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Article

Participative Policy Design to Manage Droughts And Floods in an Arid Region Under Climate Change Uncertainty: The Case of Baja California Sur, Mexico

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Abstract: Floods can be defined as one of the most frequent and destructive disasters, that cause significant damage to people, while droughts present significant challenges in first place to most vulnerable communities. In consequence, state public policies are essential to manage the risk in the face of both phenomena and contribute to the construction of resilient communities. As a request of the National Water Commission of Mexico (CONAGUA) for the Regional Water Plan (PHR), we designed and applied a methodology based on virtual consultation fora in conjunction with digital survey tools to understand the population's perception of these phenomena. The workshops were organized in the five municipalities of Baja California Sur. Then, we performed an interdisciplinary analysis that combines hydrological considerations with the most critical social, economic, environmental, and law components, applying the PESTEL analysis. The results indicate that there is a clear and widespread awareness that floods and droughts increase the risk to the livelihoods of the population; however, there are deficiencies in different areas, which complicates risk management. Timely information and the inclusion of communities in mitigation and adaptation proposals would allow for achieving more successful cases with the efforts to minimize vulnerabilities and increase the resilience of the population in the face of a changing climate. This must be a collaborative work of the entire society, governmental, social, and private stakeholders.

Keywords: participative policy, drought, floods, risk-management, climate change, resilience, Mexico

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1. Introduction

Floods can be defined as one of the most frequent and destructive disasters, that cause significant damage to people, while droughts present significant challenges in first place to most vulnerable communities. (Zuñiga et al. 2020; Romero-Monteiro et al. 2021; Imaz-Lamadrid et al. 2022). The United Nations Office for Disaster Risk Reduction (UNISDR) and the Centre of Research on the Epidemiology of Disasters (CRED), present the floods as the most frequent disaster for the period 1998–2017, that caused damage to 2.0 billion people, through 104,088 deaths, and socioeconomic impacts of US$ 656 billion (Wallemacq 2018). On world level, we can see an increasing trend in the negative impacts caused by floods, caused mainly by deforestation and performance of more productive activities on territories at risk, global warming, expansion of urban areas, and establishment of irregular settlements in risk areas (Darabi et al. 2019; Ionita et al. 2021; Imaz-Lamadrid et al. 2022).

As for droughts, they only represent 4.8% of disasters worldwide, however, they rank second in terms of the number of affected people, reaching 33%. (Wallemacq 2018). The scenarios of climate change show an expected rise of frequency and intensity of tropical cyclones, which may lead to an increase of floods and more frequent periods of droughts (Kirtman et al 2013; Melillo et al. 2014).

In Baja California Sur (BCS), the climate tends to be dry, semi-warm, and hot in a large part of the territory; especially in the lowlands, while in the mountainous area the climates can range from dry warm-semi-warm (Sierra La Giganta) to temperate in the upper parts of Sierra La Laguna. Average annual precipitation tends to be low, between 100 and 300 mm/year in much of the state, except in Sierra de la Laguna where it reaches up to 600 mm/year (Ivanova-Boncheva and Gámez-Vázquez 2012; Romero-Vadillo and Romero-Vadillo 2016). The greatest rainfall occurs in summer and as a result of the approach of tropical cyclones (Martínez-Gutiérrez and Mayer 2004; Cruz-Falcón et al. 2011; Imaz-Lamadrid et al. 2022), so they are usually short-lived and high intensity (Imaz-Lamadrid et al. 2019). Due to its climatic conditions and geographical position, Baja California Sur is prone to droughts (Troyo-Diéguez et al. 2013)

This climatological duality favors the occurrence of both floods and droughts that affect the population not only in terms of hazard but also from an economic and water consumption perspective. In the 1970s, the Civil Protection culture in Baja California Sur was practically non-existent. It was after the impact of Hurricane Liza; the worst state and national hydrometeorological disaster in terms of deaths, which both society and government agencies began with prevention activities in the face of these phenomena (Farfán et al 2013; Romero-Vadillo and Romero-Vadillo 2016; Imaz-Lamadrid et al. 2022). Subsequently, and because of the 1985 Earthquake in Mexico City, Civil Protection agencies were created and strengthened at the national level, which has helped reduce the impact of disasters (López-Levi and Toscana-Aparicio 2016). Even so, Baja California Sur has historically been vulnerable to the impact of tropical cyclones and floods, which have generated high economic costs (Montaño-Armendáriz et al. 2018; Marín-Monroy et al. 2020; Imaz-Lamadrid et al. 2022).

In case of droughts, the situation is no different. Added to the arid conditions, the management of water resources and the increased demand has led to the overexploitation of aquifers and water shortages for the population, which is exacerbated during dry seasons (Troyo-Diéguez et al. 2014; Cañez-Cota 2015; Wurl et al. 2018; Turrén-Cruz et al. 2019).

In this sense, state public-social policies are essential to manage the risk in the face of both phenomena and contribute to the construction of resilient communities (Lebel 2010; Wurl et al. 2018; Valdivia-Alvarado et al. 2021; Imaz-Lamadrid et al. 2022). In Mexico, there is an instrument known as the Regional Hydrological Program (PHR), which, based on a diagnosis, proposes short- and medium-term actions to address various problems related to water, such as: Guaranteeing water and sanitation services, reducing vulnerability to flooding and droughts, preserve hydrological systems and improve water governance conditions. At the request of the National Water Commission, a methodology is generated to develop a new Water Program for the state of Baja California Sur, considering the participation of different actors and society to define actions in the short and medium term. Our research focuses on the use of the Mentimeter platform as an instrument to promote the participation of the society in the design of public policies focused on reducing vulnerability to floods and droughts in Baja California Sur.

2. Historical Floods and Droughts in Baja California Sur

Baja California Sur is susceptible to floods as a consequence of the approach of tropical cyclones but also to events of drought during the dry season.

In 1976 category 4 Hurricane Liza impacted the southwestern coast of Baja California Sur, generating 425mm/day of rainfall in the surroundings of the city of La Paz. This amount of rain overpasses by 2.5 times the mean annual rainfall (~150mm/year). In those days, the city had a total of 70,000 inhabitants. The disaster occurred when an earth dam broke due to the intense runoffs and generated a flash flood that flowed into downtown killing 600 people and affecting 27,600 (Farfán et al. 2013). According to Cruz-Aguirre (2018), in those days, the city was lacking of technologies to prepare the people for the event, nor was there a civil protection system to manage the danger of the event. These two factors contributed to enhancing the impact of this meteorological phenomenon.

Hurricane Odile in 2014 is considered the most intense cyclonic event making landfall in the history of Baja California Sur, with category 3 on the Saffir-Simpson scale and sustained winds of up to 205 km/h. There were moderate rains that accumulated between 100-365 mm for three days. The accumulated rainfall in San José del Cabo was 265 mm (90% of it in 24 hours) while in stations around it, with elevations of 200-400 m, 320-360 mm were collected (Farfán et al. 2018).

The greatest infrastructure damage was registered in Cabo San Lucas and San José del Cabo, mainly caused by strong winds. The main impacts found were of three types: light roof blasting, impact by projectiles, and partial or total collapses. Damage from the impact of projectiles in this type of meteorological phenomenon is unavoidable. Therefore, in the face of an imminent hurricane warning, it is necessary to try to secure the parts most likely to leave projected to reduce the risk (Muría-Avila et al. 2015).

Finally, 5 municipalities in Baja California Sur, 21 in Sonora, and 1 in Sinaloa received a Declaration of Disaster published in the Official Gazette of the Federation. In the southern portion of Baja California Sur, the electricity service recovered 17 days after the passage of the tropical cyclone. Six deaths were recorded after the occurrence of Odile and it is estimated that the economic losses were 2.5 billion dollars (Muría-Avila et al. 2015).

In addition to these two significant events, several tropical storms and hurricanes of less intensity have had significant rainfall in the region. During tropical storm Lidia in 2017 it was an exceptional record of rainfall with 400 mm per one day at Cabo San Lucas and 159 mm at Sierra la Laguna Station (Figure 1).

Hurricane Olaf in 2021 reached category 2 just before entering the Baja California coast, however, downgraded rapidly to a tropical storm causing strong rainfall and a general impact on the Baja California Sur coast caused by swell.

Baja California Sur does not have rivers or permanent surface water currents, its streams are intermittent currents that carry water exclusively in rainy or winter seasons. For this reason, it's only reliable source of water is groundwater, characterized by aquifers that have been severely overexploited in the region and that are providers of water resources in periods of drought (Z. Flores 1998). Given the enormous importance that water has for the functional cycles of animals and vegetation in a region as arid as the state of Baja California Sur, it is convenient to think of rain as a determining agent when proposing possible modifications to uses of the soil in the study region (Z. Flores et al. 2015).

Even when there is intense rainfall during the summer, the rest of the year the rainfall is null (especially from March to May/June) or of low intensity (from December to February). Troyo-Diéguez et al. (2013) determined that in most of the state (except in the southern part), there are hydro-environmental drought conditions throughout the year, while Álvarez-Morales et al. (2014) define that large portion of the municipalities of Comondú, Mulegé, and La Paz are highly vulnerable to droughts. Llanes-Cárdenas et al. (2015) state that in the municipalities of La Paz, Comondú and Loreto there is an increasing trend in aridity (Table 1).

In July 2022, three BCS municipalities presented conditions of drought (one of them was extreme drought) occupying 60% of the state territory. Recently in 2021, three BCS municipalities registered some type of drought, while in 2007 all BCS municipalities presented some type of drought.

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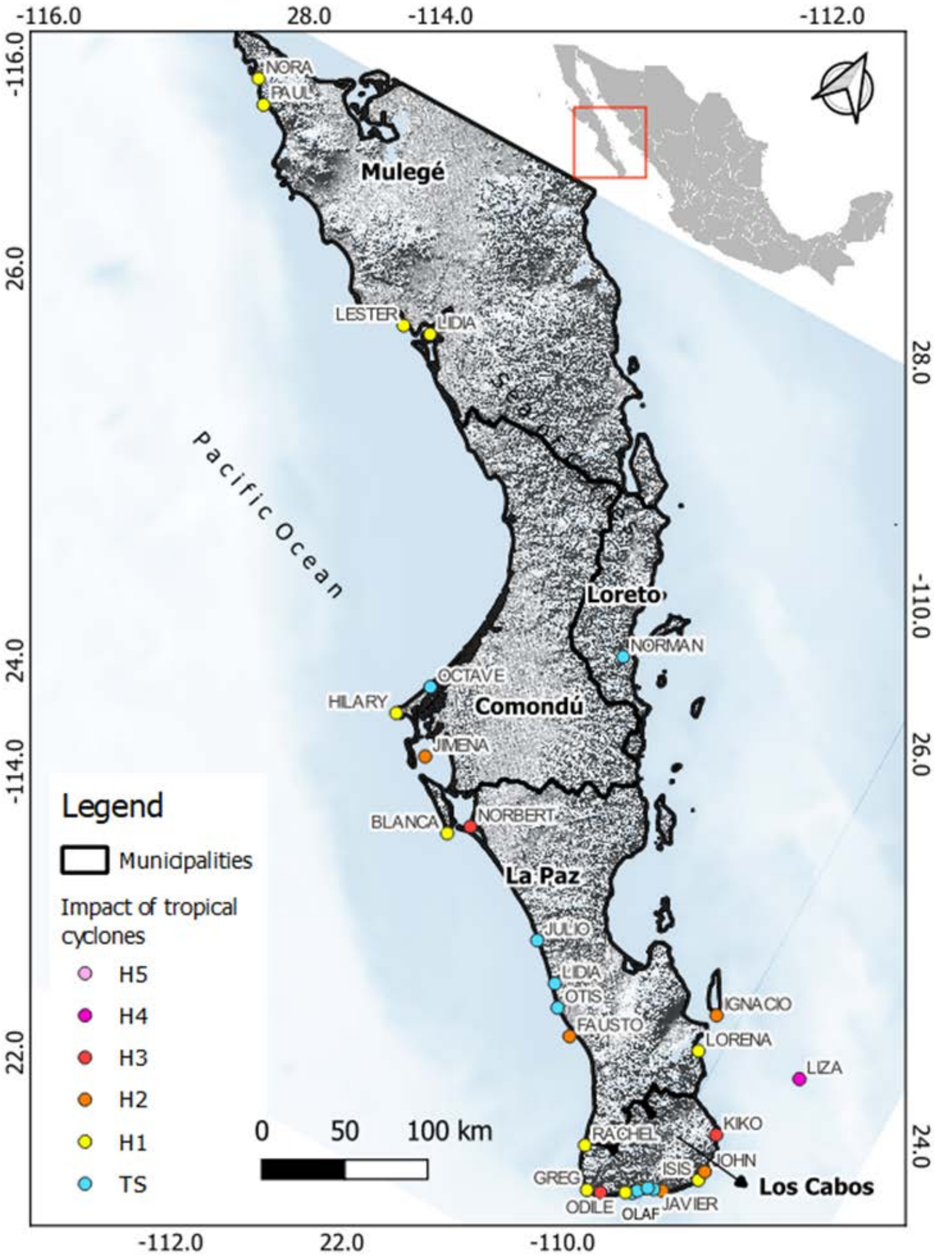

Figure 1. Location map and historical tropical cyclones making landfall from 1976 to 2021.

Table 1. Drought conditions in august from 2004 to 2021 and for each municipality (Elaborated with data from CONAGUA 2022).

Municipality	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Comondú				D2		D1		D2	D0	D0					D0	D0	D0	D2
Mulegé	D0		D1	D2		D1		D0			D0		D0			D0	D0	D1
La Paz				D2		D1	D0	D2	D0						D0	D0	D0	
Los Cabos		D0		D2		D1	D0	D2	D1									
Loreto				D2		D1	D0	D2							D0		D0	D2

Notes: Gray=no drought, D0=Anomalous dry, D1=Moderate drought, D2=Severe Drought

2.2 Climate change scenarios

Changes in temperature

Temperature is expected to increase globally. According to CEPAL (2020) in Baja California Sur temperature will increase in a range of 1.2 (RCP 4.5) to 2.0°C (RCP 8.5). Arreguín-Cortés et al. (2015) proposed an increase of maximum temperatures in a range of 1.0 (RCP 4.5) to 1.4°C (RCP 8.5). Considering the historic maximum temperatures recorded by the National Meteorological Survey (SMN), in the northern portion of the state temperatures may reach 52°C, and between 45 and 50°C in the southern portion.

Changes in precipitation patterns

Circulation models and climate change scenarios on global and regional level predict changes in rainfall patterns for Baja California Sur. According to Kirtman et al. (2013), the forecasted changes in global weather patterns show an increase in precipitation in the equator and high latitudes and a decrease in arid zones and subtropical areas. These patterns are called wet-gets-wetter and dry-get-dryer. In this context, Baja California Sur, especially its northern portion, will suffer a decrease in precipitation in a range of -10 to -35%, depending on the RCP scenario (Kirtman et al 2013; Melillo et al. 2014; Arreguín-Cortés et al. 2015; Cook et al. 2018; CEPAL, 2020). In southern portion, situation is expected to be different as tropical cyclones may be more frequent and intense during summer because of an increase in temperature in the Pacific Ocean. (Romero-Vadillo and Romero-Vadillo (2012). Therefore, runoffs are expected to increase up to 10% by the year 2040 (Kirtman, et al. 2013; CEPAL 2020); however, winter rains could be less frequent. (Imaz-Lamadrid et al. 2019). In the long term there is a high variability in the forecasts depending on the models and RCP scenarios. In this context and according to CEPAL (2020), the impact of tropical cyclones could be reduced by 2080 under the RCP 8.5 scenario, which would imply an increase of drought.

Sea Level Rise

Worldwide sea-level rise is predicted in a range from 0.16 to 1.9m for the year 2100, according to different RCP scenarios (Vermeer and Rahmstorf, 2009; Church et al. 2013). This increase together with the strengthening of tropical cyclones could generate more intense storm surges in the short-mid-term (Melillo et al. 2014). It is expected that sea-level rise will impact several communities in the state. Considering the scenarios of intensification of tropical cyclones, and sea-level rise, storm surges in the state could be more destructive in the coming years.

2.3. Instrumentation and early warning

The hydro-climatological networks are made up of a set of hydrometric and climatological observations and the infrastructure necessary for their operation (monitoring stations, equipment, personnel, and collection centers). The purpose of an operational and sustainable hydro-climatological network over time includes the use of water resources for water supply, electricity generation, aquaculture, navigation and recreation, control of floods in rivers and streams, studies of the deformation of riverbeds, sediment transport, and hydrological forecast.

It is from 2010 that the meteorological records show a pronounced drop in Mexico, due to the increase in inoperative weather stations and the delay in updating the databases, mainly from the information coming from stations located in areas of difficult access and roads of restricted communication (Brito-Castillo 2020).

Baja California Sur has 165 weather stations, of which 30 are inoperative. To date, the Baja California peninsula does not have any operational hydrometric station that records and monitors the flow of streams. This panorama hinders the calibration and validation processes in the processing of the hydrological models of the region.

The territory of Baja California Sur has a high level of risk due to threats from tropical cyclones and the vulnerability of its buildings. Its geographical and climatological conditions favor the impact of tropical cyclones, which bring with them strong winds and floods derived from both intense rains and storm surges. Timely and organized prevention actions reduce damage significantly. For this reason, it is important to know the risk in a population to establish the most appropriate measures (Romero-Vadillo and Romero-Vadillo 2016).

3. Methods

The strategies, actions, and projects to affront the impacts of floods and drought were developed based on the outcome of the five Participatory Community Workshops (PCW) held during 2021-2022 with representatives from the municipalities of BCS. These are Comondú, Los Cabos, Guerrero Negro, La Paz, Loreto, and Mulege (178 participants). Additionally, one Workshop with Experts on the topic (34 participants), was performed, to validate the main outcomes of the PCWs

The objective of the PCWs was to collect the opinions and comments of each municipality inhabitants to enrich and further specify the strategies and lines of action of each Strategic Objective. In each workshop participated social groups, main stakeholders, and government agencies (on municipal, state and federal level) that would be responsible for the implementation and monitoring of the proposed actions (Zorrilla and Kuhlmann 2015). Other participants were non-governmental organizations, producer associations (ranchers, fishermen, farmers), and educational institutions.

The participation is understood as local inhabitants' involvement in design, implementation, and monitoring of a strategy or project (Brown and Wyckoff-Baird 1992). The procedures and methods implemented in the consultation process were aimed to inform and gather the opinions of the communities that will be involved in the implementation of the actions. Thus the local inhabitants can perform as active agents of the process (IAP 2007).

The PCWs were collecting individual comments, but also the opinions of communities' representatives, NGOs and other interest groups that represent collective input.

The process of the PCWs was oriented to value diverse opinions, prioritizing the minorities and vulnerable groups (women, youth, etc.). The participative policy design was based on the following key principles (IFC 2007):

- Providing information on the topic in a language readily understandable and through accessible means to the stakeholder participants,
- Providing data on the current situation and expected scenarios in advance of the PCWs.
- Respect for local traditions, local knowledge, and communities 'decision-making processes,

Participative policy design is important to address complex decisions, taking into account specific local data, different views and interests. This provides an opportunity policy makers to address different sides of an issue. The inclusion of multiple interests turns community members into active agents during the implementation and monitoring of the policies, thus making the process more (Yee 2010).

The stakeholders in the design of policies and strategies to manage floods and droughts was categorized into the following types: government agencies, agriculture representatives, academic institutions, special interest groups, local community representatives, and non-governmental organizations (NGOs).

The methods of engagement employed played a significant role in determining objectives and indicators of the project success. The public participation methods used to engage with stakeholders in our project were the following:

- Public virtual meetings offered the opportunity to the participants in the consulting process to express their point of view and give recommendations. At the beginning of the PCWs a brief assessment of the topic to discuss was presented. Next, the participants provided their input: 1) responding some questions about the topic via Mentimeter, an Audience Engagement Platform that transforms any presentation into an interactive and engaging experience, and 2) speaking from the floor to express their opinions and/or ask questions.
- Additionally were applied surveys were applied to key stakeholders to complement the information, and to build a profile of the groups and individuals involved. These helped focus the public attention on some very important specific issues.

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Workshop attendees were organized into five working groups according to the strategic objectives of the PCWs, and assisted by a facilitator (member of the research team) and a rapporteur: (1) Water and human rights, (2) Water and productive sectors (3) Floods and droughts, (4) Watershed Management, and (5) Governance.

The discussion took place in two stages:

(a) Stage I. The participants responded to the following twelve key questions on hurricanes and drought.

1. Do you consider you could be affected by a flood?

2. Do you consider that the protection works (dams, canalization, embankments) installed in your locality are sufficient?

3. Do you feel safe before the arrival of tropical cyclones in the entity?

4. Do you consider that climate change increase drought and intensity of tropical cyclones?

5. Do you consider that the riverbeds and risk areas are strictly delimited?

6. Have you experienced an early warning system of a hydro-meteorological event that suggests changing your location?

7. Are you aware of the implementation of a program against drought in your area and what activities are being carried out?

8. Do you consider that the coordination between government and sectors of the population is good to deal with climate emergencies?

9. Do you know about the implementation of a drought-related program in your municipality?

10. Do you consider that an Official Hydrological Forecast would be useful to alert the population to the increase of water level in streams?

11. Do drought events usually affect you directly? (Economically, logistically, hydrologically)

12. Have you used an early alert system during and hydrometeorological event, which may lead you to relocate?

13. How frequently do you check the weather conditions during hurricane season?

14. How do you consider the analysis of floods and droughts presented in the Atlas of Risks and Natural Hazards of the Municipality of La Paz (2012)?

15. Write "one or two words" that summarize a solution to the flood and drought control problem.

At this stage, the impacts of extremes and climate change were identified by the assistants (e.g., drought, flooding, sea level rise, etc.). Then the consequences of the impact were defined (e.g., drought affects crops, sea level rise affects the coastal infrastructure, etc.).

Questions were formulated by Mentimeter and the assistants responded by their cell phones. Next, the results of the answers were processed by Mentimeter and organized in tables, graphs, and word clouds.

(b) Stage II. Discussion of results identified in stage I. The answers were presented in plenary and discussed. The strategies and actions to affront floods and droughts were designed by consensus. The main criteria for the discussion were the following:

- Importance for the community safety
- Inclusion of vulnerable groups
- Generation of resilience to floods and droughts
- Food safety
- Contribution to water security
- Involvement of local community members
- Financial and technological support by government and/or NGOs

Some other factors can impact the performance of the policies and strategies, such as technological innovations and new management options. Their role should be discussed and analyzed (Márquez-Salaices 2017).

A PESTEL analysis is a framework or tool used to analyze and monitor the macro-environmental factors. PESTEL is an acronym for Political, Economic, Social, Technological, Environmental, and Legal. We combine this with another analytical tool, the SWOT analysis to identify potential Strengths, Weaknesses, Opportunities, and Threats to the policy designed. Next, we characterize each factor.

- Political Factors: We take into account government participation in strategies design and implementation. The variable are government support in financing and capacity building, as well as subsidies.

- Economic Factors: In our study the economic factors include the productive activities affected by floods and droughts, and influencing the economy performance and the lifestyles of communities.

- Social Factors: We explore the social ecosystems, including community perception and willingness to affront the impacts of floods and droughts Variables include vulnerability, traditional knowledge, cultural trends and participation of inhabitants in design and performance of policies.

- Technological Factors: We consider new technologies that could enhance the strategies and action in face of risk of floods and droughts. Variables include changes in irrigation and water saving technology, hurricane early warning, innovation and implementation.

- Environmental Factors: We explore the environmental influence at present and future. Variables include climate change impacts, scenarios for sea level rise and hurricanes, and specific conditions of an arid region.

- Legal Factors: The policy design should consider the existing regulations. The changes proposed in legislation must contribute to the policy performance. Factors include environmental, health and safety regulations. Additionally, national and international legislation must be considered.

- Political factors include fiscal policies, financial support and subsidies.

The results present some strategies, actions, and projects to deal with the identified problems. These results and discussion are delivered in the next sections.

4. Results

4.1. Perception of the local community on floods and droughts

As a result of the PCWs, the participants expressed their opinions about the problems faced by the state of Baja California Sur in terms of floods and droughts.

In general, most of those surveyed participants expressed vulnerability to floods and droughts in Baja California Sur. In detail, 68% said they felt at risk of being affected by a tropical cyclone, while 69% considered it very likely to be affected by a flood. The municipality with the highest perception of security was La Paz, while Mulegé was the one perceived as the most vulnerable.

In the case of floods, the participants consider that tropical cyclones and floods are the most dangerous phenomenon in the state. In this context, there are several aspects to be addressed for the improvement of resilience. Firstly, participants emphasized the need for more high-quality studies to quantify the risk of flooding and its components (hazard, vulnerability, and exposure). This arises from various problems founded in the Atlas of Municipal Natural Hazards and Risks (ARPNM), which are instruments promoted by the government, to reduce the impact of natural phenomena on society. Among these problems, the following stand out: a) Inadequate methodologies for determining the risk, b) Resolution of the mapping, c) Carrying it out by technicians and companies that lack knowledge about the local behavior of the natural phenomena, d) Lack of updating, and e) Complicated accessibility for the population. In this context, 89% of the participants mention that each Municipality must have an updated ARPNM, while 18% were unaware of the existence of the ARPNM.

Related to the above, the participants mentioned the need to improve the climatological monitoring network. In the state, there are only 10 automated stations (EMAS), and a limited number of conventional meteorological stations (CMS). The operation and management of the CMS also complicate access to updated data. In the hydrological context, there is no automated monitoring network for floods, which complicates the prevention of incidents and the calibration of models for the delimitation of hazardous areas.

In the context of management and infrastructure, 80% of those surveyed consider that hydraulic infrastructure (retention and infiltration dams, canalizations, embankments, and dikes) is insufficient. Regarding delimitation of streams, 94% judge that it is inadequate, a situation that complicates risk management. Regarding the coordination between government orders and society, 66% mention that it is unsuitable and insufficient.

As for droughts, the population feels vulnerable to water shortages due to the overexploitation of aquifers. In this sense, 67% of the population considers that droughts generate a socio-economic impact and 77% are unaware of government programs against it. Finally, 85% of those surveyed consider that climate change is influencing the intensification of floods and droughts in the state.

4.2. Results of the PESTEL analysis: human resilience against drought and floods.

As mentioned above, due to its geographical conditions, Baja California Sur is highly susceptible to be affected by droughts and floods. The results of the forum indicate that actions have been carried out at the state and municipal levels to limit the effects of droughts and floods, however they have been insufficient. Table 2 presents the main results of the PCWs and shows the: Strengths, Weaknesses, Opportunities and Threats, according to the performed PESTEL analysis.

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Table 2. Human resilience against droughts and floods. Results from PESTEL analysis.

Internal factors	
Strengths (+)	**Weaknesses (-)**
Political	**Political**
_ Organized action of farmers to manage and maintain the irrigation infrastructure. _ The stakeholders see the necessary implementation of alternative economic activities in the face of insufficient water availability. _ The agricultural producers have agreements to reduce the use of water since 1990s- _ University and technological institutes offer educational programs in agriculture of arid zones, water management and disaster protection.	_ Deficient method to define aquifers´´ recharge. Only the water level is considered, even if it is saline or polluted. _ Deficient aquifers´ level monitoring: sporadic, obsolete equipment, lack of resources. _ Deficient management of aquifers: instead of encouraging water saving, if concessions is not fully used, the user's right is annulled. _ Lack of strategies for water saving
Economic-financial	**Economic-financial**
_Competition between economic sectors (agriculture, tourism, real estate). _ Community participation in agencies with access to financial resources.	_ Inefficient management of the hydraulic infrastructure. _ Inefficient use of technology and financial resources because of the week community´s organization.
Socio-cultural	**Socio-cultural**
_ Population identified with agricultural activities (Municipalities Comondú and Mulegé) _ Some producers have a water management culture. _ Significant number of inhabitants is supporting the need of efficient water management. _ Existence of water-saving technologies that the farmers are willing to use.	_ Lack of water culture _Sewage discharge to streams and wetlands. _ Planting crops with high water consumption
Technological	**Technological**
_ There is water exchange between agricultural farms. _ Existence of small primary water treatment plants and secondary water treatment plants for sewage water	_ Insufficient hydraulic infrastructure _Inadequate measurement on micro-and macro level _Leaks in the distribution system.

_The big hotels own proper desalination plants.	_Lack of instrumentation and control
_ Existence of some hydraulic infrastructure	_ Under-utilization of irrigation technologies
Environmental	**Environmental**
_The water supply relies only on subterranean aquifers	_ Different periodical aquifer recharge
	_ Poor water quality due to saline intrusion, pollution by fertilizers, etc.
Legal	**Legal**
_ Law of Waters of the State of Baja California Sur	_ Legal standards contain obsolete methods of estimating groundwater availability.
_ Sustainable Rural Development Law of Baja California Sur	_ Insufficient regulation for water management.
_ Law of Ecological Balance and Environmental Protection of the State of Baja California Sur	_Insufficient fines for exceeding the permitted volume of water extraction from aquifers.
EXTERNAL FACTORS	
Opportunities (+)	**Threats (-)**
Political	**Political**
_Regional Program on Water Management of the Baja California Peninsula, CONAGUA, 2022.	_Some federal programs do not consider the local specificities in the subsidies programs.
_Institutional and political concern for environmental protection and water savings.	_The federal government canceled the funds supporting recovery after disasters (cyclones, floods, and droughts).
Economic-financial	**Economic-financial**
_ Existence of financing sources for water-saving technologies	_ High prices of new technologies
	_ Subsidies for crops with high water consumption
_Possibility to access green climate funds for water saving actions and technologies.	_ Difficult access to financing (high interest rates, collateral requirements).
Socio-cultural	**Socio-cultural**
_ Existence of environmental education and capacity building for the communities.	_ Lack of interest in training, although there are options (state university, NGOs, etc.).

_ Availability of professional technical training for farmers. _ Entrepreneurship in sustainable management of water in some sectors (agriculture, tourism). _ Successful experiences in efficient use of water	
Environmental _Great quantities of rainwater brought by cyclones could be stored to avoid droughts	**Technological** _Insufficient implementation of innovative technologies _Lack of actions for water harvesting.
Legal _Law of National Waters of Mexico: regulates the exploitation, distribution and control, as well as the preservation of these waters, to achieve a sustainable development. _ Federal Law on Water Rights _ General Law of Ecological Balance and Environmental Protection _ General Law for Sustainable Forestry Development _Legislation for environmental protection and water savings	**Environmental** _ Drought increase _ Flood threats _Saline intrusion into aquifers _ Tropical cyclones affect infrastructure. _Short and medium time climate change effects **Legal** _ Lack of regulation of non-local investment in agriculture _Lack of regulation of water use by tourism developments.

4. Discussion

For the last decades and as a result of several disasters and water scarcity in Mexico, civil protection, disaster prevention strategies, and water policies have been considerably strengthened. The government (at different levels) in coordination with academic institutions and organizations has contributed to promote laws, regulations and actions aiming to reinforce the safety of society against floods and droughts following international environmental protocols as Sendai and Hyogo Protocols, and Sustainable Development actions. In terms of floods, since Hurricane Liza in 1976, the rate of deaths has decreased; however, society expressed in the forums that they do not feel safe against these meteorological events. Furthermore, they consider that the actions taken by the government and institutions have been in insufficient and inadequate. This can be explained by the fact that tropical cyclones generate important affectations, especially in marginal and low-income areas, where vulnerability and exposure are high. Some of these areas are irregular settlements in which houses are built using recycled materials, a situation that clearly contributes to increasing the risk.

Regarding droughts, people in Baja California Sur are aware about the reduced precipitation and the scarcity of water for consumption because of the overexploitation of aquifers. There is also a growing culture about water care; however, they do not monitor drought as such and are equally unaware of the programs that the government implements. Water scarcity and pollution have been major issues in Baja California Sur. Several important cities (e.g. La Paz, Cabo San Lucas) have limited access to fresh water (2 or 3 days a week), with some areas where it is received only once in several days, or even must be supplied by a water truck. Drought events tend to complicate the situation. Water scarcity and aquifers overexploitation has been assessed for several decades by researchers from academic institutions, non-profit organizations, companies, and society in general. Although several proposals have been suggested, just a few have been implemented. Society demands water in quality and quantity obtained through sustainable pathways; however, the government and sections of the private sector are in favor of the installation of large-scale desalinization plants.

Land use planning actions are needed to ensure that the population is not invading high-risk areas (flood plains, riverbanks, among others), and to avoid the destruction of coastal and inland wetlands that may contribute to reducing exposure to coastal hazards (mangroves and coastal lagoons), and to protect sources of freshwater (oases). In this context, a delineation of irregular human settlements must be performed to generate a plan of relocation. The improvement of landfills is essential to reduce pollution during intense runoff events. The protection of mangroves and oases must increase by modifying existing policies since touristic and real state infrastructure are invading these areas, especially in the south of the state.

In the matter of infrastructure, monitoring equipment must be updated, and runoff meters must be installed to get more detailed data that can be used to calibrate existing runoff and climatologic models in the region. Large dams may help to reduce the flow of water during intense rainfall events and as a reservoir of fresh water. Small recharge dams can be installed in the streams to reduce the power of the runoffs and to store water that can be infiltrated naturally into the aquifer.

More investigation is required as society considers there are lacks information and a need for more meteorological and hydrometeorological data. As the ARPNM are produced, they are not useful since they present information that is not highly detailed, obtained with unclear methodologies, and with a scale that does not allow decision-making. Furthermore, they were developed by private companies from other states without knowledge of the specific characteristics of the area, and necessary preparation to deal with these issues. Researchers and professionals from academic institutions must be responsible for the elaboration of the ARPNM using state-of-the-art methodologies and looking for strategies to make results easily accessible and suitable for decision making.

Finally, it is necessary to invest in a culture related to prevention and risk mitigation. This can be achieved raising awareness among the importance of earth sciences in high school and college, comprehensive risk management, preventive measures at home, work, and public spaces regarding the approach of tropical cyclones and water care.

5. Conclusions

This study performed an interdisciplinary analysis that combines hydrological considerations with the most important social, economic, environmental and law components, applying the PESTEL analysis. After the definition of the main hydrological components and future climate change impacts, and the conducting of the PCWs, we performed the PESTEL analysis. This is based on field research, results of the workshops and interviews applied to key stakeholders. The community comments were gathered, respecting local knowledge and specific experience, and including them in the policy design to tackle floods and droughts.

To strengthen attention to water-related emergencies, a water policy committed to comprehensive risk management is required, that´s why the Regional Hydrological Program (PHR) will strengthen hydrological and meteorological information systems, through the modernization of the measurement infrastructure and observation. It is also planned to improve the reliability and timeliness of weather forecasts by applying new technologies and promoting the exchange of sectoral information with society.

The water resources must be managed under more difficult conditions related to the climate and with a long-term preventive vision, which allows for reducing the risk of floods and droughts while reducing vulnerability and building adaptation capacities in the face of climate change. That is why the PHR will focus efforts to delimit channels and water bodies of national property and federal zones, strengthen early warning systems, as well as the prevention and mitigation actions in case of emergencies due to hydro-meteorological phenomena, as a priority in highly marginalized municipalities.

One of the main conclusions is that the agenda of hydrological programs, focused on the water resource, the risks associated with climate change, and extreme events may be more efficient, with the support and participation of the local population. The opinions and perceptions of the inhabitants, reflected in this study, show that: a) there is a clear and widespread awareness that floods and droughts are an important risk to the livelihoods of the population, and b) the society of the state of Baja California Sur has the best will to affront the negative impacts. Timely information and the inclusion of communities will contribute to achieve a greater success of the efforts to minimize vulnerabilities and increase the resilience of the population in the face of expected phenomena. In this sense is crucial the collaboration of the entire society, governmental, social and private stakeholders.

The results of this study help to produce strategies to prevent socio-economic loss and promote better flood and drought management. The active participation by local actors in the policy design, guarantees their future involvement in implementation and monitoring of strategies and remediation actions. Thus, the participative policy design is strengthening resilience and reducing the impacts of extreme events, and, consequently, improving the living conditions of the population.

Author Contributions:

Miguel Angel Imaz-Lamadrid: conceived and designed the analysis, and drafted the article.

Antonina Ivanova-Boncheva: data analysis and interpretation; contributed PESTEL analysis tool;

Maria Z-Flores: data collection; critical revision of the article,

Mara Yadira Cortes-Martinez: workshops organization; critical revision of the article

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