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Sustainable Environmental Education, Multidimensional Vulnerability, and Climate Change: A Necessary Integration at the Local Level in the Municipality of Guamá

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Abstract

According to the Centre for Research on the Epidemiology of Disasters (CRED), in 2023, Latin America and the Caribbean were affected by 67 climate events—a reality from which Cuba is not exempt. In this context, multidimensional vulnerability at the territorial level reduces the population's capacity to cope with climate change. One such territory is Guamá, a coastal municipality whose vulnerability demands a more sustainable environmental education (SEE) focused on collective adaptation to the effects of climate change. Therefore, the objective of this study is to assess the relationship between SEE and multidimensional vulnerability in the face of climate change impacts in the municipality of Guamá, Santiago de Cuba. To achieve this objective, the research employed survey and interview methods. The survey sampled 100 individuals from a total population of 2,897 families in the municipality. The interviews were conducted with 20 families experiencing multidimensional vulnerability in the area. The main findings of the research reveal regional climate variations such as increased drought periods and reduced fishing yields. In addition, vulnerability conditions that place families in unequal positions to adapt to climate

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change are highlighted, including habitat deterioration, subjective immunity, and insufficient capacity-building. It is concluded that SEE must integrate multidimensional vulnerability into its field of knowledge dialog in order to promote more ecological social practices at the local level.

Keywords
climate change, multidimensional vulnerability, sustainable environmental education, adaptation

Introduction

Environmental uncertainty is increasingly emerging at the international, national, and local levels, leading to serious disruptions in food, economic, social, and cultural systems due to the onset of climate change as a complex system. Although the 2030 Agenda for Sustainable Development fully acknowledges the negative effects of climate change (Economic Commission for Latin America and the Caribbean [ECLAC], 2023, 2024b), its impact on social relations under conditions of multidimensional vulnerability currently poses an undeniable challenge for environmental public policies. In this regard, the Intergovernmental Panel on Climate Change (IPCC) states that surface temperatures saw a notable increase during the 2011 to 2020 period, demonstrating a sustained upward trend since the 1970s (Intergovernmental Panel on Climate Change [IPCC], 2023).

Similarly, the National Aeronautics and Space Administration reported in 2024 the rise in the global annual mean temperature and its adverse effects on hydrometeorological conditions in the Caribbean region. These include the frequency and severity of tropical cyclones, intense droughts, and increased precipitation (ECLAC, 2024a; IPCC, 2023). International institutions such as the EM-DAT International Disaster Database from the Centre for Research on the Epidemiology of Disasters (CRED) indicate that Latin America and the Caribbean experienced 67 meteorological, hydrological, and climate-related events in 2023, causing substantial human, social, and economic losses as well as damage to natural resources and ecosystems (World Meteorological Organization [WMO], 2024).

Cuba is not exempt from this complex reality. As part of the group of 60 Small Island Developing States (SIDS; Extremera, 2024), the country exhibits significant fragilities or susceptibilities in coping with climate change—fragilities that are associated with economic, demographic, sociocultural, and habitat-related factors. In this sense, vulnerability is shaped by a complex multidimensionality that permeates the impacts of climate change across Cuban territories. These impacts stem from exposure to risks such as increased droughts, infrastructure deterioration due to flooding, and ecological losses in coastal areas caused by rising sea levels and coastal erosion (Cook et al., 2020; ECLAC, 2024a; IPCC, 2023).

One such territory is Guamá, a coastal municipality whose community-level vulnerability necessitates a more sustainable environmental education (SEE) aimed at adapting to the effects of climate change. Recent studies conducted in Santiago de Cuba (Borges et al., 2021; Ferrera Bergues et al., 2020) suggest the possibility of increasing frequency and intensity of meteorological events and their impact on Guamá's coastal area, which is already experiencing environmental, cultural, and economic susceptibility.

Given these conditions, SEE becomes an essential tool for building individual and collective capacities amid the ongoing crisis of ecological systems. As an educational, integrative, and interdisciplinary process, SEE in Cuba constitutes an urgent social necessity due to the country's geographic location—an archipelago situated in the tropical zone and subject to various environmental characteristics such as intense rainfall, prolonged droughts, and extreme events like hurricanes, all of which are exacerbated by climate change (Extremera, 2024; Ferrera Bergues et al., 2020).

This context highlights the relevance of this study, considering that the municipality of Guamá is not isolated from the socio-environmental vulnerability resulting from its location along the southern Caribbean Sea and its coastal positioning. These conditions make the region particularly susceptible to the adverse effects of complex environmental phenomena such as droughts, cyclones, and heavy rainfall.

To these habitat-related challenges are added demographic, sociocultural, and economic variables. Demographically, Guamá has a predominantly rural population (24,540 people, or 72.5% of the municipality's 33,836 inhabitants). Socioculturally, there is a prevailing notion of subjective immunity (Douglas, 1996), which underlies everyday social practices and limits both collective and individual adaptation to the impacts of climate change. Economically, the region faces issues related to deteriorating infrastructure, particularly in housing conditions. In this regard, 65% of surveyed individuals stated that poor housing maintenance exposes residents to environmental risks due to the region's recurrent climate events (National Office of Statistics and Information of Cuba, 2024a, 2024b).

The aforementioned variables—habitat, economic, demographic, and sociocultural—define the multidimensional vulnerability of the Guamá municipality, revealing that public actions aimed at fostering environmental education governance are still insufficient. Therefore, the objective of this study is to assess the relationship between SEE and multidimensional vulnerability in response to climate change impacts in the municipality of Guamá, Santiago de Cuba province.

The proposed objective is based on a theoretical framework comprising Leff's (2007) perspective on environmental knowledge as a dialogical, participatory process of constructing meaning around SEE. This education is self-produced within the SEIC system (social structure (S), natural resources (E), information and knowledge available on environmental issues (I), and systemic change (C); Giner, 2003), a sociological approach to understanding the effects of climate change in Guamá's coastal area. EAS and environmental knowledge are nuanced by two concepts that complement the theoretical framework: subjective immunity (Douglas, 1996) and multidimensional vulnerability (Espina, 2020).

Theoretical Framework SEE and Climate Change in Contexts of Multidimensional Vulnerability

At the United Nations Conference on Environment and Development—also known as the Earth Summit—held from June 3 to 14, 1992, in Rio de Janeiro, Brazil (United Nations, 2024), SIDS were identified as a group of developing countries characterized by social, economic, and environmental vulnerabilities. The latter represents a persistent risk for Caribbean island nations due to their geographical location, where the constant variability of climate conditions continues to intensify.

In this regard, 77% of the meteorological, hydrological, and climatic hazards that affected Latin America and the Caribbean in 2023 were associated with events such as storms and floods (Salazar-Xirinachs et al., 2024; Van der Borght et al., 2023; WMO, 2024). Of the 909 victims affected by these phenomena, 55% were due to floods and 27% to landslides (WMO, 2024), significantly impacting the quality of life in countries exposed to environmental risks due to their location in the Caribbean.

Recently, Cuba was struck by two strong tropical cyclonic systems, Oscar and Rafael, which caused loss of human life as well as extensive damage to physical infrastructure, agriculture, and the electrical grid in both the western and eastern regions of the country (Ramos, 2024). This complex climate reality demands stronger environmental education whose sustainability promotes adaptation to climate change by social groups and communities living under conditions of multidimensional vulnerability.

For Cruz and Páramo (2020), Pataca Rodríguez and Flores (2022), the Latin American and Caribbean Environmental Education Training Network (2023), Bos and Schwartz (2023), Quintero and Solando (2024), and Medina-Arboleda and Páramo (2024), SEE is understood as a sociocultural learning process that fosters the development of behaviors in individuals for the care, protection, and sustainable conservation of ecosystems. This educational effort requires the internalization of norms, values, knowledge, and skills aimed at shaping more sustainable ecological practices.

SEE also has the capacity to generate environmental knowledge focused on identifying local issues or opportunities that enhance or harm the sustainability of the current ecological system (Medina-Arboleda & Páramo, 2024; Quintero & Solando, 2024). However, the understanding and adaptation to current climate events from the perspective of multidimensional vulnerability demands a theoretical framework that integrates not only SEE as environmental knowledge socially constructed by local actors but also analytical perspectives capable of addressing vulnerability conditions related to environmental habitat, demographic, economic, and sociocultural dimensions.

From this research perspective, four theoretical approaches are introduced to interpret the results of the fieldwork conducted in the municipality of Guamá:

1. Leff's (2007) theoretical concept of environmental knowledge as the epistemic foundation of sustainable environmental education.
2. The SEIC system, which frames climate change as a complex process involving the interrelationship between:

- S: social structure
- E: natural resources
- I: information and knowledge on environmental issues
- C: systemic change or environmental degradation (Giner, 2003)

3. The concept of subjective immunity (Douglas, 1996), which underlies the behaviors of individuals, groups, and communities when facing climate phenomena in Guamá's coastal territory.
4. Finally, SEE is shaped within multidimensional vulnerability (Espina, 2020), which involves challenges such as habitat degradation, infrastructure deterioration, and the sociocultural representation of climate change among the local population.

For Leff (2007), environmental education is a: "dialogical process that fertilizes reality and opens possibilities for it to become what it is not yet . . ." (p. 59). As a dialogical process, this form of education self-produces environmental knowledge, which emerges as a: "dialogue of knowledges, fostering the convergence of cultural diversity in the construction of reality . . . Environmental knowledge produces new social meanings, new forms of subjectivity, and political stances toward the world" (Leff, 2007, p. 55).

Undoubtedly, environmental knowledge acts as a symbolic mediation between social relationships and the ecological environment and is a fundamental component of SEE, particularly in contexts of multidimensional vulnerability.

As a transformative premise of environmental education, environmental knowledge is an integral part of the SEIC system, which includes:

1. Social structure as the space where multidimensional vulnerability takes shape, as a result of economic, cultural, and social inequalities.
2. Such vulnerability exists within an ecological environment where natural resources are increasingly scarce and polluted. In this regard, Espina (2020) defines vulnerability as a set of conditions that limit the ability of families, communities, and individuals to withstand or recover from the effects of a threat (environmental or climatic), take advantage of existing territorial opportunities, and access socioeconomic resources (such as education) that improve well-being.

In the case of Guamá, achieving SEE requires overcoming adverse conditions related to habitat, economy, and sociocultural factors that reduce the population's capacity to adapt to climate change.

3. This involves strengthening communication and access to environmental knowledge from within these multidimensional vulnerability situations. However, the dissemination of such knowledge is shaped by subjective immunity among social actors. This concept refers to the population's ability to

minimize negative outcomes and underestimate not only perceived controlled risks but also infrequent or non-recurrent events (Douglas, 1996).

4. These circumstances give rise to ecological practices that affect the livelihoods of coastal communities and hinder their capacity for recovery at the local level. Hence, it is essential not only to sustain environmental knowledge but also to minimize habitat degradation, infrastructure vulnerability, and subjective immunity as key sociocultural dimensions of vulnerability.

Methodology

The scientific research methods employed in this study were the survey and the interview. The survey was conducted with the aim of collecting standardized information about the level of environmental education in the municipality, particularly in contexts of multidimensional vulnerability. A sample of 100 individuals was selected from the population of 2,897 families in the municipality of Guamá. The sample was chosen with a 10% margin of error and a confidence level of 95.57%, based on the characteristics of probabilistic sampling. Notably, random sampling was used, based on the principle that all individuals in the population have an equal probability of being selected (Hernández-Sampieri & Mendoza-Torres, 2018).

To ensure the validity and reliability of the survey, Cronbach's alpha coefficient was employed—a measure of internal consistency that assesses the reliability of the items in the instrument used for data collection. The coefficient value obtained was 0.711 (Table 1), a level deemed acceptable for this type of study, as supported by Pedhazur & Schmelkin (1991). Data analysis was conducted using the professional statistical software SPSS, version 25.

The interview was applied to 20 families in situations of multidimensional vulnerability in the municipality of Guamá, whose social dynamics produce and reproduce inadequate practices regarding environmental education. These families were selected through purposive sampling, where the strategic criterion of selection (Ruiz, 2012) was based on their vulnerability, determined by variables such as environmental habitat, economic status, sociocultural background, and demographic factors. It is worth noting that the selection criterion also incorporated assessments made by the Municipal Directorate of Labor and Social Security in Guamá.

In general, households experiencing multidimensional vulnerability face overcrowding and limited physical accessibility, infrastructure problems in housing, the presence of vulnerable groups, and women caring for these populations. These households are self-organized within climatic conditions that shape collective representations of environmental education, particularly in relation to the geographic risks of Guamá's coastal location.

The interview guide used with families aimed to explore their vulnerability conditions, the climate changes observed in the region, and how the population responds to these changes. The key questions included:

Table 1. Reliability Statistics.

Cronbach's alpha	Number of items
.711	71

1. What issues define the vulnerability of families in this area?
2. How do you assess the preparedness of these families for environmental phenomena such as cyclones or hurricanes?
3. What actions does your family take in response to such environmental events?
4. What changes or transformations have you observed in your community's environmental or climatic conditions?
5. What impacts have these climate changes had on your locality?
6. How would you describe the behavior of the population in adapting to climate change?
7. What factors influence the population's behavior in adapting to environmental phenomena and their impacts on the territory?
8. What environmental education actions are being carried out in your area in response to climate change?

Finally, the study was approved by the Ethics Committee of the Guamá Municipal Directorate of Labor and Social Security. All participants signed an informed consent form prior to inclusion, which explained the objectives and benefits of the research. Confidentiality was ensured by anonymizing both the data and the identities of the participants.

Results

The municipality of Guamá is located in the southwest of Santiago de Cuba province. It borders the municipality of Segundo Frente and the province of Granma to the north, the municipality of Pilón (Granma province) to the west, Santiago de Cuba to the east, and the Caribbean Sea to the south. Guamá's total land area is 950.53 km², with a population density of 35.6 inhabitants/km², according to recent data from the National Office of Statistics and Information of Cuba (ONEI, 2024a). The population is composed of 33,836 inhabitants, of whom 17,542 (51.8%) are men and 16,294 (48.2%) are women (ONEI, 2024b). The urban area accounts for 27.5% of the population (9,296 inhabitants), while the rural area represents 72.5% (24,540 inhabitants).

As seen, the majority of Guamá's population resides in rural communities (Chivirico, Uvero, La Magdalena, La Plata, Ocujal del Turquino, Madrugón, El Francés, Aserradero, and Caletón Blanco), where multidimensional vulnerability presents risks associated with habitat, sociocultural, economic, and demographic factors. Below are the most significant findings concerning the relationship between SEE and climate change in local vulnerability contexts.

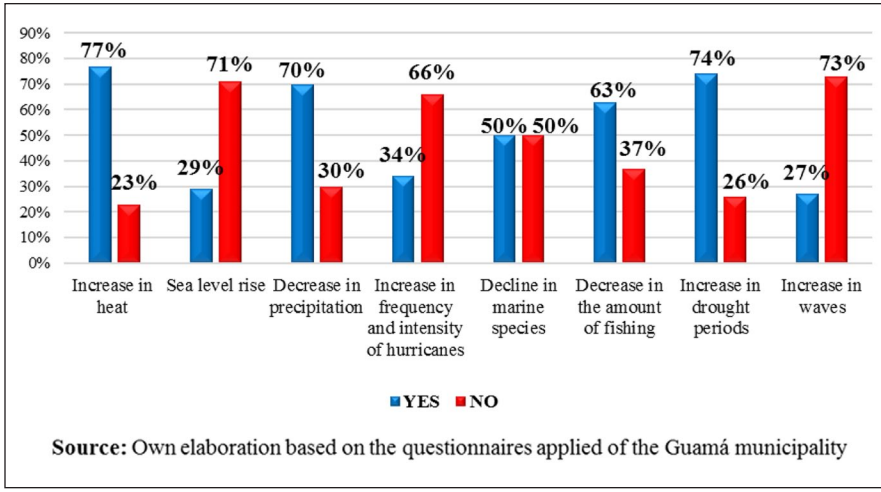

Figure 1. Changes in climatic conditions or habitat conditions in the territory.

Among the 100 respondents surveyed, 59% were women and 41% men. While both groups face the adverse effects of climate change in this coastal zone, women experience greater gender inequality when adapting to the complex conditions of their environment. Many rural women rely on the ecosystem for essential resources to carry out domestic tasks (e.g., water, food, cooking fuel). However, the degradation of terrestrial and marine ecosystems caused by climate change places women at a disadvantage relative to men.

The ONEI (2023) reports that 22.82% of rural women aged 15 to 74 dedicate more time to unpaid domestic and caregiving tasks than men (13.96%). Among people aged 15 and older, 34.1% of women report performing these tasks, compared to only 0.9% of men. Rural women also spend 38.33 hours per week on unpaid labor, compared to 23.45 hours for men.

Although both urban and rural women dedicate more weekly time to domestic and caregiving work, rural women exceed urban women by nearly 4 hours per week (34.97). In addition, rural women face greater challenges regarding infrastructure issues, electricity access, resource shortages, and geographical or environmental constraints. These include intense droughts and soil degradation that reduce crop yields, as well as hurricanes that damage agriculture and public services infrastructure.

From an intersectional perspective, the gender inequalities characterizing rural life in Guamá's coastal zones reveal two intersecting lines: first, social stigmas rooted in androcentric culture, and second, the unforeseen impacts of climate change on natural resources and the domestic sphere. These include declining food and water availability, and the degradation of marine ecosystems and their biodiversity. Figure 1 reflects these elements, the changes that have occurred in the climate, and the alterations linked to the environmental conditions of the community.

According to the SEIC system, the most notable climatic changes at the community level include rising temperatures, decreased rainfall, prolonged droughts, and declining fishing yields—all signs of environmental degradation in Cuban coastal communities. In Guamá, natural resources are increasingly depleted, directly affecting daily practices such as farming and fishing. These impacts are linked to land loss, mangrove destruction, flooding, and infrastructure damage (Ferrera Bergues et al., 2020; Godefoy Núñez et al., 2020).

Interviews with families in situations of multidimensional vulnerability confirmed these findings:

> We've definitely noticed changes; there's less fishing now, and the droughts last longer, which affects our crops. We try to adapt because with strong hurricanes and rising sea levels, we need plants that are more resistant to the climate changes (Family in a situation of multidimensional vulnerability).

These interviews align with survey results on the adverse effects of climate change in Guamá. About 66% of participants acknowledged severe environmental impacts; 20% disagreed, and 14% were unsure. The territory's high sensitivity and susceptibility to natural threats—such as flooding, strong winds, and heavy rain—have deteriorated local infrastructure and generated multidimensional vulnerability tied to economic, sociocultural, and demographic factors.

Interviewees recognized these vulnerabilities, stating:

> There are families in the community that are vulnerable . . . they have economic problems and some don't work. We ourselves live in overcrowded conditions, and the environment isn't great, especially the condition of the house. I also have elderly relatives who need constant care (Family in a situation of multidimensional vulnerability).

As shown, multidimensional vulnerability self-organizes through the dynamic interplay of various factors (Figure 2).

As shown in Figure 2, the main determinants are:

- Economic conditions (62%), such as infrastructure, public services, and technical networks.
- Sociocultural factors (52%), including collective perceptions of climate change.
- Food security limitations (51%) that hinder families from withstanding extreme environmental events.
- Community and institutional capacity-building gaps (45%) for decision-making.

Additionally, behavioral factors influence how social actors adapt to climate change (Figure 3).

These include:

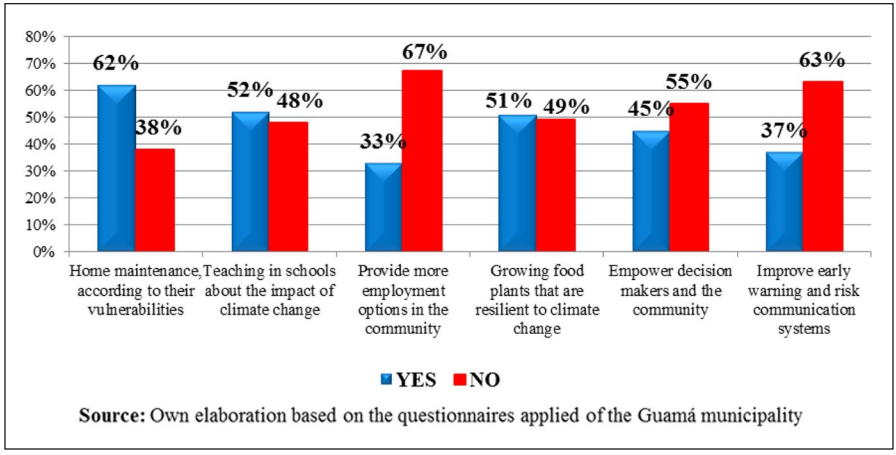

Figure 2. Vulnerabilities to climate change at the community level.

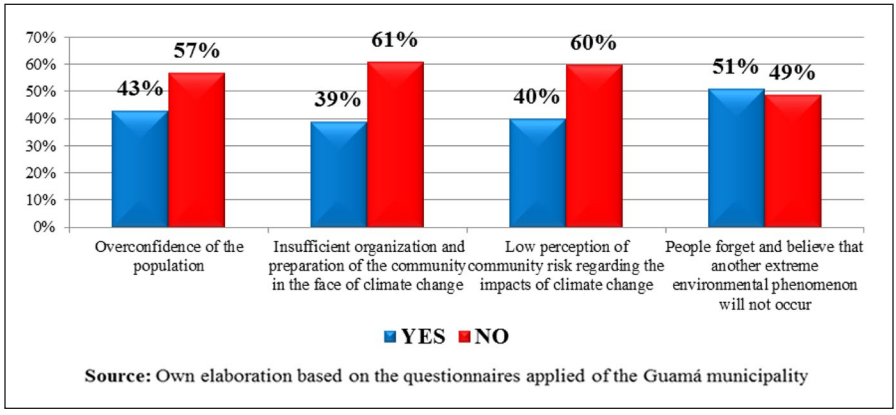

Figure 3. Factors that influence population behavior to adapt to climate change.

- Low risk perception (40%)
- Excessive confidence (43%)
- Collective forgetting or the belief that extreme weather events won't recur (51%)

Although the initial figures do not exceed those of the individuals who disagreed with these factors as drivers of behavior, they are significant enough to warrant attention in future SEE initiatives.

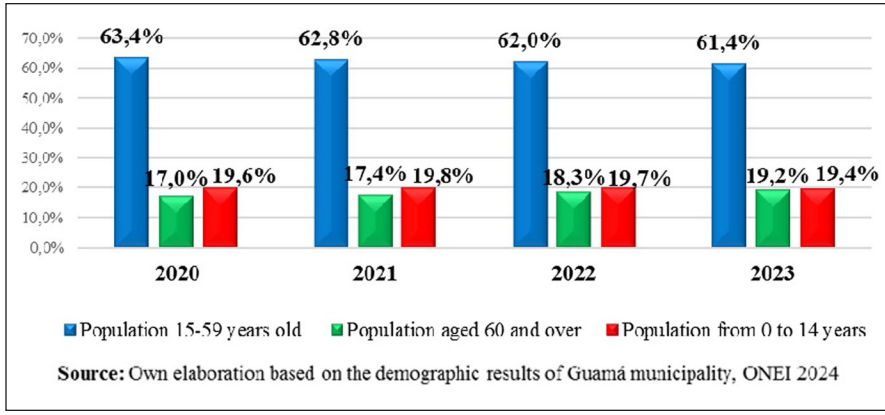

Figure 4. Degree of aging of the population and its trend 0 to 14 and 15 to 59 years, Guamá municipality.

The third factor—subjective immunity—is a key sociocultural dimension. It reflects the population's collective confidence in the face of complex environmental events (hurricanes, heavy rains, floods), forming part of daily life in Guamá. About 51% of respondents said no preparedness activities are carried out, while 49% believed they are. This suggests that subjective immunity emerges from a lack of preparedness for adverse climate effects in the municipality.

In October 2024, cyclonic activity exceeded historical averages (1991–2020), with 15 tropical storms, 10 of which became hurricanes. The index measuring storm duration and intensity reached 115%, well above the historical average for the June to October period (Cutié et al., 2024).

Despite this, the Cuban state has strengthened its environmental education and risk management systems, helping relocate vulnerable groups to safer areas in Guamá. About 69.5% of participants said that appropriate conditions exist; 30.5% disagreed. As a dialogical, subjective, and symbolic process, SEE produces new practices, relationships, and knowledge aligned with ecological commitment. However, environmental knowledge must emerge alongside transformative and participatory responses to multidimensional vulnerability at the local level.

Finally, strengthening SEE in coastal zones via the SEIC system requires incorporating sociodemographic factors into vulnerability analysis. These include the number of people requiring evacuation, labor resources available for climate adaptation, and public policy dependency on ecological security measures. Figures 4 to 6 summarize the sociodemographic factors that characterize multidimensional vulnerability in Guamá.

First, the data highlight the degree of population aging in the territory during the years 2020, 2021, 2022, and 2023 (Figure 4). Although Guamá is not among the most aged regions of Santiago de Cuba (the population aged 60 and over reaches 19.2%,

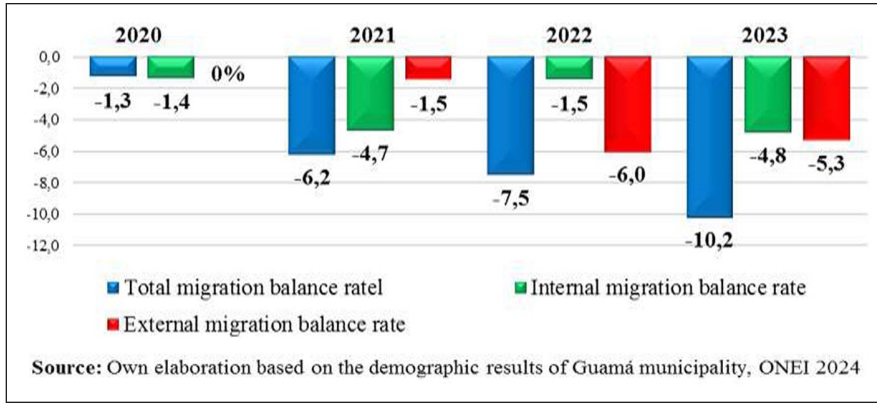

Figure 5. Total, internal, and external migration balance rate, Guamá municipality.

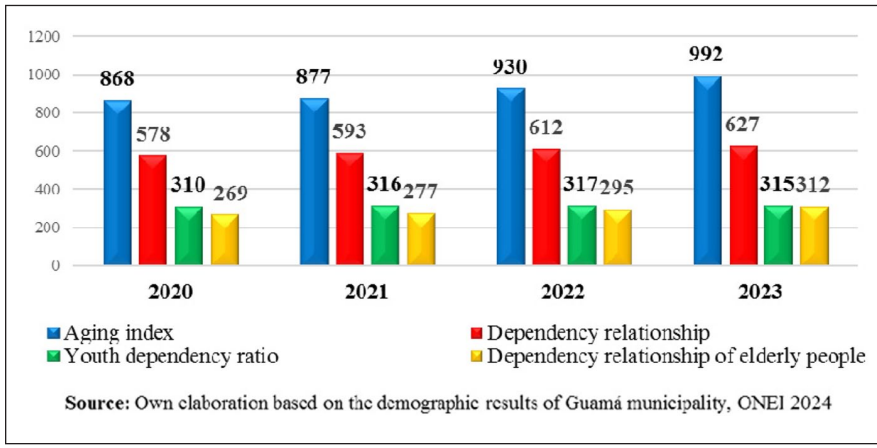

Figure 6. Aging index and dependency ratio, Guamá municipality.

below the provincial figure of 22.2%), it has experienced a slight increase over the past 4 years: 17.0% (2020), 17.4% (2021), 18.3% (2022), and 19.2% (2023). At the same time, the population aged 15 to 59 has declined—though not drastically—over the same period: 63.4% (2020), 62.8% (2021), 62.0% (2022), and 61.4% (2023). This age group is highly relevant to public adaptation policies and labor resources, particularly in terms of capacity-building and local recovery in response to extreme climate events.

Second, the municipality has experienced a negative trend in its total net migration rate over the years 2020 (−1.3), 2021 (−6.2), 2022 (−7.5), and 2023 (−10.2) (Figure 5). Within this rate, the figures for 2023 are notable, with external net migration at −5.3 and internal at −4.8. These variables explain the loss of population at the local level

within a broader context of economic challenges for the country. Similarly, the trend in net migration impacts the labor resources of the territory, thereby reducing the community resilience of social actors (individuals, groups, organizations, and institutions) in organizing adaptation strategies to climate change through SEE.

Third, the aging index in the municipality of Guamá (the ratio between people aged 60 and over and those under 15) has undergone changes in recent years. Although it does not surpass the aging index of the province or the municipality of Santiago de Cuba (1260 and 1327, respectively), the studied territory has shown a steady increase from 2020 to 2023 (Figure 6). This trend has implications for the municipality's dependency ratio, which has shown a slight upward trend over these years: 578 (2020), 593 (2021), 612 (2022), and 627 (2023). Similarly, the elderly dependency ratio rose from 269 in 2020 to 312 in 2023—an important factor to consider for local adaptation policies addressing climate change.

The trend observed in the dependency ratio within the municipality of Guamá will require greater integration among environmental education, multidimensional vulnerability, and the effects of climate change. This relationship will not only demand more economic resources or assets to protect the vulnerable population of the territory but also the incorporation of new symbolic assets and meanings to reconfigure environmental knowledge. Therefore, strengthening collective awareness and ecological knowledge through SEE emerges as a necessary strategy for fostering good practices in adaptation to extreme climate phenomena at the territorial level.

Discussion

Climate Change and Multidimensional Vulnerability: Integration Through SEE

Cuba's geographic location in the Caribbean places the island in an increasingly complex climate scenario that challenges both public policy and social actors. The damage to human life and material losses experienced across the country have led to the implementation of new socio-environmental strategies such as the State Plan for Climate Change Response and Law 150 of 2022, which regulates the management of natural resources and the environment. These economic, social, and legal instruments interact dynamically to protect human life and its quality under conditions of multidimensional vulnerability (Borroto Gutiérrez et al., 2022; Ministry of Science, Technology and Environment of Cuba, 2019).

However, for these socio-environmental strategies to be effective, they must be supported by SEE as an educational, comprehensive, and interdisciplinary process. As Leff (1998) asserts, this also requires local environmental management, understood as:

> The environmental knowledge of communities, where awareness of their environment, knowledge about the properties and sustainable management of their resources, symbolic formations, and the meanings of their social practices converge, integrating various processes in the exchange of knowledge about the environment (p. 131).

Among these processes are: the environmental knowledge of each community, cultural practices, traditions, experiences and skills in managing natural resources, shared meanings, and language. All these elements converge in SEE as a form of collective environmental awareness that fosters public decision-making. This awareness, in turn, contributes to shaping knowledge about the environment and the quality of life for social groups, particularly within contexts of multidimensional vulnerability associated with housing, economic hardship, demographic shifts, and sociocultural factors such as subjective immunity.

This highlights the importance of measuring vulnerability from a multidimensional perspective, using three key dimensions:

1. Exposure to environmental risks.
2. Sensitivity or fragility of families and communities to extreme events.
3. Adaptive capacity or self-organization to overcome crises (economic, environmental, or social; FAO et al., 2023; Valderrama-Guevara, 2023).

Multidimensional vulnerability is thus a social product—the result of dialogical interactions between various dimensions: economic and labor-related, health, sociocultural, educational, and institutional—conditions that shape the everyday reality of families and communities.

Agreement 9152 of the Council of Ministers (2021) defines vulnerability as a situation that:

1. Limits or hinders the capacity of a person, family, household, group, or community.
2. To anticipate, withstand, and recover from the effects of a natural, economic, social, or health-related hazard.
3. To seize available opportunities within their territory across various socioeconomic domains and relational networks.
4. To guarantee their subsistence, quality of life, and well-being or prevent their deterioration.

In Cuba, the State Plan for Climate Change Response (Tarea Vida) recognizes that several impacts will increase social, economic, and environmental risks at the local level in the coming years (Ministry of Science, Technology and Environment of Cuba, 2019). These impacts will mostly affect territories with high multidimensional vulnerability, particularly families and communities living under complex economic conditions. Key projections include:

– An increase of 0.9°C in the average annual air temperature, and a 1.9°C increase in the average minimum temperature, alongside a significant reduction in the diurnal temperature range.
– A decrease in cloud cover and increased solar radiation.

- More frequent and severe droughts, particularly in summer, occurring once every 5 years on average.
  - A rise in precipitation during the dry season and a slight decrease during the rainy season, especially in central and eastern Cuba.
  - Increases in sea surface temperatures and lower tropospheric temperatures.
  - Permanent loss of emerged land, potentially reaching 2.3% by 2050 and 5.5% by 2100—figures that may rise as studies on islets and cays conclude.
  - Marine intrusion vulnerabilities, currently affecting 574 human settlements and 263 water supply sources.

Public policies are already being implemented to promote adaptation in sectors like agriculture, given the threats posed by sea level rise and drought. According to Paz (2019), Borroto Gutiérrez et al. (2022), and Extremera (2024), some of these measures include:

- Strengthening links with productive entities to identify and implement adaptation strategies.
- Applying the Sustainable Land Management approach with an integrated vision of water, soil, and forest resources to support ecosystem services and food security.
- Land use planning and conservation, crop diversification, and the development of varieties adapted to changing climate conditions.
- The use of technologies to improve irrigation efficiency and water supply.

In the case of Guamá, the coastal population is the most susceptible social group to multidimensional vulnerability and the factors limiting adaptation to extreme weather events. The existence of vulnerable human settlements and infrastructure exposed to hazards such as rising sea levels and heavy rainfall represents a daily risk for those living on the coastline.

In this municipality, multidimensional vulnerability is self-produced through conditions that disrupt social relations. These conditions emerge from economic, labor, sociocultural, housing, and sociodemographic issues, all exacerbated by the impacts of climate change. Vulnerability in this context results from macro–micro interconnections and is organized through the interdependencies among:

1. Degree of exposure to environmental risks.
2. Levels of fragility or inability of households or communities to confront or recover from them.
3. The family and community resilience developed by social actors.

In this regard, capacity-building through environmental education becomes essential for enhancing the sustainability of resilience and adaptation to extreme environmental

events (Issue-Based Coalition on Climate Change and Resilience in Latin America and the Caribbean, 2024; United Nations Office for Disaster Risk Reduction 2020).

Thus, SEE should be viewed as a cross-cutting axis in the design and implementation of policies and actions aimed at protecting natural resources, individuals, and social groups. Climate change not only transforms the way of life in communities but also increases the vulnerabilities of diverse population groups, underscoring the need to strengthen local environmental knowledge.

This knowledge—or collective environmental awareness—makes it possible to disseminate and share information, generating new cultural patterns and social practices in the interactions with natural resources and the ecological environment.

Conclusions

The emergence of climate change in Cuba and its impact on the country's coastal areas demand the strengthening of connections between environmental education and extreme environmental events, particularly under conditions of multidimensional vulnerability. This type of vulnerability is shaped by variables such as economic conditions (e.g., infrastructure quality), environmental habitat, sociodemographic factors, and sociocultural dynamics, all of which produce measurable changes in local adaptation practices to climate change.

Due to its geographic location, the municipality of Guamá is not exempt from the impacts of extreme environmental events affecting the territory, population, and local economy. Coastal erosion, saltwater intrusion, and drought are among the phenomena generating serious environmental and social issues, including shoreline loss, salinization of household wells near the coast, crop failure, and damage to housing and infrastructure with physical and structural vulnerability, among others.

Many of these issues arise in contexts of multidimensional vulnerability, marked by exposure to environmental, sociocultural, economic, and demographic risks among Guamá's population. In this sense, various theoretical perspectives are introduced to examine the relationship between SEE and climate change in vulnerable contexts. These include Leff's (2007) sociological approach to environmental knowledge, the SEIC complex system that interrelates socio-environmental components (including multidimensional vulnerability; Espina, 2020), and the concept of subjective immunity drawn from Douglas's (1996) sociocultural framework.

From these theoretical standpoints, the results reveal territorial-level climate changes, notably rising temperatures, reduced rainfall, prolonged droughts, and a decline in fish stocks. Despite the impact of extreme weather events on the locality, the population's social practices are influenced by a collective construction of subjective immunity. Added to this are conditions of multidimensional vulnerability that place families in unequal positions to adapt to climate change. These include habitat deterioration, collective representations of environmental phenomena, and insufficient capacity-building, among others.

SEE incorporates environmental knowledge as a tool for developing collective environmental awareness among local social actors. This form of education must integrate multidimensional vulnerability into its dialogue of knowledge on climate change

to promote more ecological social practices and foster greater adaptation to extreme environmental events in the municipality of Guamá.

Limitations

The limitations of this study are associated with the emergence of other variables that may shape the multidimensional vulnerability of many families but were not addressed in the research. These include, for example: labor market integration, health status, and food security. The latter is particularly affected by climate-related transformations in the territory. Therefore, it is considered necessary to conduct future research on the effects of climate change on these variables and on the contributions of environmental education to the sustainability of good ecological practices that integrate them.

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