Qualitative indicators for community water resilience in floodable areas: Agricultural pantry of La Mojana, Colombia

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Abstract

The subregion of La Mojana is a national geostrategic region. It includes the basins of the rivers Magdalena, Cauca, and San Jorge. This location has abundant wetlands, *zapales* (particular marshes from the region), and swamps where there are cyclical floodings and droughts. This region is also considered to be a great reservoir of freshwater, very rich in biodiversity and a place with productive wetlands. It is considered a food reservoir, and despite its cattle-raising tradition, 20% of the rice consumed in Colombia is cultivated here. In addition, it consists of water and land ecosystems that stimulate an agricultural, cattle raising and fishery base: productive fields which generate 90% of the economic productivity of the area.

Between 2021 and 2022, frequent and historical floodings affected 24253 acres of agricultural land, especially the 9633.2 acres of rice crops. There has also been registered some damage to other production units such as corn (645.2 acres), plantain (194.5 acres), cows (6757), pigs (6083), horses (603), poultry (40287), and more than 550000 fish. According to the Register of Victims (*Registro Único de Damnificados,* in Spanish), no less than 45000 people were affected by the winter wave in 2021.

In order to achieve the objectives stated in this article, three phases will be developed: the first one involves the construction

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of the conceptual framework, explaining the nature of the community water resilience category and the pre-identification of the categories and dimensions that are going to be used in the construction of the indicators. In the second phase, a methodological description is established. Finally, in the third phase, an estimation of the qualitative indicators is formulated. The results will help decision makers to generate projects that minimize the damages caused by the flooding.

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Introduction

The groups of natives that populated La Mojana were the Zenúes – gold, water, and ceramic worshipers. They established themselves in three provinces: the first was Finzenú, located near the Sinú River – a place of mysticism and spirituality and a place known for its mysticism and spirituality and, therefore, a place for worship. The second province was Panzenú, located near the San Jorge River – that in those times worked as an economy and trading location. The third was Zenufana, located in the lower valleys of Cauca and Nechí – an area with plenty of minerals and gold production. The feature that these collectives held in common was that they settled in hydrological ecosystems that contributed to the development of different cultural, economic and political practices (Plazas & Falchetti De Saens, 1981).

Geographically, the Momposina Depression subregion (Figure 1) has an edaphic composition of wetlands that belong to the river network of the Colombian Caribbean, such as the Magdalena River, Cauca and San Jorge, which act as water regulators in the municipalities of four regions: Sucre, Córdoba, Antioquia, and Bolívar (CBS & CORPOMOJANA, 2002). To obtain its results, this study was concentrated territorially in the municipalities of San Marcos

Figure 1 - Municipalities that make up La Mojana

Source: MINHACIENDA (2016). Action Plan for Flood Risk Reduction and Climate Change Adaptation in La Mojana (2016).

(El Pital, Cuenca, El Torno, and Las Flores sidewalks), San Benito Abad (Las Chispas, Pasifueres, Chinchorro, Tosnovan), located in the region of Sucre, and Ayapel (Cecilia, Sincelejito, and Seheve), located in the Córdoba region.

In addition to the mercury water pollution developed in La Mojana, rivers have altered their capacity to buffer and regulate water in winter due to the construction of artificial canals of almost 30 meters wide and 5 meters deep, and the engineering works used for the drying of the swamps. In addition, this territory has other problems such as drying out, limitations in the interaction between the river and swamps, sedimentation, and inadequate outflows of sewage. Other socio-environmental problems are tree felling, unsustainable fishing practices, and the exploitation of gold and mercury (CBS & CORPOMOJANA, 2002).

This region has been subjected to the sudden expansion of rivers on a regular basis for the last 30 years. By 2022, for example, the floods had left more than 100000 victims, 35000 damaged goods, and extreme losses in livestock, rice, and other products from small groups of peasants (Díaz, 2022). Looking at the history and evolution of the impact of floods in the region, it can be observed that these data have remained unchanged in history.

After analyzing the rain period between 2010 and 2011, Urquijo and Vergara (2013) stated that it brought 500 deaths and more than 3.6 million victims, being one of the strongest rainy periods, especially if compared with the one between 1998 and 2008: between April 2010 to June 2022 – just in these 14 months – 1734 flooding events were registered, representing the 45% of the total events occurred between 1998 and 2008.

With this information, different international missions and national institutional projects have been studying the region since the 1970's, like the Colombian-Dutch Mission (*Misión Colombo-Holandesa*) which offered recommendations that were overlooked until the present, such as the adequation, connection and periodical cleaning of canals, the building of new roads, the improvement of public services, and hydrological planning alongside community development processes (Himat, 1977; Departamento Nacional de Planeación & FAO, 2003; Aguilera Díaz, 2004; Departamento Nacional de Planeación, 2012; Urquijo & Vergara, 2013; IDEAM, 2017). Finally, in 2022, the National Council of Economic and Social Politics (CONPES, *Consejo Nacional de Política Económica y Social*) is looking forward to fostering climate resilience and sustainability in La Mojana. It can be said that many technical and academic views have been shared regarding what is now an over-diagnosed but little-intervened territory.

Some academic studies have focused on the physical form of the threat in this region and on the value of the physical and social vulnerability, but neither of these two analyses has been integrated into the risk assessment (Villegas, 2020). Other groups of studies refer to an ecological view and the

ecosystem services associated with biodiversity (Caraballo & De la Ossa, 2011; Humboldt, 2018). Another line of research is related to production systems, namely, small rice producers that are part of this farming economy (Cadena Cuello & Romero, 2021). On the other hand, for the last decade, different researches about the need of studying on a regional and local scale have prevailed, aiming to design the intervention and environmentally restauration scenes. Despite this, there are very few works referring to social indicators of qualitative perspective that also contemplate the contribution of the resilient communities that live in hydrological areas, who are prone to experience frequent floods.

In this context, the present study was developed to formulate a group of hydrological qualitative indicators that consider the features of resilient abilities in La Mojana. This was formulated by contemplating the community involvement and the knowledge dialogue, and by considering a phenomenological approach that aims to change the traditional research on which descriptions and data are taken from a distance, from the observer and narrator perspective, with descriptive surveys that are limited to a subject that is alienated to the world, and which captures and materializes this information. It is hoped that this study becomes a useful tool for researchers, entities responsible for managing emergencies, entities that integrally manage water resources, and, in general, for everyone in charge of land planning and management.

Therefore, it's important to move forward with the study of these amphibious communities in regard to their resilient processes, cultural practices, ways of living, governments, and valuable information on territorial ordering processes, as much as it is important to advance with the planning of a public policy approach in diverse orders. In this context, this article will include the results of a rich human and investigative experience considering the population of two regions in the North Colombian Cost (Sucre and Córdoba), three municipalities (San Marcos, San Benito Abad, and Ayapel), and eleven sidewalks.

The configuration of community resilience

The concept of resilience is multivalent in nature, considering the use made by various authors and disciplines. For some, it came about in the 80s within the Social Sciences to explain the positive skills that people developed in complex contexts: shortage, permanent loss, dysfunctional families, and extended stress situations (Arciniega, 2013).

Other authors date the beginning of these studies in observations made since the 70s in the field of child psychology, with children in threatening

and unprotected environments who achieve a positive adaptation thanks to the possibility of interacting early with healthy growing-up environments (Kaplan, 1999; Lynch & Cicchetti, 1998).

Later, studies on resilience in adults resulted in new responses and typologies, especially for the various problems that the category has generated in its multiplicity. That is why Bonanno (2012) identified resilience as a personality trait, as special unattended psychopathology, and as a category that can be considered a psychological and emotional balance.

A meta-analysis study conducted by Lee *et al.* (2013) involving 31 071 participants and 33 studies showed that there are personal factors that preserve and generate resilient processes, namely: confidence, positive affection, self-efficacy, self-esteem, social inclusion, and risk factors such as anxiety, depression, distress, and perceived stress.

However, in terms of environmental studies, resilience has been studied for a longer time and was initially applied in Holling's work (1973), who, through the field of ecology, showed that the concept was meant to understand and manage complex systems linked to people and nature. Later, from the systemic theories, it was defined that the term resilience would be the ability of a system to absorb and recover from a new event (Klein *et al.*, 2003) fully and harmonically.

In the 1980s, when the concept of resilience was consolidated in various disciplines, such as biology, geomorphology and anthropology, its main use was still that of invulnerability. In Rutter (1993), the concept appears as an exclusive, constant, and unalterable format. Vulnerability and resilience were born as general characteristics, not permanent nor inherent to the people or groups, given that they change according to the type of adversities or circumstances in which individuals are found. After many studies, it is still not clear how this concept should be used and what are its determining factors or how they can be measured. Although, recent literature on threats and disasters often refers to the concept of resilience as a guiding principle behind effective threat risk management, making it operational for policy, which poses critical challenges in terms of its evaluation (Gómez & Rivas, 2017).

On the other hand, the concept of community resilience was born mainly in the 1990s, with theories of natural hazards applied to multiple social situations: tremors, floods, hurricanes, hunger, and human displacement (Arciniega, 2013; Brangwym & Hopkins, 2010; Marzana *et al.*, 2013).

In conclusion, resilience is not just the ability to withstand a hostile experience, it also involves actions of greater importance which means detecting and warning of possible misfortunes with the ability to recover after the harm (Uriarte Arciniega, 2010).

Community resilience is the ability that a group of people has to overcome situations of stress and stand above any difficulties. It involves assuming

adversity together, collectively developing the ability to be constantly informed from a wide basis of strengths and opportunities. This dimension has a multiplicity of common practices to perform, like increased confidence and achieving protective and restorative actions; therefore, it is not only necessary to compile information to face difficulties (Acinas, 2007). The community is strengthened through the possibility and ability to build collectively and achieve the required results.

In short, we can define community resilience as a collective dynamic where common goals and shared needs are achieved through collectively overcoming difficulties. It is for this reason that each group, from its social, political, and economic experience, finds a mastery of techniques and skills acquired through common learning. This includes shared emotions, emotional control, and collective memory. It is necessary to emphasize that it is not only a problem of overall aptitude but also of technical and creative knowledge to face the challenges and obtain, from this perspective, a collective integration (Alzugaray, 2019).

Resilience at the community level determines forms of social connection with nature since they are built with collective effectiveness in mind. That is to say, the ability to interact collectively facing human difficulties to reach an expected end. In this way, the collective faces, without major difficulty, the impacts of the disasters attending to aspects of locality, communication, and mutual support, thus creating diverse positive emotions (Fredrickson *et al.*, 2003).

The effects of adversities are not only conditioned by individual actions, but they also depend on organized collective motions, such as the help from organized families, the experience of the communities in critical intervention, and the experience in the intergroup emotions (Wlodarczyk *et al.*, 2017). However, when negative experiences are constant and handled individually, social isolation, depression and anxiety occur (Rubin *et al.*, 2006). Resilience, from a psychological standpoint record how trauma is transformed into growth actions (Bonanno, 2012).

In summary, resilient individuals develop strategies that are appropriate to face problems from a self-efficacy perspective. This way, they recognize the value of emotions and positive affection that comes from taking on traumatic events that are also collective (Fredrickson *et al.*, 2003; Fredrickson *et al.*, 2008). Community leadership allows individuals to face these problems given that they set, organize, and stimulate collective actions so that organized communities can solve and confront adversity. This organizational dynamic consists of self-efficacy, persistence, creativity, independence, challenge, audacity, and, mostly, of being prepared for adversity.

As Uriarte (2010) points out, several definitions for resilience were brought up in the last decades and can be grouped into three categories: resilience

as systemic stability against the coup, as reparation, and as transformation. The first refers to coping with a difficult situation; the second involves the ability to resist, to protect integrity; and resilience as transformation refers to strengthening people's skills and competencies for adaptation to changes, and to strengthening from weaknesses.

From the above, it can be observed a field of knowledge is being formed: one of resilience as a whole and one of community resilience. These two options are conformed by multiple publications with theoretical bodies and concepts that are still vague, without conceptual and methodological clarity, which lead to difficulties for mediation and proper evaluation (Sharifi *et al.*, 2016). The concept of resilience is increasingly being used in a practical and reflective manner, in academic and political circles where there are a variety of entities, including national and local organizations, and international organizations.

Aguirre and López (2017) point out from the theory of complexity that community resilience is linked to the transcendental biography of individuals, as well as to the particularities of belongingness, the environment, and its context. This perspective suggests that resilience at a collective level is achieved through systematic interrelationships and interactions (more than just individual activities) addressing the social entity. However, despite the attempts by many to characterize and quantify resilience in a socio-ecological context, it has been proven that providing its measurement outside a numerical scale was not possible (Cabell & Oelofse, 2012). Within the qualitative perspective of resilience, traditional knowledge must contribute to scientific research through knowledge dialogue.

Community water resilience to flooding

In relation to resilience and its effects on floods, it's been three decades since a new point of view was developed within the social sciences to study natural disasters, urban and regional planning, as well as the territorial order, in contrast to the naturalistic view of the natural sciences, which considered calamities to be isolated geophysical factors that are not systemic and are considered as disconnected from the most vulnerable communities. In this sense, the experience of going through a disaster doesn't depend on the event as much as it does on the fragility of the society exposed to danger and on the preparation that each community makes to face it (Aversa *et al.*, 2020).

In a study on flooding in the Upper Thames River region in Canada, Peck, Karmakar and Simonovic (2007) consider three components of analysis: threat, exposure, and vulnerability. These factors offer a broad understanding of the manifestation of a flood in specific localities, to the extent that it allows the generators of public policies and territory planners to design new spatial

planning and the configuration of infrastructure with traditional and technical knowledge.

Peck *et al.* (2007) point out that in flood vulnerability there is a need to quantify susceptibility and the attention to the different difficulties generated in a region or population. Balica, Douben and Wright (2009) take a different perspective. They define the vulnerability to floods that manifest in a community as something that is always susceptible to new exposures and permanent threats. For this reason, they combined three categories of water resilience: the ability to resist, recover, and transform. The risk analysis methodology is based on four categories described by Balica *et al.* (2009) and Peck *et al.* (2007): physical, economic, infrastructural, and social.

In general, floods are one of the risks that occur mostly in various ecological landscapes, affecting much of the economy and daily life, this being a feature included in the risk assessment. In addition, this assessment is not purely of parametric nature. Around the world, there is a need to improve the understanding of risk and its vulnerability with new forms of comprehension based on qualitative knowledge. A new variety of theories and concepts in the practical study and experience of risks of and vulnerability to floods should guide the process.

In many countries, the Geographic Information System (GIS) has been able to show the impact of flooding in areas with periodic monitoring of days and months, locating its impact in critical facilities, such as emergency service stations, roads and bridges. These studies accept that land use and soil type are considered the two major mechanisms of flood exposure (Balica *et al.*, 2009).

Water resilience emerges as a concept from the contribution of these authors and organizations in the following manners: GOAL (2015) configures resilience as the ability to anticipate an external difficulty capable of resulting in flooding; from natural risk management; Meza (2021) sets this concept as an urban trait that occurs with the strengthening of resilience with socio-natural and political-economic components; the International Federation of the Red Cross, the Mexican Red Cross and the Red Crescent Societies (2016), within the Flood Resilience Program, propose resilience as a recent concept that is dynamic along with psychosocial aspects of individual responses under stress situations; and, finally, the International Federation of the Red Cross (2014) considers resilience as the ability of organizations or nations exposed to natural disasters, crisis, and vulnerabilities to prevent the effects of water environmental disasters and the ability to prepare to affront them.

In recent years, several studies have included the individual perception of risk as another element within the exposure that integrates experiences, cultural knowledge, and relationships between those and nature. Therefore, today we understand the logic of vulnerability to floods, especially from

social perceptions, and their representations since these allow us to adapt and recognize the mechanisms on the way to decrease the exposure of recurrent events with vulnerable populations (Won & Zhao, 2008; López, 2010; Soares *et al.*, 2014).

Qualitative indicators for flood events

The indicators generate outstanding, vital, and unique information, and provide conclusive evidence. The information for its construction can be qualitative, quantitative, or mixed, considering a set of objectives. Ideally, these express a relationship between two or more variables and are delimited in time and space. Some features to consider in its design are the accessibility to a region and the perception of a subject as an opinion. Its methodology should explain what and with whom it will be measured, considering clear objectives to establish needs, strengths, and the calculation of their measurement (CNEPDS, 2013).

The various indicators related to floods are more urban than rural (Ferrari, 2007) and have been carried out through surveys that measure the vulnerability to floods of different cities. In Mexico, for example, Hernández and Ramírez (2017) used a methodology of flood risk analysis applicable to urban basins, for which they defined vulnerability rates that consider the degrees of exposure, susceptibility, and resilience throughout the basin. Accompanied by special modelling processes in times of flooding and risk maps, this methodology allows, with a base of information generated by INEGI, from Basic Geostatistics Areas (AGEB), to specialize a group of indicators (Balica *et al.*, 2012; Alcocer Yamanaka *et al.*, 2013).

On the other hand, indicators for integrated urban planning actions have been organized for intermediate cities that are periodically affected by river floods, an example of which is the one carried out by González *et al.* (2020) in the central valley of Chile. The most used indicators for floods assembled for public policies are defined from three properties: subsystem redundancy, learning time after each event, and localized response capacity (Hong & Liao, 2012; González *et al.*, 2020).

Another set of flood indicators was carried out by an international humanitarian organization dedicated to the care of communities (GOAL, 2015). The perspective used covers five key thematic areas, namely:
1. governance;
2. risk assessment;
3. knowledge and education;
4. risk management and vulnerability reduction; and
5. emergency preparedness and response.

On the other hand, the methodology of community-based resilience analysis (CoBRA) is carried out in two stages. Firstly, analyses of the lifestyles or social capital and, secondly, adaptability and strategies. Another of the methodologies suggested by Mayunga (2007) contemplates a comprehensive analysis of resilience from an approach based on human, physical, economic, and social capital. In this study, it was decided to use a more adapted methodology, based on a modification of the CoBRA analysis, among others.

Materials and methods

The research method in this investigation was applied in the municipalities of San Marcos (El Pital, Cuenca, El Torno, and Las Flores), San Benito Abad (Las Chispas, Pasifueres, Chinchorro, and Tosnovan), located in the region of Sucre, and Ayapel (Cecilia, Sincelejito, and Seheve), located in the region of Córdoba. Regarding the population participating in this study, 231 people of different ages and genders were selected.

Following the theories of perception, the following process was used to develop the appropriate methodology:

1. Firstly, strategies were set to describe and interpret the perspectives of the world considering the person living these experiences and not the one observing them. Fewer descriptions of the other person were displayed, and more personal perspectives were included. This means that there was no intervention in the view of the person living these experiences and the graphic, written, verbal and emotional limitations and possibilities were considered and were not modified.
2. Secondly, an ethnographic diary or grid was used, containing notes from researchers in the field. The goal was not to interpret but to contextualize the collective behavior of each community.
3. Finally, the compilation of data was carried out, for which grids were used to note down everything each participant had said, having total respect for the text integrity, to then make a proper reading of the information collected.

The applied methodology is performed from a phenomenological-perceptual approach. The perception here is modified from the traditional perspective, supported by psychological projective techniques, such as mental maps and surveys (Morales, 2012). The perception of flood risk used in this study is subjective. According to García (2012), this perception is formed with the personal history of each participant, and their experience combined with the quantity and quality of information coming from beliefs and attitudes. Therefore, the information obtained here is of personal introspection and intersubjective character. For this, several tools were used, such as the cause-effect tree, the timeline, and the focus groups.

The cause-effect tree. It was applied to one sidewalk by each municipality. Initiated with a brainstorm, the objective was to make a participatory, democratic diagnosis. This methodology allows the community not only to be a source of passive information but to be involved in the formulation of objectives, as well as the diagnosed results, each participant is given a card of different colors to write individually what they think about the strategies used by each person and then by the community to deal with floods and the potential of eco-systemic services in this process.

The timeline. As a methodological option, it was possible to respond to the needs of temporal understanding that allows, for this case, the action of the communities with the eco-systemic services in the floods' real-time and the direct connection. Therefore, the timeline is defined as a participatory research methodology that seeks to relate specific, concrete, determined events and actors chronologically, from the temporal location and the description of events related to a specific theme. These are recorded exactly as described by the participants, taking into account the mode, time and place of the events or events of a community.

For this development, elder participants with a long lifetime in the municipality were chosen. This tool is configured with historical notions, as it seeks to emerge and challenge the memory of floods and their practices resilient to the onslaught of water. The events identified from the community perception will be related and complemented with the journalistic records of the time.

Focus groups. A focus group is the expression of a group-order interview through a topic script or an organized interview with the interaction between participants to produce information.

PHASE 1. Community preparation: Local co-researchers were invited. These people were in charge of dynamizing the exercise with the community, meeting it in a place and facilitating the logistics of the meeting.

PHASE 2. The community was made aware of the methodology and its application.

PHASE 3. Development and socialization: The eco-systemic services, water resilience and floods were explained to each group. For this purpose, the groups were divided according to the defined categories. In addition, a considerable number of participants who could not read and write were assisted in writing. Finally, the experience is socialized and placed in the illustrated tree.

PHASE 4. Conclusion and education: After socialization, the meaning of the results was explained to the community and the process was evaluated.

PHASE 5. The community was consolidated (Leadership): The community ratifies the leaders who will accompany them in the restoration processes and future processes.

PHASE 6. With the systematized results and the appropriation of several methodologies to define vulnerability indicators with floods, the following categories were found: climate, knowledge dialogue, and applied ancestral knowledge.

Table 1 - Application of methodology places

Municipality	Sidewalks Centre Population	Place of the activity development	Number of participants	Gender	
				M	**F**
San Marcos	El pital	Home of Inalides Villadiego (co-investigator)	24	6	18
San Marcos	Cuenca	Home of Robinson Núñez (Legal representative association)	39	15	24
San Benito Abad	Chispas	José Luis Sandoval (co-investigator)	31	5	26
San Benito Abad	Pasifueres	Home of Leticia Zambrano (co-investigator)	18	6	12
San Marcos	El Torno	Communal Space "Morrocoy"	59	16	43
San Marcos	Las flores	Educational Institution "Las Flores"	42	23	19
San Marcos	Tosnován	Home of Liliana Chávez (co-investigator)	6	2	4
San Benito Abad	Chinchorro	Home of Francisco Luna (co-investigator)	12	2	10

Source: UNICORDOBA working group.

The paradigm is phenomenological since the world is observed as something unfinished, so the meaning is given in detail by those who live in it. Within this framework, the researcher self-recognizes as an interpreter of the realities constructed by the study subjects and demands a degree of understanding of the meaning, sense and structure of social participation. Figure 2 shows the written perception of a group of people from the Cuenca sidewalk, about their living and the floods. The essence of the collective action and its realities taken by the subjects of study are therefore sought.

Figure 2 - Example of a problem tree
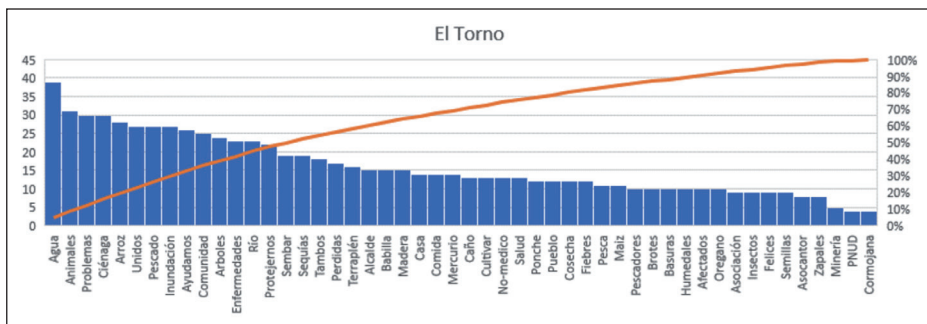

Source: working group.

Community perception is the concept that was put into circulation. In the first instance, it considers stimuli as the source of the individual's perception and then integrates group experiences, attitudes, values, needs, social circumstances or expectations. Traditionally, perception is more inspired by psychological projective techniques, such as mental maps and sociological techniques, such as surveys (Morales, 2012). However, the cause-effect problem tree and timeline tools opted for phenomenological theories that involve leading participants to personal introspection encounters.

Results

In San Marcos, Ayapel, and San Benito Abad, the methodological cause-effect problem tree tool was implemented to give an account of the social perception of eco-systemic services, their implications and community resilience concerning floods. Likewise, by using the contributions obtained from the methodological tool of the timeline, it was easier to address the short and long-term memory of people with more years of life in each community.

With this systematized information and a varied selection of data it was possible to study different methodologies to develop qualitative indicators and measure vulnerability in floods such as community-based resilience, lifestyles, social capital in resilience (CoBRA), human and physical capital (Mayunga, 2007) governance and built environment (Jacinto *et al*., 2020) threat, exposure, and vulnerability (Peck *et al*., 2007), and infrastructure (Balica *et al*., 2009 and Peck *et al*., 2007). Finally, the most used flood indicators are those of Liao (2012) designed to be articulated in public policies and González (2020), which defines three properties: i) redundancy of subsystems; ii) learning time after each event, and iii) localized responsiveness, with which a set of qualitative indicators specific to the floodable region of La Mojana, Colombia was configured.

Figure 3 - Word Recurrence in the El Torno Community

Source: working group.

Each participant was given a card of different colors in which words connected with phrases that were written freely and were previously explained and argued. They contained the categories: good living, eco-systemic services and floods, community resilience, and governance. From the above, it was obtained for the analysis a group of information that, in terms of research of perceptions, allowed an objective and systematic description of everything described in this study. Likewise, a graph was made of each sidewalk and each municipality as presented below with the case of the community of El Torno, where the most recurrent names are referred to the "aquatic man" (water, fish, trees), to the dynamics of risk (shortages and destruction), and adaptation (land, affected, adaptation). These results, although they seem obvious, take on meaning and validity in contrast to the other communities of San Marcos, since in terms of environmental rehabilitation, they are indicating a path and sensitivities.

Figure 4 - Sammon's Method Applied to El Torno Sidewalk
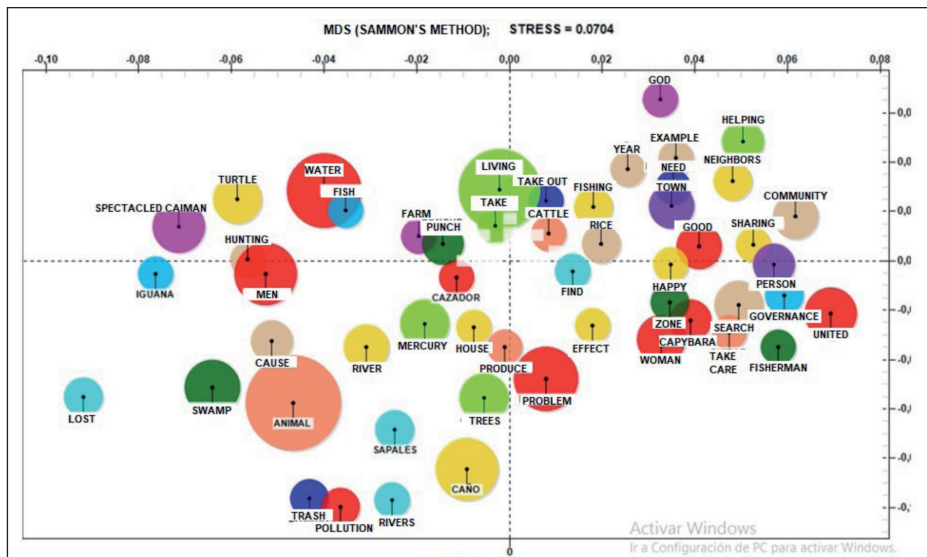
Source: Data from Information Analysis Software T-LAB.

The data were also systematized in the Software T-LAB, composed of a set of linguistic and statistical instruments for content analysis, discourse analysis and text mining represented in a graph by a municipality. In this model, the groups of points represent a thematic unit. Meanwhile, the segment located in the lower-left is associated – sometimes more than others

– with the problems that are affecting the area; this is the reason for the identification of words associated with the contamination of the place within the system studied, such as, for example, river, mercury, garbage, swamp, *zapales* (marshes) and house.

The relationship system of these words shows that the community is being strongly affected by both pollution and mercury. It is important to take into account that its vital system is closely linked with water, since it provides and constitutes, in part, the most important eco-systemic service of supply. Faced with this vulnerability, the community emerges to confront the difficulties of the system, helping itself (a situation that is evident in the graph in the upper-right and the lower-right, although the latter has correspondence with the mechanisms to be resilient, given that expresses actions to be developed).

Also, they show emotional feelings like being happy. There seems to be some tension when this emotionality is presented by environmental problems. What this shows is that the ties with the territory go beyond the border that restricts them. Also, in the upper-left are evidenced some of the main products that may be associated with their diet. Animals, in this case, have higher priority over vegetables. It is interesting to point out that the word animal is found in the lower-left segment, this is because the destabilization of the ecosystem is affecting the presence of fauna.

Characterization of water resilience in the municipalities of San Marcos, San Benito Abad, and Ayapel

San Marcos community water resilience. Embankments (a bank of earth and sand to prevent flooding in an area) have become the mitigation measure for the effects of floods. The medium provides some food sources, such as fish and hunting animals, and rice and subsistence crops are produced. It has good supplies of fish, common caiman, and turtles, and it is also a good environment for planting rice and growing plantain. It also has timber trees for bridges, canoes, and *tambos* (structures to get protected from flooding), among others. To deal with the floods,

Figure 5 - Ayapel's Water (Associations)
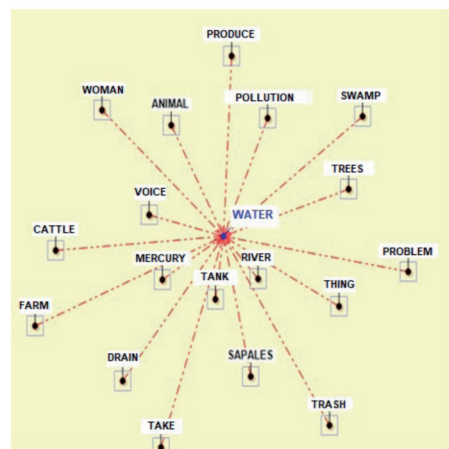
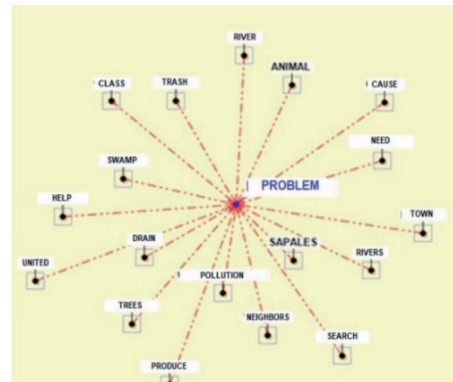*Source*: Data from Information Analysis Software - T-LAB

the population from this area built a handmade containment wall, they expanded *cambuches* (huts made of plastic) where food is stored, especially rice, to not suffer from hunger in difficult times. Also, the population of the area fight food shortages through productive courtyards, orchards, and vegetables. As for their well-being, the area is thriving, as it provides food, vegetable, fruits, fish, and others.

Ayapel community water resilience. In this community, the population doesn't take part in local organizations, or boards, and, in general, they have a lack of associations. However, they identify several actors in the area, including the United Nations Development Programme (UNDP), Unicordoba, and Corpoayapel. In adverse times when rains are lurking, each family builds *tambos* and embankments, and in terms of vegetation, the flood-resilient spices are oak and bell rice, corn, and subsistence crops that are produced in the area. There are animals such as turtles

Figure 6 - San Benito Abad's Problem (Associations)

Source: Data from Information Analysis Software - T-LAB

and yuyo ducks. Within this ecosystem, the San Matías pipe offers water, and fish, and serves as a waterway. In addition, it is understood that the pipe fulfills a regulatory function since it works for the swamp to discharge its water at times when it is heavily charged. Productive activities of an artisanal type that are transmitted through generations, such as canoe construction, trammel, tying, and farming practices are those that are perceived in this community as important for the development of economic practices. Local knowledge related to productive activities, food and plant-based remedies is still transmitted. The knowledge of fishing and agriculture is also transmitted from generation to generation through oral tradition. Water as presented in the chart of associations is stressed by the presence of mercury, increased litter, and livestock.

San Benito Abad community water resilience. In terms of governance, there is a consolidated community organization, and the role of women has been decisive in the association of farmers and fishermen, as well as the community action boards-JAC and civil associations such as ASOPASFU (Association of Fishermen and Farmers of Pasifueres). In the territory, there

are organizations such as Pastoral Social, UNDP, and CORPOMOJANA. In terms of resilience, some families have implemented climate change mitigating fruit orchards with UNDP. In the face of constant flooding, the houses have been adapted, building for it *tambos* or mounds of earth that prevent the water from the pipe to penetrate the homes. The pipes serve as regulators of the waters of the Cauca River and provide fish for their food. They say that in the *zapales* they obtain different edible species such as punch and turtles and that in the area there is also the presence of timber trees, usually used in the construction of houses. In terms of resilience, the residents claim to build "terrified at home, the construction of dams for summertime", they also plant trees far from the houses, to avoid accidents with falls. This is combined with good relationships between neighbors, "because if I don't have something, someone else has it".

Table 2 - San Marcos Timeline

Source	Before	During	After
Community perception	Memories indicate that the problems in the area have been occurring since the decade of the 50s, with floods that affected crops and animals; they assure they did not receive any humanitarian aid. Since the 50s and 60s, vegetation has been declining, mountains have begun to disappear.	In 1984, large-scale flooding was registered, higher than that of 1950, given that the increasing floods occurred in November, when the rice is harvested, resulting in economic and subsistence consequences. It was pointed out that the greatest flood affection took place between 2010 and 2013, given that the area was flooded for more than two years, forcing the community to live in dairy farms.	During the current year, the floods have left disastrous consequences, several trees have been lost and the health of the residents has been affected (headaches, flu, sickness, etc.); without leaving aside the crop loss due to pests.
Newspaper reports and notes	"In San Marcos, the inhabitants indicate that since 1950 disasters add to the strong rains with an increase of 16.1% in relation to the normal conditions in times of winter" (UNDP, 2012). "The deterioration of the ecosystem continued to increase and the flood of 1950 forced the García Márquez family living in Sucre to move to Cartagena" (El Tiempo, 2012).	"In 2010, winter reached enormous levels of social and economic impact. It can be said that this winter is the worst in the last 30 or 50 years." (El Florano, 2011) "In 2010 came the flood, rivers and streams broke their homes with violence. Plants and animals died. The crops were ruined, and the land was contaminated" (El Espectador, 2016).	"In San Marcos, they decree public calamity due to floods. Although it has stopped raining, the rupture of the Cauca River in Colorado (Antioquia) is jeopardizing La Mojana, among the flooded areas are El Torno, El Pital, Las Flores and others" (El Universal, 2017).

Source: Data from Information Analysis Software – Atlas ti. 7.

Table 3 - Water indicators for the development of community resilience in La Mojana, Colombia

Categories	Subcategories	Unit of measure periodicity indicator	Typology	Instrumental Data source	Conceptual description	Reference
Dialogue of knowledge	Conversation between actors	Number of conversations Number of people with memories	Qualitative biographical	Group interviews Timelines Problem tree	No imposition of arguments from each of the parties, seeking to recognize each individual, and their practices	V.M. (2003). Barrera-Bassols, N. (2008), L. and Olivé, L. (2015)
	Conversations on living experience	Number of people of different ages talking	Qualitative Perceptive	Participant Observation Discussion group Timelines Problem tree	All people of various ages, sexes and trades need to formulate their views. For this, the ability to deal with new agreements and provide dimensions and knowledge is required	Valdez, C.J. (2008) Bohm, David (2001)
	Listening to the lack of knowledge	Number of questions to solve from different actors and levels of knowledge	Qualitative Narrative	Projective techniques Assemblies of feelings Problem tree	Uncertainty and ignorance push people into thinking towards action and memories	Boisier, S. (2003) Fals Borda, O. (1988) Freyre, P. (2005)
Weather-related	Water cycle	Number of creeks Number of types of clouds Number of rains per day-per week Number of wells with drinkable water	Qualitative descriptive	Focus group observation In-depth interviews Timelines	Climate change, deforestation and erosion have strong impacts on the water cycle and increased rainfall	Pidwirny, M. (2006) Dingman, S.L. (1994) US EPA (2015)

Table 3 - continued

Categories	Subcategories	Unit of measure periodicity indicator	Typology	Instrumental Data source	Conceptual description	Reference
	Floodings	Number of days-years flooded Number of houses near the river Number of clean canals Number of alarm systems Number of routes prepared for evacuation Number of native trees planted	Qualitative descriptive	Focus group Participant observation Documentary analysis and press Social mapping	Water always maintains its natural dynamics, its meanders, then its forms and cohesion, as well as its floods in a systemic way, any modification increases the risk of floods	Cruz Vergara y Sánchez, 2011 Hernández, Barrios-, Héctor, & Ramírez (2017) Balica, S. (2012)
Governance-related	Citizen participation	Number of participative diagnostics Number of projects done with the community with local authorities Number of people participating in service areas (education, health) Number of communal and social associations and organizations	Qualitative critical	Social dialogue Document analysis Problem tree Participant observation	Considered as a community becoming aware of the issues that slow their development, their critical thinking and the organization of associative forms that facilitate the common good	Whittingham, M. (2005 Ramos, H. (2015). Revesz, B. (2005). Rhodes, R.A.W. (2005)
Ancestral knowledge applied	Good living	Number of medicinal plants Number of edible plants Number of houses with vegetable gardens Number of preserved species Number of activities with reciprocation	Qualitative descriptive	Critical ethnography Timeline Problem tree Participant observation	To live well is to recover the memory of our peoples, their culture, and their life, in harmony with nature, and the cosmos according to a systemic sense	Gudynas, E. (2011), Alaminos, A., and López, B. (2009), Cubillo, P., Hidalgo, A.L., & Domínguez, A. (2014)

Table 3 - continued

Categories	Subcategories	Unit of measure periodicity indicator	Typology	Instrumental Data source	Conceptual description	Reference
	Ancestral technologies against floodings	Number of embankments Number of built tambos Number of grounded houses Number of dams for summertime	Qualitative interpretative	Critical ethnography Timeline Problem tree Participant observation	From a set of alternative technologies, taken up to face the challenges of climate risk, and floods, multiple and varied technological systems have been generated associated with the management and conservation of water, soils, and vegetation	Ibáñez B. Isch, E. Panario Gutiérrez (2020)
	Learning experiences	Number of people that share their experience with the FVI flooding control.	Qualitative interpretative	Critical ethnography Timeline Problem tree Participant observation	In light of uncertainties and new learning about the future, new strategies are designed to be flexible, resilient, able to adapt to changing conditions, multifaceted and with new options	Torres Guevara, J. (2014)
Socio-environmental conflicts	Assessment languages	Number of actors in conflict	Qualitative descriptive	Actors map and in-depth interview	It refers to the different conceptions of territory, nature, and the environment while establishing a dispute about what is understood by development and, more generally, by democracy	Alier, J.M. (2021). Environmentalism of the poor: environmental conflicts and valuation languages. Icaria

Table 3 - continued

Categories	Subcategories	Unit of measure periodicity indicator	Typology	Instrumental Data source	Conceptual description	Reference
	Impacts of extra-activism	Number of days with a strong smell coming from the water Number of days with changes in the color of the water Number of days with the most presence of material being dragged in the river	Qualitative descriptive	Participant observation Calendar	Ext activism is defined as the exploitation of large volumes of natural resources, which are exported as commodities and generate enclave economies (localized, such as oil wells or mines, or spatially extended, such as soybean or palm monoculture)	Staffolani, Claudio, & Cuesta Ramunno, Estibaliz. (2020). Social representations and risk perception in the relationship between environment and health. Implications for regional development in the province of Santa Fe (Argentina). Social Studies Alimentación contemporánea y desarrollo regional magazine, 30(56) Wagner, LS (2014). The paradoxes of extractivism. *NUEVOS CONTEXTOS DE* , 155

The timeline is usually developed with elderly people who have a broad historical notion of the area. The events identified from the community perception will be related and complemented with the journalistic records of the time. For its development, the following stages were taken into account:

- For the analysis of the human-nature relationship, the socio-ecosystem components of resilience, governance and well-being are taken into account. Based on these, it is possible to understand aspects such as the ability to return to a state of equilibrium in socio-ecosystem systems, the management of the territory and the affective bond that the environment produces in society.

- The study of the SSE will be key to the sustainability of the territory, where a balance is established between environmental and socio-economic development. "Socio-ecological systems are based on the idea that the socioeconomic system cannot grow beyond the biophysical limits established by the ecosphere" (Martin López *et al.*, 2012).

It is concluded that the main categories for the elaboration of community water indicators, for the case of La Mojana in Colombia, are a dialogue of knowledge, climate, governance, applied ancestral knowledge and socio-environmental conflicts. The above was developed from a phenomenological qualitative field research triangulated with various flood analysis methodologies of urban rivers.

Conclusions

The three main rivers in Colombia converge in La Mojana (Cauca, San Jorgen, and Magdalena), making this confluence one of the most varied and attractive water systems in the world. Half a million residents out of 11 municipalities from Antioquia, Bolívar, Córdoba, and Sucre live in this complex system. The Adaption Fund demonstrated that between 2008 and 2020, La Mojana has been impacted by 495 hydrometeorological events. Among these, 338 were floodings and flash floods that concluded in thousands of people affected, nearly 76000 deteriorated houses and 1200 destroyed. Studies of this area have a noticeable ecological and environmental trend, but the ones that offer the creation of qualitative indicators are greatly inferior. Regarding community water resilience, this category has been developing in topics related to urban areas, instead of rural lands.

So far, even if there was an increase in the efforts of formulating and implementing public policies, numbers, and data show that there is a need to move forward with articulating solutions with local governments. Regarding qualitative studies that aim to create indicators for cases of community water resilience, this article presents three major scientific advances. Firstly, having

the perception of the residents of the area allows the information collected from the data to move towards the understanding of the collective and individual behaviors, which is essential for the intervention and the forecast of projects that look for the reduction of the damage caused periodically by floods in the region.

Secondly, this article – unlike some qualitative and quantitative studies that result in generalizations – made a thorough effort to collect primary material, in the search of the particularities of each one of the eleven sidewalks, highlighting and strengthening their group identities and their environmental realities.

Finally, a design of indicators was elaborated, aiming to consider the experience of previously successfully applied methodologies about community resilience in vulnerable groups that are permanently exposed to flooding. This design of indicators was also aiming to systematize and apply a variety of qualitative methods, in order to complement and build indicators from a community perception and from a contextual and participatory perspective.

The presented indicators are essentially supported by a knowledge dialogue, applied ancestral wisdom and memory, the socio-environmental conflict, governance and climatology. Each of these categories has a theoretical description and a source of data collection, which combines the collected information by the communities from the communities. In addition, these indicators will provide solutions towards decision-making and the spatial and territorial planning processes.

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