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RISK MANAGEMENT AS AN ENVIRONMENTAL DETERMINANT: CASE STUDY IN THE VILLAGE OF EL PLAYÓN BAJO SINÚ (CÓRDOBA, COLOMBIA).

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Abstract

Floods are among the most frequent natural hazards and their management is a fundamental task when planning solutions to reduce their impact on communities. Hence, risk management is considered an environmental determinant, primarily in areas where proximity to bodies of water can generate some type of disaster for the surrounding population. The objective of the research was focused on structuring guidelines for the incorporation of risk management as an environmental determinant in the El Playón village in the department of Córdoba-Colombia. For its development, it was necessary to collect both primary and secondary information, results that were the basis for the application of the driving forces (DPSEEA) model, a method capable of identifying "the relationships between environmental conditions and health" through six categories. The results suggest that the applied model allows providing information that can be adapted to any type of scenario, as the indicators may vary depending on the evaluators. This research is a foundational document when generating proposals regarding the strengthening of communities in the face of flood problems, scenarios that can put their lives at risk.

***Keywords**: Risk; Environmental determinant; Driving force model*

Introduction

Globally, concerns about environmental hazards and risks due to global climate change, characterized by their high frequency, duration and intensity [1, 2], have become a significant concern in the international arena, as stated by the 2005 World Conference on Disaster Reduction (WCDR) in Kobe, Japan, the Sendai Framework for Disaster Risk Reduction 2015-2030, the Rio+20 World Conference in 2012 and the Intergovernmental Panel on Climate Change (IPCC) (IPCC) [3, 4], due to the importance of ecosystems for human survival [5].

It is therefore essential to integrate risk management with land-use planning [6–8] which can be categorized as an environmental determinant (superior hierarchy rules within territorial planning).

Among the phenomena generated by climate change are droughts [9], rising sea levels [10], heat waves and floods, the latter of which are complex natural threats [11, 12], resulting

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from the interaction between extreme hydrometeorological phenomena, geomorphological predisposition and anthropic susceptibility and are categorized as one of the most frequent, costly and deadly natural disasters in the world [13–16], exerting enormous influence on human life and health, erosion of riverbanks [17], loss of crops, livestock, infrastructure [10] and deterioration in the natural functioning of ecosystems [18]. Recently, the world has experienced serious flooding disasters, which caused around 7 million deaths worldwide in the 20th century [19], with mortality of up to 20,000 people per year and displaced people reaching approximately 25 million, representing approximately 1/5 of global losses [20], with losses estimated to reach $52 billion by 2050 [21]. Indeed, the risk of flood disasters will increase, with no doubts about the human influence on present and future climate [22], generated by the exponential population growth, land use change and other systemic transitions [12, 23]. Colombia is one of the three most vulnerable Latin American countries to the phenomenon of climate change due to its geographic location, as demonstrated by the impact of the La Niña event in 2011 [24]. The department of Cordoba is not exempt from this problem, as 28% of its territory is located in high-risk areas, with most of the risk caused by periodic flooding exacerbated by the La Niña climatological event, totaling more than 295,731 flooded hectares, mainly in the Sinú and San Jorge River basins.

Recent evidence on the matter suggests that environmental risk assessment has been recognized since 1970. According to the National Academy of Sciences (NAS), risk assessment methods consist of four stages: identification, evaluation of metrological response, exposure assessment and risk description [25]. Various methods have been implemented for risk assessment, such as multi-criteria decision-making (MCDM) [26], [27], analytic hierarchy process (AHP) [28], or cumulative cost-benefit analysis (ACBA) [29]. Through these methods, environmental risk, receptors, risk sources, uncertainty and driving factors have been identified [30]. However, there is no recognized standard for its evaluation [31] and although flood risk management has improved in recent decades, little is known about the impacts of floods on human health due to being ignored or underestimated in recent decades [32]. Moreover, adequate public policies that contribute to disaster risk reduction, especially in the most exposed and socially vulnerable regions to threats such as Latin America and the Caribbean, are still lacking [33]. Another point to consider is that community participation is crucial in risk-related issues for the preparation and resilience of adverse events [34], promoting not only transparency and democratic decision-making [35], but also the adoption of decisions taken by official risk management institutions.

In Colombia, the driving force model interconnects environmental factors and health impacts. Typically, structural actions should focus on driving forces and the pressures that cause environmental deterioration [36]. This methodology has been employed in cases associated with pesticides, water-related diseases, climate change and air pollution caused by particulate matter [37]. Despite the importance of risk-related issues, knowledge is still incipient in the department of Córdoba, hence the relevance of this study towards adequate risk management in territorial planning using the driving force model as a method. The objective of the research was to structure guidelines for incorporating risk management as an environmental determinant, using the case study of the El Playón village, Bajo Sinú (Córdoba, Colombia). Flood risk studies generate valuable inputs to contribute to flood resilience plans for communities in flood-prone regions [38].

Experimental part

Selection of the area of study

The Playón is a village in the municipality of Lorica (Fig. 1), in the department of Cordoba, located at coordinates 2574852.301m (N) and 4690289.982m (E), on the left bank of the Sinú River. It is located in the Caribbean hydrographic zone, Sinú zone and Sinú sub-zone [39]. It has an approximate area of 8.26 hectares and can accommodate 143 families, for a total of 488 people [40].

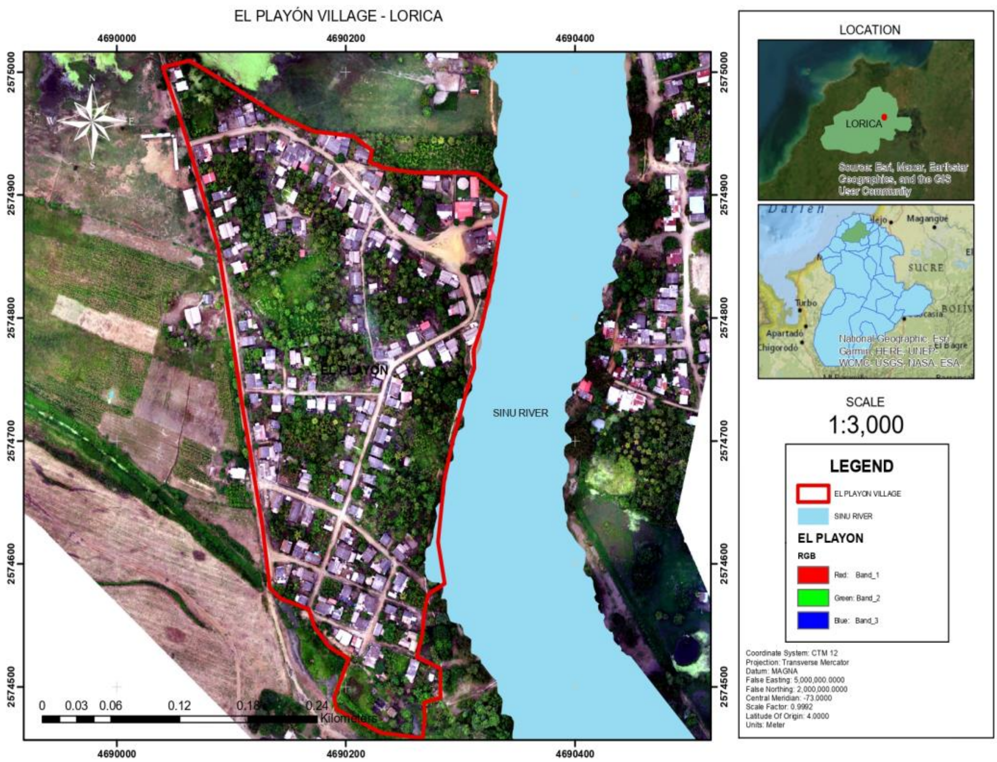

Fig. 1. Location of area of study

The climate is warm tropical with a semi-humid regime, with an average annual temperature of 27°C and peaks exceeding 40°C in some months of the year, with daily variations of up to 10°C [41]. Geomorphology is of an alluvial plain type, with fine and medium-textured soils that are susceptible to frequent flooding and waterlogging, with imperfect or very poor natural drainage. The tree cover is represented by oak, polvillo, camajon, guamo cedar, almond, guayacán, custard apple, fruit trees such as orange, tangerine, mango, coconut palm, corozo palm, as well as shrubs and bushes. The main socioeconomic activities are fishing, livestock and subsistence farming.

Data collection

The research design of the study was primarily based on structured closed-ended surveys, as well as the search for documents and online sources such as environmental regulations established by the Ministry of Environment and Sustainable Development, in order to identify the environmental determinants in the study area. To ensure the inclusion of environmental factors and their impact on land use decisions, it was essential to verify the inclusion of strategic areas and ecosystems defined in the Technical Guide for the Development of Planning and Management of Watersheds of the POMCA at the basin level, participation in territorial planning categories and the impact of this stage (determinant of the environment) on territorial plans.

Driving forces model and application

The review and previous analysis served as a basis for the development of the Driving Forces-Pressure-State-Exposure-Effect-Action (DPSEEA) Model proposed by Carlos Corvalán and promoted by WHO/PAHO, in order to analyze the causal network of environmental factors that have negative effects on human health, facilitating the definition and prioritization of actions by category: drivers, pressures, state, exposure and effects. The categories proposed in the DPSEEA model are represented in figure 2.

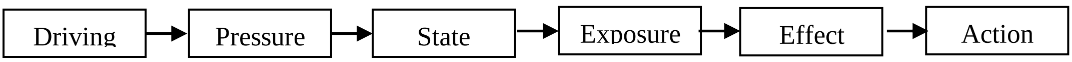

Fig. 2. DPSEEA model categories [25]

The DPSEEA methodology allows the identification, through six categories of "the relationships between environmental conditions and health." Driving forces are the driving factors that directly affect environmental conditions and can be structural, social, or demographic in nature. Common examples of driving forces include population size and composition, resource use and levels of education (per capita income, population size, or household energy consumption) [42]. Pressure refers to both anthropogenic and natural manifestations generated by driving forces. State refers to the conditions and quality of the environment generated by pressure. Exposure refers to the way in which an environmental risk comes into contact with humans, whether through breathing, hydration, nutrition, or skin contact; it also takes into account the frequency and intensity of contact. Effect refers to the consequences for the health of the population. Actions refer to interventions to mitigate or correct damage [43].

To apply the methodology, it was necessary to define one of the aforementioned categories as the entry point into the model, allowing for analysis of the environmental health event of interest. Similarly, the DPSEEA methodology required five moments or stages for its development, as mentioned in Table 1.

Table 1. Stages for the application of the DPSEEA model

Stage I	Identification of the environmental health event of interest
Stage II	Identification of indicators
Stage III	Preparation of the technical sheet for indicators
Stage IV	Information analysis
Stage V	Preparation of the Action Plan

Calculation of the population sample and survey design

To carry out Stage IV of the DPSEEA model, a sample of the population located in flood-prone areas of the study area was required. For this, random sampling was employed, a type of probabilistic method in which all individuals are completely selected at random and each one has an equal probability of being chosen [44–47]. Its calculation was developed from equation 1.

$$\text{Sample size} = (Z^2 * p(1-p)/e^2)/(1+Z^2 * p(1-p)/e^2 N) \qquad (1)$$

where: N - population size; e - margin of error (expressed as a decimal percentage); p - percentage value (as a decimal); Z - z-score, which is the number of standard deviations that a particular proportion deviates from the mean. Its values are tabulated according to the desired level of confidence. As a result, 80 households were sampled in this study, with a margin of error of 7%.

The direct questionnaire to the community, through the development of characterization and territory recognition sheets, was structured in four blocks: General Information, Social Characteristics (identifying how the households are composed), Housing Condition, Health Component and Institutional Component (Training on risk topics - Interest in participating in risk prevention campaigns, Emergency Response Organizations present in the neighborhood, Existence or absence of a community emergency response plan, Presence of temporary shelters for emergency response). This form was created based on experiences during visits made to the community, together with questions resulting from a monograph produced from this research.

Results and discussion

The DPSEEA methodology was developed with the aim of organizing information, guiding, prioritizing and implementing intersectoral actions to impact the determinants of social, environmental, health and economic well-being of the population. Finally, environmental guidelines were developed for the incorporation of risk management in territorial planning.

The selected event of interest was "Health impacts due to slow flood scenarios in the population of El Playón village" and the effect category was defined as the entry point for the model application. Previous research has shown that only the severity of floods had a statistically significant effect on public health problems, both directly and indirectly [48, 49]. The more disastrous a flood situation becomes; the more serious the public health problems will be. On the other hand, if flood situations are less disastrous, public health problems are also less severe, depending on the magnitude or not, the consequences on the physical state [50] have been widely recognized in the literature [51, 52]. The negative relationship between these phenomena and the economic situation of households is evidenced in high costs [53, 54] in communities with few resources, especially in developing countries.

After applying each of the five stages proposed in the DPSEEA methodology, it was determined that stage I, corresponding to the identification of the environmental health event of interest, was the threatening phenomenon of flooding, often caused by the overflowing of the water body, as reported by most studies [55, 56]. However, there are others who attribute local rains as the main source and cause of floods [57]. According to the population, the last flood occurred during the intense rainy season in 2017 and although the town has some areas where the threat does not impact severely, the population affected by this situation corresponds to the total population of the village, affecting not only the dynamics of the water body but also the non-material benefits that people obtain from ecosystems in the form of spiritual enrichment, recreational activities and aesthetic experiences [5, 58]. Flood conditions affect the close relationship between the community and water bodies, as their socio-economic and cultural dynamics are mainly based on the use of the ecosystem and territory, activities such as fishing, water extraction for domestic use and water for livestock are altered. Despite the monetary, social and material damages [48, 59], there is another consequence of floods that is not considered, which is the increase in the discharge of pollutants exacerbated by erosion and the redistribution of historically contaminated sediments during these phenomena [60], a problem that is exacerbated during floods of great magnitude, becoming potential sources of contaminated water [61].

From stage 2, indicators were identified in each category of the driving force model, as shown in Table 2. Indicator-based methods are considered semi-quantitative approaches [62], as their result is a numerical quantity that does not represent the true characteristic, but aims to be indicative of something in the environment that is not measured but is of interest [63].

Table 2. Description of indicators for each of the categories of the Model

Model Category	Social Determinant	Name of Indicators
Driving force	Development policies (Structural determinant)	1. Institutional and local infrastructure capacity. 2. Demographic growth. 3. Level of poverty in the population. 4. Community plans or programs oriented towards prevention, mitigation and/or response to risk scenarios. 5. Development environment.
Pressure	Disaster risk and emergency care (Intermediate determinant)	1. Disaster risk and climate change (droughts, floods). 2. Presence or absence of climatic anomalies. 3. Deforestation. 4. Land use conflicts. 5. Quality of life (inadequate housing, overcrowding). 6. Coverage of public services.
State	Favorable and unfavorable conditions in the environment (Intermediate determinant).	1. Precipitation volume. 2. Strategic ecosystems (forests, wetlands). 3. Watersheds (water supply, water regulation, water vulnerability). 4. Number of threatened households. 5. Community-based adaptation models. 6. Waste disposal.
Exposure	Impact and affected people of risk scenarios victims (Intermediate determinant)	1. Rural population. 2. Population under 5 years old exposed. 3. Population over 65 years old exposed. 4. Total number of families threatened by flood scenarios.
Effect	Derivation of risk scenarios (Major determinant).	1. Incidence of associated diseases. 2. Morbidity and mortality associated with floods. 3. Infrastructure damage. 4. Affectation of food security.

On the other hand, Figure 3 shows the relationships between the indicators of the different categories explained in Table 2.

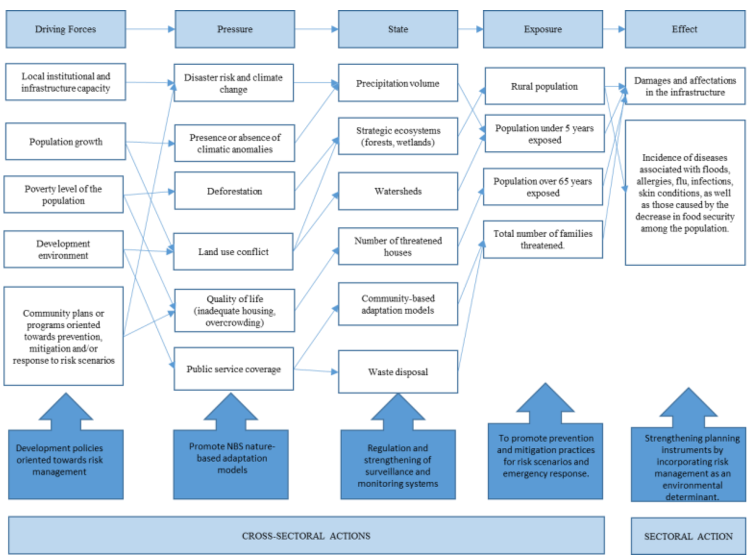

Fig. 3. Relationships between the indicators of the categories described for identifying flood risk and their effects on the population

Although the structural, intermediate and major determinants were exposed based on each category of the DPSEEA model, in El Playón village, since it presents a specific problem, the number of indicators used for the driving forces model was reduced by using only one for each category. It is essential to mention that the selection of these indicators may vary depending on the knowledge of the environmental health event and the availability of baseline data and information for their prioritization.

For this study, Figure 4 summarizes each of the indicators used.

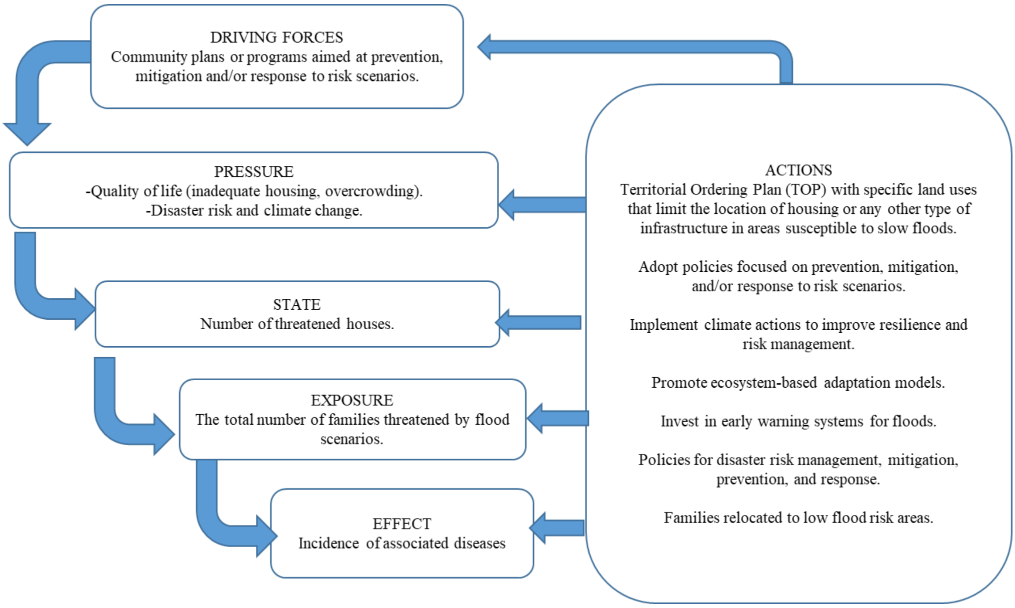

Fig. 4. Indicators related to flooding scenarios in the El Playón village

Stage 3 was related to the development of the technical data sheet of indicators for each category, including their description, calculation and horizon, allowing the tracking of each one and ensuring the sustainability of the actions or measures that will be implemented. Table 3 displays the aforementioned information.

Table 3. Technical data sheet of indicators related to health effects due to slow flooding scenarios in the population of the El Playón village.

Indicator name	**Community plans or programs aimed at the prevention, mitigation and/or response to risk scenarios**
DPSEEA model category	Driving force.
Social determinant	Development policies (Structural determinant).
Description	The response capacities of environmental and municipal authorities for disaster risk management were evaluated.
Indicator calculation	Number of community plans or programs aimed at the prevention, mitigation and/or response to risk scenarios.
Source of information	Information directly collected in the study area (Characterization survey).
Spatial scale	Community-based (El Playón village).

Indicator name	**Quality of life before and after the disaster.**
DPSEEA model category	Pressure.
Social determinant	Disaster risk and emergency response (Intermediate determinant).
Description	The characteristics of housing, such as the quality or type of materials used, the type of construction, habitability, distribution of spaces and infrastructure adjustments, are essential for preventing losses during flooding events and therefore determining physical vulnerability. It is also important to evaluate the emergency response of residents, the type of known strategies for prevention and/or response to possible risks and actions of the Disaster Recovery Plan.
Indicator calculation	Number of inadequate housing units, number of known strategies for emergency preparation and response, knowledge of the Disaster Recovery Plan.
Source of information	Information collected directly in the study area (Characterization survey).
Spatial scale	Community-based (El Playón village).

Indicator name	**Favorable and unfavorable conditions in the environment.**
DPSEEA model category	State
Social determinant	Knowledge of living and working conditions in the territory (Intermediate determinant).
Description	The environmental, social and structural conditions that are currently evident in the population increase physical vulnerability, increasing the risk of damage, including collapse, in the case of extreme events such as moderate and large-scale floods. The study area is located in an area with high strategic ecosystems that have been overexploited, conditions that demonstrate the lack of models that respond to the particular needs of the population but that integrate and conserve the environment. The high volume of precipitation, the lack of water regulation in the area, the high degree of deforestation of forests and wetlands, the adoption of adaptation models based solely on community needs and the percentage of homes with high threat levels demonstrate the unfavorable conditions in which territories with areas susceptible to slow floods, such as El Playón, are located.
Indicator calculation	Number of favorable and unfavorable conditions or aspects in the territory.
Source of information	Information directly collected in the study area (Characterization survey).
Spatial scale	Community-based (El Playón village).

Indicator name	**Families threatened by flooding scenarios.**
DPSEEA model category	Exposure.
Social determinant	Health and well-being impact of risk scenarios (Intermediate determinant)
Description	Families located in the areas of influence of the Sinú River are considered threatened and given the flooding scenarios described and presented in the first chapter of this research, they could suffer health or material harm.
Indicator calculation	The number of families threatened by flooding scenarios.
Source of information	Information directly collected in the study area (Characterization survey).
Spatial scale	Community-based (El Playón village).

Indicator name	**Incidence of damages and impacts at the environmental, social and structural level.**
DPSEEA model category	Effect.
Social determinant	Results of emergency risk scenario (major determinant).
Description	Cases of diseases associated with slow-onset floods, such as allergies, skin infections and flu-like symptoms. Disruption of the main sources of income for the population, resulting in decreased food security and quality of life. Damage and impacts on the individual and collective infrastructure of the community, leading to overcrowding in less vulnerable households, as well as difficulty accessing nearby urban centers.
Indicator calculation	Number of reported cases of diseases, number of families with losses of homes and crops, number of threatened common areas.
Source of information	Information directly collected in the study area (Characterization survey).
Spatial scale	Community-based (El Playón village).

From Stage 4, regarding the analysis of information according to surveys applied in the field through characterization and recognition sheets, the population has 560 inhabitants, where more than half (55%) of the 80 households are composed of 1-3 people [64].

Often, the materials used in housing construction are a factor that influences the extent of damage caused by flooding events. The resistance of the housing materials can determine the degree of damage when present and future flooding events occur [46]. From the results obtained, the highest percentage of housing units have deficient or regular infrastructure (72.5%). These conditions increase vulnerability and raise the risk of buildings suffering damage, including collapse, in the presence of extreme events such as medium and large-scale floods. This information allows us to characterize the houses, showing the limitations with which these families can live on a daily basis. Similarly, prior knowledge of this data is important for estimating material losses due to extreme flooding events, associating them with the major or minor impacts that the threat could represent in economic terms. As for the health component, the population reports that they do not experience any type of physical deterioration (34.2%). However, allergies and skin infections (32.9%) were the second most common perception, as evidenced by other studies [65].

The interaction between the population, physical, environmental and social elements present in the area, as well as the interactions that can be made with the social structure, contribute to the environmental health being linked to practices such as the use, manipulation, appropriation and exploitation of environmental components, as well as to the problem of slow flooding in the village. Hence, flood risk management is fundamental as it focuses on the future and seeks to minimize a problem before it occurs, unlike crisis management, which is concerned with the present and focuses on solving problems that occur [66].

Regarding the institutional component, in terms of the response capacity of environmental and municipal authorities for disaster risk management, it was deficient, according to the community. Training on risk-related topics had a null percentage, with the community being in total disagreement with what was proposed by *A.C. Travieso Bello et al.* [67], who stipulates the need to have planning frameworks with adaptability and foresight. The fact that the community is uninformed, but with a high participatory predisposition (58.8%), avoids concern and preparation for risk, as they are not aware of it [68]. With respect to the health center, there is no evidence of a facility providing primary care services to the community in the study area. Additionally, there are no emergency response agencies, the community emergency response plan is non-existent (98.7%) and shelters in case of emergencies (100%) are not implemented.

Stage 5 was related to the development of the action plan. Table 4 indicates the actions and/or interventions that, according to the DPSEEA model, should be taken for the slow flood risk management component in El Playón village. Finally, the actions should consider the well-being approach in environmental health associated with flood and risk scenarios, envisioned to design and implement programs, models, policies [64], laws and multidisciplinary research, contributing to achieving better results in the incorporation of risk management in territorial planning.

Table 4. Actions and/or interventions that, according to the DPSEEA model, should be chosen for the slow flood risk management component in the El Playón village

Category	Determining Level	Type Determinant	Action/Intervention
Driving force	Structural	Development policies	Make progress in meeting SDG 11 and 13 targets. TOP with specific land uses that limit the location of housing or any other type of infrastructure in areas susceptible to slow flooding. Adopt policies aimed at prevention, mitigation and/or response to risk scenarios.
Pressure	Intermediate	Disaster risks and emergency response	Implement climate actions to improve resilience and risk management. Promote Nature-Based Solutions (NBS) models.
State	Intermediate	Knowledge of living and working conditions in the territory.	Investment in early warning systems for floods. Families relocated to low-flood risk areas. Ensure compliance with regulations and strengthen surveillance and monitoring systems.
Exposure	Intermediate	Impact of risk scenarios on health and well-being.	Promote environmental education. Promote practices for prevention, mitigation and/or response to risk scenarios.

Effect	Intermediate	Results of emergency risk scenarios.	Articulate territorial planning instruments with risk management, as an environmental determinant. Involve the community in implementing strategies for knowledge and planning of territories, such as multitemporal analysis, identification of degradation drivers and proposing real actions in the communities. Implement actions aimed at integrated flood risk management that address greater coordination among environmental authorities and public and private institutions. Implement community early warning systems that generate reduction strategies, but also knowledge of risk. Strengthen and support community organizations that implement rural development strategies.

From Table 4, the determinants of structural order are those attributes that generate impacts on the environment [65], relating to macroeconomic, political and social issues that influence the development model. Those of intermediate type generate differential exposures, such as territorial ordering. Although those of proximal type are not included in this research, they refer to those factors that cause more direct exposures to individuals.

Conclusions

DPSEEA is a holistic methodology that takes into account the different categories of a problem, allowing the identification of driving forces, pressures, states, exposures and effects. In this case, the starting point was "Health impacts due to slow flood scenarios in the population of El Playón village." Thanks to the indicators established for each of the categories, it was possible to generate an understanding of the existing relationships between the environment and health. Including flood risk management as an environmental determinant means minimizing loss of life and economic damage from flood disasters, using both structural measures such as dams, levees, seawalls, reservoirs, pumping stations, embankments, tide gates, diversion channels etc. and non-structural measures such as policies and laws, public awareness, flood forecasting and warning, evacuation, training and education, land use adjustment, regulations and insurance, financing and subsidies, spatial and flood management plans etc. The latter are less costly and more sustainable than the former and they are also comprehensive and have fewer negative effects [65]. According to the identification and knowledge of the environmental determinants for territorial planning, an instrument that considers the social cost and the environmental impact that this means, its importance is verified as elements that seek to maintain the natural base, supporting and guaranteeing the ecosystemic functionality and the socioeconomic development of the population. That is why studies like the one carried out in El Playón are necessary to understand the behavior of the territories, their needs and how, through territorial planning, guarantees can be provided for sustainable development. Additionally, the DPSEEA model, being a method that allows for the establishment of variable indicators, can be adapted to other types of threats such as storms, instability, among others.

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