the right moment could give way to effective adaptive responses to climate change.

During the development of this study, intervention prints from national and international agencies specialized in environmental, development, and climate change were found; in all cases, projects were not adapted to the ample cultural and environmental diversity existing in Mexico (Kohlitz, Chong, & Willetts, 2019). It was worrisome to find that support, evaluation, and fund assignment criteria were homogeneous to rural communities in the arid land in the North and the tropical and rainy areas from the South (Monterroso & Conde, 2015).

Furthermore, it was observed that actions propelled by such intervention projects were designed with a short-term vision possibly to attract and enroll rural community members. However, most actions did not have mediums let alone long-term planning resulting in derelict infrastructure. Moreover, something problematic, but not limited to external support, was the intervention projects not being coordinated along with the three levels of government found in Mexico. This partially caused programs not to have continuity neither monitoring to assess their effectiveness.

Finally, this study relied on the specialized literature to design data collection tools through a detailed operationalization of selected variables from an extensive pool of concepts. However, during fieldwork, we encountered unexpected situations that guided us to modify methods and adapt tools. It must be recognized that not all variables were as important as believed in the beginning. For example, not age neither gender played a determining role in the adaptation process. Neither the ample classification of adaptative responses was present in our study, or even some links between exposure and risks were strengthened from external intervention pursuing to increase adaptation.

Furthermore, during the development of community workshops, we had to adjust methods to get participation and involve community members; it was common to have demands of immediate solutions and even face mistrust because of previous failed interventions from both national and international agencies. In some cases, inhabitants from rural communities reported illegal activities from agro-industries, "*caciques,*" and even organized crime carrying out illegal logging and appropriation of water bodies. We firmly believe that, in the future, if we pretend to advance climate adaptation in rural communities, more studies about climate adaptation from a social complexity perspective should be developed.

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