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System of prospective actions for the disasters prevention in farms of the "Hermanos Barcón" Productive Pole

Sistema de acciones prospectivas para la prevención de desastres en fincas del Polo Productivo "Hermanos Barcón"

Sistema de ações prospectivas para a prevenção de desastres em fazendas do Polo Produtivo "Hermanos Barcón"

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ABSTRACT

Climate change significantly affects agricultural production processes, due to its influence on the increase in temperatures and climate change, which severely increases the occurrence and intensity of extreme events. These reasons justify the present work in agricultural production cooperatives located in the southern plains of the province of Pinar del Río, an area characterized as an agroecosystem of marked vulnerability to the effects of climate change. The objective of the research is to propose a system of prospective actions of Environmental Management, which increases resilience and response capacity on hazards, vulnerabilities and risk to extreme events, in farms of the "Hermanos Barcón" Productive Pole. The methods used include theoretical and empirical methods, together with the application of the Delphi Method for the definition of indicators for the preparation of disaster risk and vulnerability maps, and the user satisfaction method or Iadov technique used for the validation of the action plan. The results obtained show that the farms diagnosed have a high level of risk and vulnerability, as they are located in an area that is highly susceptible to extreme events and latent threats due to climate change. The application of the system of prospective actions allows greater preparedness to face climate change and increases the capacity to respond to extreme events by increasing resilience, which guarantees the development of more sustainable agricultural and livestock production.

Keywords: agriculture; extreme events; climate change; hazard; vulnerability; risk.

RESUMEN

El cambio climático afecta de manera sensible los procesos de producción agropecuaria, debido a su influencia en el aumento de las temperaturas y las modificaciones del clima, que incrementa de manera severa la ocurrencia e intensidad de eventos extremos. Estas razones justifican el presente trabajo en cooperativas de producción agropecuarias ubicadas en la llanura sur de la provincia de Pinar del Río, área caracterizada por ser un agroecosistema de marcada vulnerabilidad a los efectos del cambio climático. La investigación tiene como objetivo proponer un sistema de acciones prospectivas de Gestión Ambiental, que incremente la resiliencia y capacidad de respuesta sobre los peligros, vulnerabilidades y riesgo ante eventos extremos, en fincas del Polo Productivo "Hermanos Barcón". Los métodos empleados incluyen métodos teóricos y métodos empíricos, unidos a la aplicación del Método Delphi para la definición de indicadores para la confección de los mapas de riesgo y vulnerabilidad ante desastres, y el método de satisfacción de usuarios o técnica de Iadov se emplea para la validación del plan de acciones. Los resultados alcanzados evidencian que las fincas diagnosticadas presentan un alto nivel de riesgo y vulnerabilidad, al estar asentadas en una zona muy susceptible a los embates de eventos extremos y las amenazas latentes al cambio climático. La aplicación del sistema de acciones prospectivas permite una mayor preparación para el enfrentamiento al cambio climático y aumenta la capacidad de respuesta ante eventos extremo, al incrementar la resiliencia que garantiza el desarrollo de producciones agropecuarias más sostenibles.

Palabras clave: agricultura; eventos extremos; cambio climático; peligro; vulnerabilidad; riesgo.

Translated from the original in Spanish

RESUMO

As mudanças climáticas afetam significativamente os processos de produção agrícola, devido à sua influência no aumento das temperaturas e nas mudanças climáticas, que aumentam severamente a ocorrência e a intensidade de eventos extremos. Essas razões justificam o presente trabalho em cooperativas de produção agrícola localizadas nas planícies do sul da província de Pinar del Río, uma área caracterizada como um agroecossistema de acentuada vulnerabilidade aos efeitos das mudanças climáticas. A pesquisa tem como objetivo propor um sistema de ações prospectivas de gestão ambiental para aumentar a resiliência e a capacidade de resposta a perigos, vulnerabilidades e riscos diante de eventos extremos nas fazendas do Polo de Produção "Hermanos Barcón". Os métodos utilizados incluem métodos teóricos e empíricos, juntamente com a aplicação do método Delphi para a definição de indicadores para a elaboração de mapas de risco e vulnerabilidade a desastres, e o método de satisfação do usuário ou técnica Iadov é usado para a validação do plano de ação. Os resultados obtidos mostram que as fazendas diagnosticadas apresentam um alto nível de risco e vulnerabilidade, pois estão localizadas em uma área altamente suscetível ao ataque de eventos extremos e às ameaças latentes das mudanças climáticas. A aplicação do sistema de ações prospectivas permite maior preparo para enfrentar as mudanças climáticas e aumenta a capacidade de resposta a eventos extremos, aumentando a resiliência que garante o desenvolvimento de uma produção agrícola mais sustentável.

Palavras-chave: agricultura; eventos extremos; mudança climática; perigo; vulnerabilidade; risco.

INTRODUCTION

Climate change is a great challenge for humanity and especially for island countries. It is also emerging as a global challenge, generating great concern in the scientific community and the productive sectors, mainly due to the potential impacts that a changing climate can have on natural systems, society and production of goods and services, where its negative effects seriously compromise their economic, political, social and ecological development (Barreira Rodríguez & García O'Reilly, 2023; Dávila Cevallos, 2023).

In the agricultural sector in Cuba, there are a series of important challenges that must be faced with appropriate techniques and technologies. It has been observed for some years in Cuba that climatic changes are occurring as a reflection of global phenomena and the particularities of Cuban geography. These changes have had repercussions on the production of some agricultural crops, for these reasons, it is very important to implement strategies and develop tools that facilitate the adaptation of agriculture to the changes that the climate is experiencing and will continue to experience in the future (García Álvarez, 2020).

The Intergovernmental Panel on Climate Change (IPCC, 2023) states that global warming and climate change have resulted in more frequent and more intense extreme weather events that have generated increasingly dangerous impacts on nature and people in all regions of the world. The solution lies in achieving climate-resilient development, which implies integrating climate change adaptation measures with actions aimed at reducing or avoiding greenhouse gas emissions, and for these decisions to be effective, they must be based on scientific and local knowledge, contributing to an approach that will facilitate climate-resilient development and generate locally appropriate and socially acceptable solutions.

In response to these fundamentals, the Republic of Cuba in its Official Gazette, in Law 150/2022 of the System of Natural Resources and the Environment, in its Article 16 clause "h" establishes "the prevention and rehabilitation with respect to the occurrence of hazards of natural, technological and sanitary origin that include the provision of the necessary resources for these purposes and consider the results of the studies of Danger, Vulnerability and Risks, as well as the economic valuation of the environmental impacts and damages".

Given its preventive and preventive nature in its statement and in order to respond to these priorities and demands, the research is developed in the "Hermanos Barcón" Productive Pole, belonging to the Tobacco Collection and Processing Company of Pinar del Río, located in the southern plain of Pinar del Río, with a high level of degradation and marked vulnerability to climate change, in order to develop a study of Hazard, Vulnerability and Risks in this scenario.

The identified problem is defined as: What factors influence the limited capacity to face and respond to hazards, vulnerabilities and risks before disasters in the "Hermanos Barcón" Productive Pole, in the municipality of Pinar del Río?

The formulated objective is defined in proposing a system of prospective actions of Environmental Management, which increases resilience and response capacity on the hazards, vulnerabilities and risk to extreme events, in farms of the "Hermanos Barcón" Productive Pole.

MATERIALS AND METHODS

In order to fulfill the objective, methods, techniques and procedures were used that facilitated the collection and processing of information to solve the research problem. The following theoretical and empirical methods were used:

- The theoretical methods employed include
  - Structural systemic: Its purpose was to trigger a structure of steps for the design, implementation and substantiation of a proposal for a system of prospective actions of Environmental Management for disaster reduction.
  - Documentary analysis: for the analysis of all the bibliography consulted and the deepening of the referents and theoretical foundations of the subject through the study of normative documents and action plans elaborated at different levels.
- The procedures developed include
  - Induction-deduction: contributed to the development of logical and objective reasoning on the different aspects addressed and that support this research work.
  - Analysis-synthesis: for the detailed analysis of the bibliographic and documentary sources consulted, and from them to establish the basis for the proposal of the system of prospective actions of Environmental Management for disaster reduction.
- The empirical methods applied were:
  - Surveys: They were conducted anonymously to learn about preparedness and capacity to respond to hazards, vulnerabilities and risk in the face of extreme events, as well as preparedness to face climate change.

The population of producers in the community, linked to the Productive Pole, comprises a universe of 70 farmers or producers of that population, the size of the sample to be surveyed was determined for a finite population, and the following equation was applied:

$$n = \frac{N \times \sigma^2 \times {Z_\alpha}^2}{e^2 \times (N-1) + \sigma^2 \times {Z_\alpha}^2}$$

Where:

n = sample size

N = population size

ó = standard deviation of the population (0.5)

Z_α = value obtained using confidence levels (for 95 % equals 1.96)

e = acceptable sample error limit (assumed 0.05)

On this basis, the following calculation is performed:

$$n = \frac{70 \times 0.5^2 \times {1.96_\alpha}^2}{0.05^2 \times (70-1) + 0.5^2 \times {1.96_\alpha}^2} = 52.2 \approx 52$$

Calculated sample of workers to be surveyed takes the value of 52 farmers or producers and a Microsoft Excel spreadsheet is used to obtain the result.

The Delphi Method expert system was applied to define indicators for the creation of disaster risk and vulnerability maps, as a preliminary step to the creation of the prospective action plan.

The effectiveness of the action plan was validated through the user satisfaction method or Iadov technique.

RESULTS AND DISCUSSION

Characterization of the "Hermanos Barcon Productive Pole" environment

The research was carried out in the "Hermanos Barcón" Productive Pole in the municipality of Pinar del Río, belonging to the Tobacco Collection and Processing Company of Pinar del Río, located in Las Taironas Popular Council. This productive unit has an area of 2141.41 ha dedicated to agricultural production, located 18 km south of the city of Pinar del Río. It is bordered on the north by the road to Sitio and El Punto reservoir, on the south by the town of 23 of the road to La Coloma and lands of the Empresa Forestal Integral Pinar del Río, on the east by the areas of the Empresa Forestal Integral de Pinar del Río and on the west by the road to La Coloma.

The natural conditions of the environment are characterized by:

The climate can be considered within the tropical humid savanna bioclimate classification and the fundamental variables that determine its behavior are:

- Precipitation: The annual average in the areas of greatest economic importance is 1 346.5 mm and more than 80% of this in the rainy period (May-October).
- Temperature: The temperature behaves as follows: the average annual minimum is 20.4 ºC, with an average maximum of 29.8 ºC.
- Relative Humidity: The average relative humidity is 80%.
- Relief, in general the area is characterized by a flat topography.
- Hydrography, the main rivers in the research area are Paso Viejo and Guamá, in addition to an important source of water such as the "El Punto" dam.
- Soils, these soils present a flat topography, where drainage is regular, in some areas it is evaluated as deficient and the level of groundwater salinity increases as one moves south.

The geographical location of the "Hermanos Barcón" Productive Pole places it in the southern plains of Pinar del Río, with a high level of degradation and marked vulnerability to Climate Change, with the negative influence of the coastal environments and its proximity to that area, which significantly influences its agroecological processes.

Methodological foundations to establish a system of prospective actions of Environmental Management for disaster prevention

Throughout the process of perfecting Cuba's disaster reduction strategy, the scope of actions to estimate and reduce the risks of the different hazards affecting the country has been deepened. This has been influenced by the implementation, in 2005, of Directive No. 1 of the Vice President of the National Defense Council, which has been improved. In 2010, the second edition of this directive was published, and today it has been updated in 2022 as a tool that facilitates the identification of measures and decision making to reduce risks, taking into account the studies and research on hazards, vulnerabilities and disaster risks that the Risk Assessment Group of the Environment Agency has developed.

The basis of the strategy must take into account the various classifications for events, phenomena or occurrences, which can also be extrapolated to disasters. For example, it is possible to classify them:

1. By origin
    - Natural (which are those that have a natural phenomenon as a catalyst).
    - Unnatural (catalyzed by inadequate or excessive anthropic action).
2. Speed of appearance
    - Sudden (not necessarily implying the impossibility of preparation).
    - Slow (they allow, under previous organization, the establishment of phases for their attention).
3. For its impact
    - Total (large scale reaches the country).
    - Partial (affecting a specific region or zone).
4. Probability
    - Potential (corresponding to earthquakes, landslides, volcanic eruptions).
    - Temporary and recurrent (hurricanes, heavy rains and others).

These classifications facilitate their study and understanding and, above all, clarify the ways to adequately deal with disasters and establish strategies to mitigate their effects and prevent them.

Recognizing that disaster hazards are not only associated with natural, sanitary or technological hazards, but are closely related to vulnerabilities in the national territory due to its island characteristics, the present work is developed for disaster prevention in the "Hermanos Barcón" Productive Pole, due to the importance of agricultural production for the province, given the level of vulnerability of agricultural production that takes place in open environments, with the threat of external factors that have a significant impact on the agroecosystems where these processes are carried out.

In order to achieve a successful system of prospective Environmental Management actions to increase resilience and response capacity to hazards, vulnerabilities and risk in the face of extreme events, many important components must be considered:

- Component I: Diagnosis of the main hazards, vulnerabilities and possible risks that may occur in the environment of the "Hermanos Barcón" Productive Pole.
- Component II: Definition of indicators for the construction of vulnerability and risk maps.
- Component III: Construction of vulnerability and risk maps of agroecosystems.
- Component IV: System of prospective actions based on environmental problems.
- Component V: System of prospective environmental management actions based on extreme events.

The integration of these components will allow an effective Environmental Management, with a real prospective character for the prevention and confrontation of the possible dangers, vulnerabilities and risks that may arise in the environment of the "Hermanos Barcón" Productive Pole.

Perception of the producers of the "Hermanos Barcón" Productive Pole on hazards, vulnerability and risk to extreme events

In order to carry out the environmental diagnosis based on the perception of the Productive Pole producers, the methodology for the community environmental diagnosis for research purposes from the academic graduate program recommended by Linares Guerra et al. (2021) was used as a basis.

On this basis, a survey was conducted to determine the level of capacity to identify hazards, vulnerabilities and latent risks in the environment and their relationship with the climate change scenario, as well as their interaction with the productive processes developed in the entity.

The survey conducted among the 52 producers of the related Productive Pole revealed the following criteria and ideas about their perception and capacity to face hazards, vulnerabilities and risks in the face of extreme events, and the following conclusions can be drawn from the information obtained.

- The total number of respondents:
  - Perceives that environmental risks exist.
  - Recognizes that the area is very vulnerable to weather phenomena.
  - Recognizes that they lack preparation in environmental issues.
  - Regrets that they do not receive more talks on environmental issues.
- 98.1% acknowledge having limited preparedness to face hazards, vulnerabilities and risks.
- 96.2 % acknowledge not applying good environmental practices.
- For 71.2 %, it is perceived that there is insufficient soil and water resource management.

- 73.1% have a low perception of climate change risk.
- 88.5 % express that they have insufficient knowledge of the Life Task.
- 96.2% express insufficient knowledge of environmental regulations.

The results of the survey to producers show that there is no consolidated knowledge on issues related to environmental legislation and environmental culture in general, due to the lack of training programs that systematically address these issues to achieve greater preparedness to face climate change, coinciding with the results obtained by Hernández Páez et al. (2021).

Another important element to highlight is that, in general, respondents recognize that they lack preparation on environmental issues and, in particular, on how to deal with the problems of climate change, as well as the dangers, vulnerabilities and risks that this implies.

In summary, this result shows that climate change causes over time a series of phenomena that modify and destabilize the parameters established for the climate of a place, during the annual cycle of temperature, precipitation and atmospheric movement, which is accentuated by the anthropic effects that cause an increase in deforestation, soil degradation, greenhouse gas emissions and the deterioration of biodiversity. All this increases vulnerability and associated risks in agroecosystems (Paucar Chanca et al., 2024).

Diagnosis of the main hazards, vulnerabilities and possible risks that may occur in the surroundings of the "Hermanos Barcón" Productive Pole

Main hazards of natural origin that may originate in the ecosystem

- Extreme weather events
  - Strong winds
  - Heavy rains
  - Sea penetrations
  - Thunderstorms
- Other hazards of natural origin
  - Given its proximity to the sea, salinity is a permanent danger both for the facilities to be built there and for planned agricultural production.
  - High temperatures, due to the problems that could be caused by sunstroke.

    - Drought is one of the hydrometeorological events that constitutes a new threat, coupled with the scenario of climate change.
- Technological hazards
    - Spillage of toxic substances due to the development of agricultural and livestock productions
    - Dam breaks. In this particular case of the "El Punto" dam, which is upstream of the productive entity.
- Other hazards
    - Fires due to proximity to forested areas

Main vulnerabilities that can originate in the ecosystem

Within physical vulnerability, three types have been differentiated: Structural, Non-Structural and Functional.

- Structural vulnerability
    - Structural vulnerability is defined as the resistive capacity of buildings to the destructive forces of the different hazards. For this purpose, the constructive typology, technical condition and height of the buildings will be considered, as well as location parameters, type of soil, elevation, etc., depending on the hazard and the characteristics of the crops and their association.
- Non-structural vulnerability
    - This section studies non-structural vulnerability based on the destructive effects of each of the probable hazards in each of the subsystems: architectural, equipment, furniture and technical networks, crops, forestry and fruit trees.
- Functional vulnerability
    - The functional capacity and its strategic importance are analyzed, especially when taking into account the economic weight of the activities that take place in its surroundings.
- Social vulnerability
    - Its location and its social purpose are integrated, ensuring that there are no factors that contribute to increase vulnerability and, therefore, will have a positive impact on the nutrition of the population residing in the environment and the municipality.

- Ecological vulnerability
  - The Productive Pole is located approximately 5 km from the coastal zone, considered a fragile ecosystem, with a high level of anthropogenic degradation due to poor management.

Main risks that may originate in the ecosystem

Risk is the magnitude of losses in human lives, economic losses and interruption of social activities of a territory, community or facility due to the conjunction or correlation between a hazard, the vulnerability of the elements in exposure and the capacity of its members to avoid its conversion into an event of disaster magnitude.

- High degree of risk
  - Floods
  - Strong winds
  - Groundwater salinization
  - Heavy rains
  - Soil degradation
- Medium risk level
  - Technological
- Low risk grade
  - Electrical discharges
  - Forest fires

Based on this diagnosis, there is evidence of the need to create hazard, vulnerability and risk maps for extreme events, together with prospective actions to address them.

Definition of indicators for the construction of hazard, vulnerability and risk maps

In the methodologies developed, the study of vulnerability hazards and disaster risks to extreme meteorological events (strong winds, floods, droughts, others) in the Agriculture sector in the "Hermanos Barcón" Productive Pole in the municipality of Pinar del Río is carried out, which implies the creation of maps and the design of prospective actions of Environmental Management for the prevention of disaster risk in this environment. An expert consultation was carried out with the application of the Delphi Method, according to Ramírez Chávez and Ramírez Torres (2024) to effectively determine the indicators to be specified for a correct evaluation of the problem to be investigated, as shown in table 1.

Table 1. Proposed variables and indicators for assessing hazards, vulnerability and disaster risk

No.	Variables	Indicator
1	Climate and weather conditions	Droughts
		Floods
		Temperatures
		Heavy rain and hail
		High winds, tornadoes, thunderstorms, cyclones, storms
		Soil moisture (water deficit)
2	Geographic	Area prone to natural disasters
		Topography
		Type of soil
		Susceptibility to erosion
		Distance from the sea
		Water resources network
3	Types of crops	Temporary
		Permanent
		Crop yields
		Resilience
		Deforestation
		Vegetative cover
4	Infrastructure and technologies	Irrigation systems
		Availability of machinery
		Available infrastructure
		Infrastructure vulnerability

5	Human Resources	Availability of workforce
		Preparation of human capital
		Training programs
		Relevance and commitment
6	Market and supply chain supplies	Storage capacities
		Availability of access roads
		Mobility capacity
		Vulnerability of its flow
		Market availability
7	Socioeconomic	Population density
		Population centers
		Satisfaction of needs

Source: Adapted from Ramírez Chávez and Ramírez Torres (2024)

In the final evaluation of the surveys applied to the experts, it was determined that the seven variables identified constitute factors directly involved in the vulnerability of the agricultural sector to extreme weather events (strong winds, floods and intense droughts), with the highest percentage values for climate and weather conditions, types of crops, geography, infrastructure and technology.

The result expressed by the experts corroborates the expression of previous works, which likewise coincide with these variables and indicators to take into account in the studies developed on issues of development of maps and actions for disaster risk prevention in the face of extreme events, from the environmental point of view in ecosystems (Cedeño Hidalgo et al., 2019; Nazco Torres et al., 2022).

Risk estimation

To calculate the level of expected destruction or loss, mathematically expressed as the probability of exceeding a certain level of economic and social consequences in a certain place and time, the probability of a disaster occurring is also indicated. It is expressed through the following formula:

$$R_e = \sum_{i=1}^{n} V_{ii} * P_i$$

Where:

R_e= specific risk

V_{ii}= vulnerability of the exposed assets to a hazard of i-th intensity

P_i= probability that the next event will have i-th intensity (1%)

n = number of intensity intervals analyzed.

To the extent that its value is close to the value "0", the hazard or vulnerability is very unlikely that a disaster could occur.

Vulnerability calculation

To calculate vulnerability, the general vulnerability equation was taken into account, in which all the indicators classified as important and very important were analyzed, taking into account the types of crops per tenant and the cultivated areas, which were in turn used to calculate each of the variables and indicators, normalizing them against the cultivated area per tenant, The most vulnerable areas to each phenomenon (floods, droughts, water deficit, strong winds) were determined for each tenant and crop, following the criteria of 100% for very important indicators, 67% for important indicators, and 33% for moderately important indicators. Finally, the total vulnerability of the Productive Pole to a given hazard is the sum of all its vulnerabilities, calculated independently, assuming a vulnerability value for each tenure of agricultural production farms according to the Saffir/Simpson hurricane scale (SS1-SS5), where its value is divided by 100 to limit the value between 0 and 1, and is reported in decimals.

$$VT = VE + Vne + VF + Vs + Vec + Vecn$$

Where:

VT= total vulnerability

Ve = structural vulnerability

Vne = non-structural vulnerability

VF = functional vulnerability

Vs = social vulnerability

Vec = ecological vulnerability

Vecn = economic vulnerability

On this basis, the vulnerability of each tenure of the producers of the agricultural production farms present in the "Hermanos Barcón" Productive Pole is calculated.

Vulnerability and risk map of the agroecosystems present in the agricultural production farms integrated to the "Hermanos Barcon" Productive Pole

The cartographic output of the vulnerability and risk characteristics of the agroecosystems that make up the farms integrated to the Productive Pole will be based on from the use of Geographic Information Systems, with classification attributes (Jalane et al., 2024) and all the information related to each element that is part of the different vulnerabilities.

According to the elements exposed to the risk, this is expressed in the number of people affected or damages and expected economic losses and can be considered for a given moment or for a given period. With the use of the formula the Specific Risk was calculated, the intervals for the classification of hazard intensity are as follows: (0.00000-0.06779) Low Range; (0.06780-0.13558) Medium Range and (0.13559-0.20337) High Range for the return periods corresponding to hurricanes.

The calculation yielded a Specific Risk of 0.203 (representing a High Risk), concluding that, out of 73 plots, 14 have Medium Risk for 16% and 59 have high Specific Risk for 84%. Based on these results, a risk map was drawn up representing the different types of risk for each tenure of the cooperatives' farms located in the Productive Pole, clearly showing their stratification and highlighting the elements of risk to the different hazards. Figure 1 shows the Specific Risk map of the "Hermanos Barcón" Productive Pole.

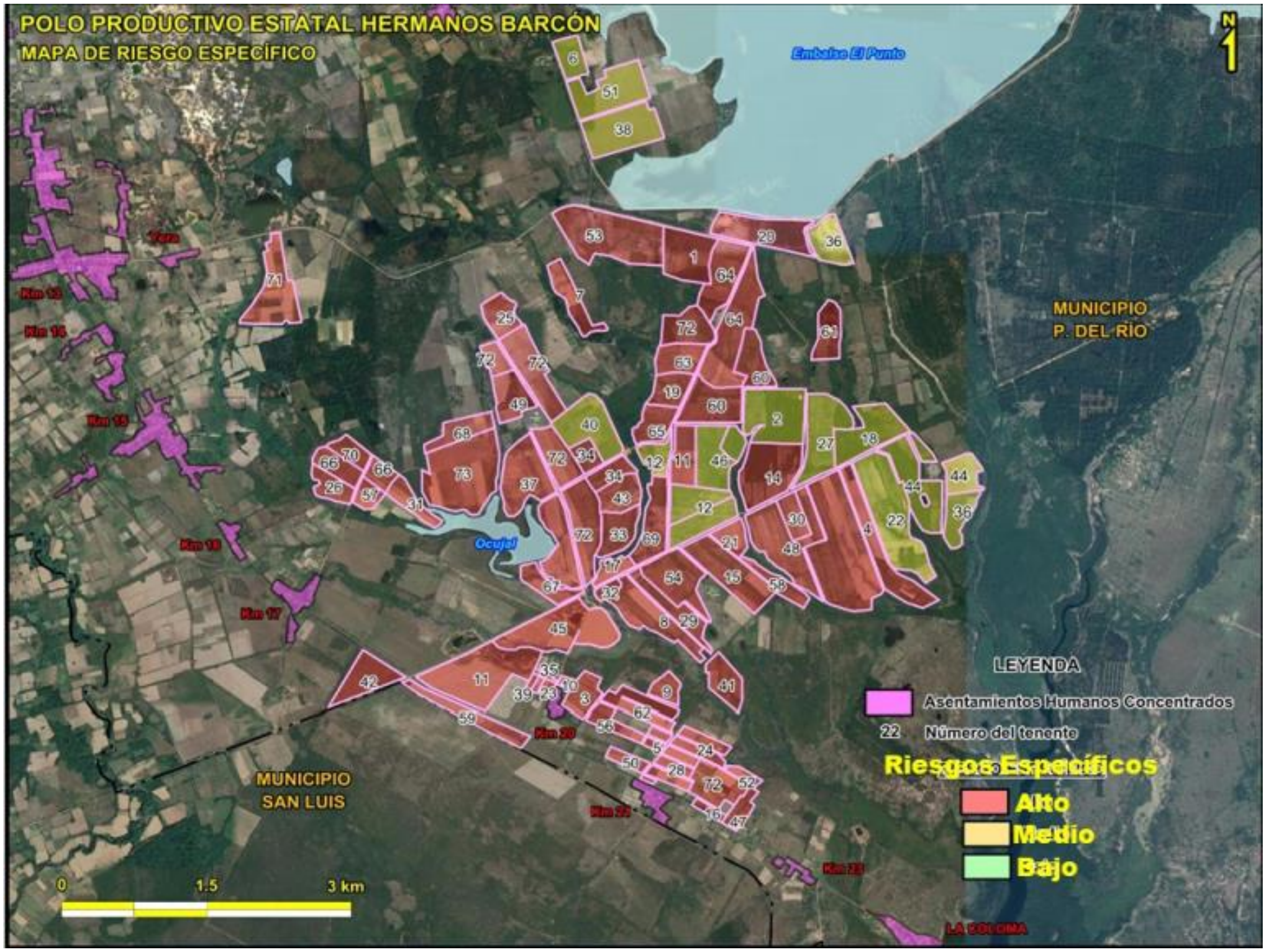

Figure 1. Specific Risk Map of the "Hermanos Barcón" Productive Pole
Source: Own elaboration

Vulnerability ranges: (0-25) Low Vulnerability; (25-54) Medium Vulnerability; (54-100) High Vulnerability. The calculations showed that for the five ranges of hurricane categories, the holdings of the "Hermanos Barcón" Productive Pole acquire a medium category, since they are between the ranges 0.25 and 0.54. With the calculated values, the vulnerability maps of the "Hermanos Barcón" Productive Pole were prepared, representing the holders of the areas in each farm of the agroecosystem. Figure 2 shows the vulnerability map of the farms, according to the Saffir/Simpson hurricane scale (SS1-SS5).

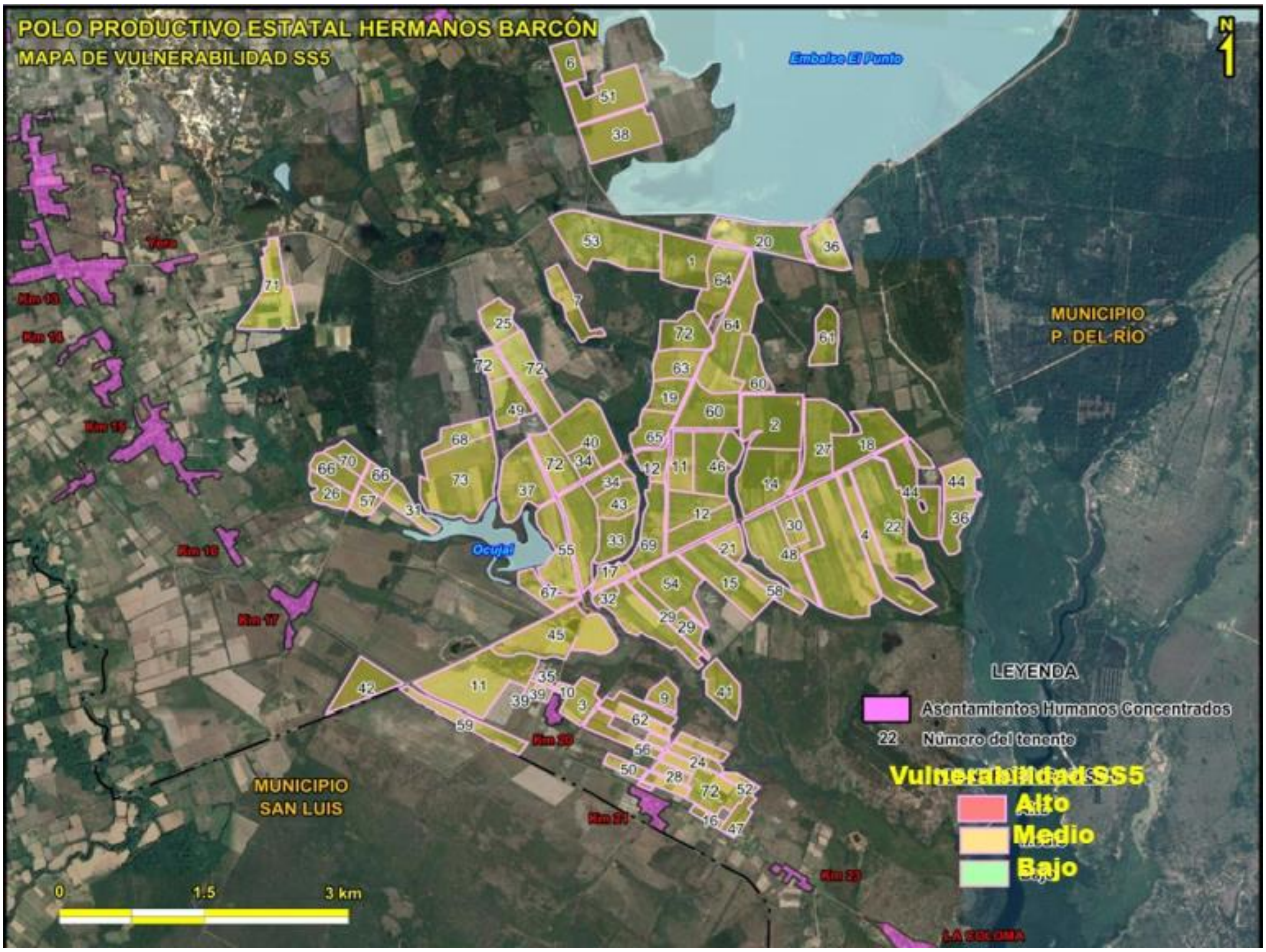

Figure 2. Vulnerability map of farms for hurricanes SS1-SS5
Source: Own elaboration

The risk and vulnerability maps show the susceptibility to extreme events of the territory where the farms of the "Hermanos Barcón" Productive Pole are located; these maps indicate that there are favorable conditions to be affected by extreme climatic events such as heavy rains, strong winds, hurricanes and floods, given its proximity to the coast and the edaphoclimatic conditions of the environment, These maps indicate that there are favorable conditions to be affected by extreme weather events such as heavy rains, strong winds, hurricanes and floods, given its proximity to the coast and the soil and climatic conditions of the environment, coupled with the lack of protection of agroecosystems due to deforestation and degradation of biodiversity, which causes a higher level of fragility of the environment to these phenomena.

To reduce the level of vulnerability and risk, the response capacity of farmers and their farms must be increased, which is related to mapping out actions to develop the capacity to withstand events and recover their agricultural functions and infrastructure.

The "response capacity" of the farms depends on the actions developed to reduce the risks of climatic events, allowing them to survive, resist and recover from the damage caused by such phenomena, which demonstrates the need to design proactive actions to minimize the negative effects of these extreme events.

System of prospective actions based on the environmental problems diagnosed in the "Hermanos Barcón" Productive Pole

The general structure of the prospective action system according to the environmental problems diagnosed in the "Hermanos Barcón" Productive Pole is shown in table 2 below.

Table 2. General structure of the prospective action system according to the environmental problems diagnosed in the "Hermanos Barcón" Productive Pole

No.	Environmental problem	Shares
1	Lack of environmental culture and preparedness to face extreme events.	• Implement an environmental training program for producers, workers and the local community. • Raise awareness among producers, workers and the local community regarding risk perception in the face of hazards, vulnerabilities and extreme events. • Create in advance the perception and capacity of producers and managers to face environmental hazards and risks. • Promote capacity building among producers to adopt practices that increase resilience to extreme events.
2	Limited capacity to address hazards, vulnerabilities and risks.	• Identify and evaluate the specific environmental hazards and risks faced by the production area. • Strengthen the response and recovery capacity of agroecosystems in the face of possible disasters.

		• Promote Good Agricultural Practices to increase adaptive capacity and resilience to extreme events. • Implement participatory management practices to address hazards, vulnerabilities and risks in the environment.
3	Zone vulnerable to climatological phenomena, which causes environmental risks.	• Identify vulnerable areas and zones. • Continuously monitor and evaluate the agroecosystem situation through participatory management. • Establish a climate risk management plan. • Identify, through participatory action, potential hazards and vulnerabilities to extreme climate events, and establish preventive measures to minimize their impact. • Create prospective capacities in the community and the agroecosystem to face extreme events. • Improve the infrastructure and equipment of production facilities to cope with extreme events. • Establish partnerships and collaborations with environmental and governmental organizations.

Source: Own elaboration

Prospective actions designed to address the environmental problems diagnosed require procedures to ensure their management and compliance, described below.

- Systematically evaluate the environmental impact of the activities carried out in the area every six months and propose measures to improve and prevent environmental problems.
- Establish an environmental committee to constantly monitor and evaluate the environmental impact of the activities carried out in the area.
- Establish contingency plans and action protocols to minimize damage and accelerate recovery.

- Evaluate the agricultural practices used in the area and assess their impact on vulnerability, crop susceptibility to environmental impacts and extreme events.
- Risk assessment and analysis, identification of mitigation measures and implementation of controls to reduce negative impacts.
- Identify and map the agricultural areas most vulnerable to extreme events and types of risks in order to anticipate possible damages.
- Design an adaptation plan that includes risk prevention and mitigation measures such as the construction of infrastructure resistant to extreme weather events, the implementation of early warning systems and crop diversification.
- Periodically monitor and evaluate the effectiveness of the measures implemented, making adjustments as necessary to improve the resilience of the productive zone to extreme climate events.
- Promote participation in networks for the exchange of information and best practices, and collaborate in the development and implementation of environmental protection policies and programs.

The implementation of these procedures allows fostering greater resilience and response capacity of agroecosystems to hazards, vulnerability and risk in the face of extreme events, since it allows the prospective actions of Environmental Management to contribute to the solution of existing problems in the agroecosystem of the "Hermanos Barcón" Productive Pole

System of prospective actions for Environmental Management in the "Hermanos Barcón" Productive Pole based on extreme events

The development of the system of prospective actions of Environmental Management for disaster risk prevention in the "Hermanos Barcón" Productive Pole, based on extreme events, is characterized by the following actions.

Strong winds

- Actions in the Prevention Phase
    - Maintenance and preparation of agricultural facilities to ensure their resistance to strong winds.
    - Implement protection systems such as windbreaks and natural barriers to reduce crop exposure to winds.

- Establish an emergency plan that includes specific preventive measures to protect crops and infrastructure in case of high winds.

- Actions in the Preparation Phase
  - Keep informed about weather conditions and be aware of early warnings.
  - Secure agricultural equipment and tools to prevent damage during winds.
  - Protect sensitive crops by installing temporary protective structures such as netting or tarpaulins.
- Actions in the Response Phase
  - Act quickly upon the arrival of strong winds to implement planned preventive measures.
  - Constantly monitor the situation and make adjustments to the emergency plan as necessary.
  - Coordinate with local authorities and other farmers to collaborate in the protection of crops and agricultural facilities.
- Actions in the Recovery Phase
  - Assess the damage caused by high winds and develop a recovery plan to restore the affected areas.
  - Prioritize the cleanup and repair of damaged agricultural infrastructure to minimize economic losses.
  - Implement additional protective measures to prevent future damage from high winds.

Intense rains

- Actions in the Prevention Phase
  - Consolidate the drainage system in the agricultural area to prevent flooding and waterlogging.
  - Maintain irrigation and drainage canals to ensure their proper functioning.
  - Protect vulnerable crops by promoting protective structures such as protected crops or tunnels.
- Actions in the Preparation Phase
  - Systematically monitor weather conditions and be alert to heavy rainfall warnings.
  - Secure emergency supplies, such as water pumps and protection materials to be prepared for possible flooding.

    - Train agricultural personnel on safety procedures in case of heavy rains and evacuation.
- Actions in the Response Phase
    - Act promptly upon the arrival of heavy rains, implementing preventive measures such as closing irrigation floodgates and developing drainage works.
    - Evacuate workers and animals from the agricultural area in time if necessary.
    - Coordinate with local authorities and other farmers to collaborate in the protection of crops and agricultural facilities.
- Actions in the Recovery Phase
    - Assess the damage caused by the heavy rains and develop a recovery plan to restore the affected areas.
    - Prioritize the cleanup and repair of damaged agricultural infrastructure to minimize economic losses.

Intense droughts

- Actions in the Prevention Phase
    - Implement efficient and sustainable irrigation systems to optimize water use in agriculture.
    - Perform adequate soil management to improve its water retention capacity and reduce erosion.
    - Diversify crops to reduce dependence on drought-sensitive species.
    - Promote water conservation practices such as rainwater harvesting and the use of drip irrigation techniques.
- Actions in the Preparation Phase
    - Constantly monitor weather conditions and soil moisture levels to anticipate possible droughts.
    - Establish contingency plans and action protocols in the event of drought, including measures to reduce water consumption in agriculture.
    - Train agricultural personnel in drought-resilient crop management techniques and efficient water use.
- Actions in the Response Phase
    - Implement emergency measures such as the application of supplemental irrigation or the use of mobile irrigation systems to mitigate the effects of drought on crops.

  - Prioritize water supply to the most sensitive and strategic crops for agricultural production.
  - Coordinate with local authorities and other farmers to share resources and drought response strategies.
- Actions in the Recovery Phase
  - Assess drought damage to crops and agricultural infrastructure and develop a recovery plan.
  - Implement soil rehabilitation practices such as the application of organic fertilizers to restore soil fertility and increase its moisture retention capacity.
  - Diversify crops and strengthen the resilience of the agricultural system to future droughts through the introduction of more resistant varieties and sustainable agricultural practices.

The system of prospective actions of Environmental Management for disaster risk prevention allows contributing to the increase of knowledge, perception, commitment and participation of all producers and the community to effectively face the impacts of extreme events and, in particular, the effects of climate change.

Validation of the system of prospective actions of Environmental Management for disaster risk prevention in the "Hermanos Barcón" Productive Pole

The validation of the system of prospective actions of Environmental Management for disaster risk prevention applied to the community of producers of the "Hermanos Barcón" Productive Pole of Pinar del Río consisted of a sample of 78 actors involved in the production process; of them, 70 producers belonging to the cooperatives, two producers to Base Business Units inserted to the Productive Pole and 6 managers of the main entity. The application of this survey with the Iadov technique showed the following results.

The result of this validation shows that 51.3 % of the respondents express "clear satisfaction" and 30.8 % argue that they feel "more satisfied than dissatisfied" with the implementation of the system of prospective actions of Environmental Management for disaster risk prevention in the "Hermanos Barcón" Productive Pole of Pinar del Río.

The Group Satisfaction Index achieved is 0.6, which means an index of satisfaction with the proposal, considering that the Iadov technique establishes the range of 0.5 to 1 as an indicator of satisfaction according to Fernández de Castro Fabre and López Padrón (2014), which shows a positive assessment for the implementation of the prospective actions system.

The respondents' main criteria in the open-ended questions on user satisfaction are:

- They consider that the system of prospective actions of Environmental Management contributes to increase the environmental culture and the resilience of the community of producers and managers to face extreme events and climate change.
- They express satisfaction with the proposed actions to contribute to the improvement of capacities to overcome the hazards, vulnerabilities and risks present in the agroecosystem of the Southern Plains of Pinar del Río, which is highly fragile in the face of extreme events.
- It is their judgment that the system of prospective actions can help mitigate environmental impacts and coping with extreme weather events on the surrounding ecosystem.
- They express that it can contribute to achieve more sustainable and resilient agricultural production in the highly vulnerable environment of the Southern Plains of Pinar del Río.

The study revealed that the farms diagnosed have a high level of risk and vulnerability, as they are located in an area that is highly susceptible to the effects of extreme events and the latent threats of climate change.

The system of prospective actions of Environmental Management for the prevention of hazards, vulnerabilities and risks to disasters, achieves with its application a greater preparedness to face climate change and, in turn, a greater capacity to respond to extreme events, given the increase of its resilience that guarantees the development of more sustainable agricultural and livestock productions.

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Conflict of interest

Authors declare no conflict of interests.

Authors' contribution

Tania González Vázquez and Raymundo Vento Tielve participated in the conception, study design and preparation of the draft.

Carlos Llanes Burón participated in the research design and interpretation of the data collected.

All the authors reviewed the writing of the manuscript and approve the version finally submitted.

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