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The Incredible and Sad Story of Boca de Cachón: How a Rural Community in the Hispaniola Is in a Prolonged, Heartless, and Predictable Climate Crisis

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Abstract: This article aims to briefly review the socio-economic impact caused by the flooding of Lake Enriquillo on the inhabitants of Boca Cachón due to the complex local phenomenon related to climate variability. Between 2003 and 2014, Boca de Cachón and the communities surrounding Lake Enriquillo were deeply affected by flooding of the Lake's rising waters. Lake Enriquillo is the largest wetland in the Caribbean and the first designated RAMSAR site. In turn, Boca de Cachón could be considered the first human settlement formally displaced because of climate variability in the Dominican Republic and probably one of the first in the Americas in the twenty-first century. Boca de Cachón is a rural Municipal District located to the northwest of the municipality of Jimaní, with a population of around 3000 inhabitants on the southwest border with the Republic of Haiti and located in the Biosphere Reserve Jaragua-Bahoruco-Enriquillo. Given the future climatic scenarios for the Dominican Republic and the possible climate change that could exacerbate by excess or, by default, the socio-environmental problems in the Lake's belt, it is necessary to support the communities in their capacity-building processes. The lessons learned from Boca de Cachón can serve as a learning space for adaptation processes in rural environments in the Caribbean region.

Keywords: climate change; resettlement; rural environment; adaptation; Caribbean; Dominican Republic; Boca de Cachón

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1. Introduction

This article aims to review the case of Boca de Cachón, from a literature perspective, considering the point of view of the socio-economic impact caused by the flooding of Lake Enriquillo on its inhabitants. Boca de Cachón is a rural community located in the southwest of the Dominican Republic, in the heart of the Bahoruco-Jaragua-Enriquillo Biosphere Reserve (RBJBE), in the Dominican side of the border with the Republic of Haiti, the two countries that share the Hispaniola, the second island in size in the Caribbean region after Cuba and the first European settlement in the Americas. Boca de Cachón is a Municipal District located northwest of the municipality of Jimaní, the local capital of the Independencia province [1]. With a population of around 3000 inhabitants [2], this rural community has been amid a climate crisis little known in the world, but with important implications for the rural contexts of developing island states highly vulnerable to climate change and climatic variability, as is the case of the Dominican Republic (DR). Figure 1 shows the location of Boca de Cachón in the southwest of the DR and the communities in the surrounding of Lake Enriquillo, which in turn we will refer to them as the Lake's belt communities, affected by the flooding of Lake Azuei in Haiti and the flooding of Lake Enriquillo in both sides of the island [3].

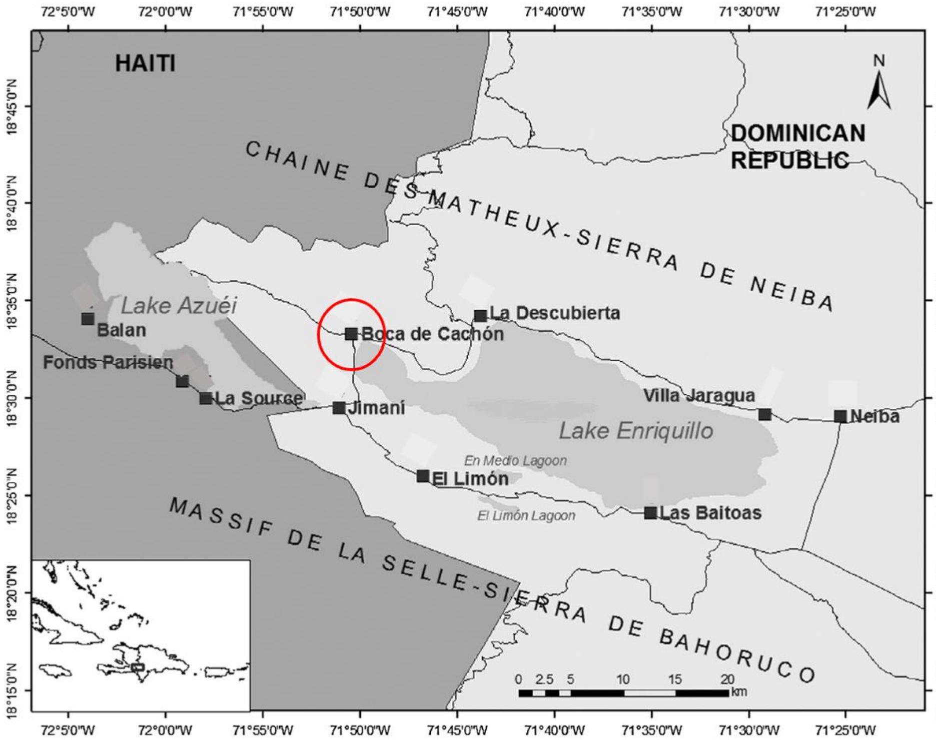

Figure 1. Boca de Cachón and lake belt communities. Source: Based on Sheller and León (2016) [3].

Between 2004 and 2014, Boca de Cachón and the Lake's belt communities were deeply affected by flooding of the Lake's rising waters [4,5]. In 2014 they became the first human settlement displaced due to the effects of climate change in the Dominican Republic (DR) and probably one of the first in the Americas in the second decade of the twenty-first century [6]. The DR is a developing insular country located in the Caribbean, which, as has been stated, shares the island of Hispaniola with the Republic of Haiti. The DR has a surface area of 48,670 sq. km., representing approximately two-thirds of Hispaniola and about 10.5 million [7]. The DR is the largest economy in Central America and the Caribbean, with a gross domestic product or GDP of over US $81 billion in 2018 and an annual growth rate of 6.6% between 2014 and 2018 [8]. The country is considered an upper-middle-income country with a gross national income per capita of around the US $7370. The DR is also considered a high human development country, as defined by the United Nations Development Program [9], despite the significant social distortions in poverty and income distribution [10].

A key issue is the sensitivity of the Dominican economy to the effects of climate change and climate variability. Still, this sensitivity is not new and is part of the general climatic vulnerability of the Caribbean region. Between 1999 and 2018, the Republic of Haiti was considered the third most affected country by extreme climate events, along with Puerto Rico and Myanmar, while the Dominican Republic was in the top 50 most vulnerable countries [11]. A 2015 World Bank study, in collaboration with the MEPYD, estimated the average annual economic impact of climate change at around the US $420 million, which was equivalent to 0.69% of GDP [12] (p. 55). According to the estimates, the impact of extreme events such as hurricanes and tropical storms could reach 3.3% of the GDP (around the US $1997 million), with a probability of occurrence of 5% each year [12] (p. 17). Table 1 shows a summary of the economic impact of the significant hydro-climatic events of the second half of the TWENTY-CENTURY and the first decade of the TWENTY-ONE CENTURY.

Table 1. Estimated Macroeconomic Impact of Major Hydroclimatic Events in the Dominican Republic.

Event	Year	Impact (US $ millions) *	% GDP
Hurricanes David and Federico	1979	1750	16
Hurricane George	1998	2624	14
Flooding of Rio Yuna and Rio Yaque Norte	2003	61.3	0.2
Hurricane Jeanne	2004	417	1.3
Tropical storm Noel and Olga	2007	437	1.2

* In 2005 dollars. Source: own elaboration based on TWBG, 2015 [12].

The report of the World Bank and MEPyD makes a complete account of the economic impact of extreme events in the DR. These events have positioned the DR as the 8th most-affected country (from a list of 183 countries) by climatic events with significant economic losses [12] (p. 11).

2. Methodology: Building a Context-Specific Approach to Complexity

In formal terms, this article arose from the need to provide the academic community with an ideographic or descriptive perspective of the Boca de Cachón issue [13], caused by the increase in the waters of Lake Enriquillo in response to a more complex phenomenon of climate variability. This ideographic approach, although it is part of incipient research on local dynamics of social adaptation to climate change in the Enriquillo region, was insufficient by itself, which is why and without trying to approach it for nomothetic purposes, as building a more heuristic and explicative background [14], it was amplified and enriched by the literature review and by defining an analytical framework based on a complexity approach, which rests on four elements highlighted in this section.

Thus, the departing point is to count with an instrumental definition of climate change which also covers climate viability. According to the Intergovernmental Panel on Climate Change (IPCC), in a broad sense, climate change refers to “any change in climate over time, whether due to natural variability or as a result of human activity” [14] (p. 871). It implies a wide range-perspective and a complex dynamic interaction of positive and negative feedbacks between climate, social, ecological, economic, and cultural structures at different levels, such as individuals, households, communities, regions, and countries [15,16], allowing us to put the Boca de Cachón case in the analytical context of climate variability, and then supporting a context-specific local-based understanding of complexity as a multiscale interaction of environmental and climatic factors. It includes a dynamic of multilevel interaction between positive and negative ecosystem services synergies with local [17], national, and regional climatic patterns and the socio-economic factors that interact with the ecosystems and local climate variability at the local level [18]. Four epistemic elements are considered to expose the complex approach to the Boca de Cachón challenge as a study subject:

1. The broader socio-economic context and the asymmetries in which Boca de Cachón is embedded at the regional and country-level
2. The landscape of the Jaragua-Bahoruco-Enriquillo Biosphere Reserve (RBJBE) that hosts the community of Boca de Cachón
3. The phenomenon of the rising water and flooding of Lake Enriquillo and their socio-economic impact at the local level
4. The complex dynamics of ecosystem services and their socio-economic interactions based on the local impacts of Lake Enriquillo flooding

To simplify the analysis but without falling into a reductionist perspective, it can be stated that the first two elements can be considered as given factors, somewhat exogenous and that they form part of the analytical context in which the Boca de Boca community is inserted. The third element, the phenomenon of the rising water, is the incidental factor, although not necessarily stochastic, that acts as a catalyst for the fourth element, unleashing a complex dynamic that relates ecosystem services with local socio-economic interactions [16]. The first three factors will be addressed as part of the same block in the third section, and the fourth will be treated separately in the discussion section due to its analytical implications. Therefore, this review exposes the socio-economic and environmental context in which the displacement of Boca de Cachón occurs to support two epistemic objectives. The first one is to increase our understanding of the complex socio-economic dynamics associated with climate change in a rural environment in the Caribbean region, which is one of the most sensitive locations to climate change [19]. The second is to provide a starting point for a broader development initiative related to studying the adaptation processes of the communities of the Lake's belt.

3. Results: Rising the Case of Boca de Cachón

Despite the remarkable advances in terms of economic growth of the DR and lesser impact but positive results in terms of poverty reduction and social inclusion [20], such advances have been seen to a lesser extent in the southwest of the country [21] and specifically in the Enriquillo region where the Biosphere reserve that hosts the Boca de Cachón is located.

3.1. At the South of the South: The Socio-Economic Context of Boca de Cachón

The Enriquillo Region, one of the ten regional divisions and has 368,594 inhabitants [22]. About 53% of its surface corresponds to a protected area, making it the largest area of protected ecosystems [23]. Based on the results of the poverty characterization study carried out by the Ministry of Economy (MEPyD) [21], the three most populated municipalities in the Biosphere Reserve have high levels of relative poverty. Such is the case of the Municipality of Pedernales, with 75.5% of households living in poverty, the municipality of Paraíso with 76.8%, and the municipality of Jimaní, which hosts Boca de Cachón, with 71% of households living in poverty. In addition, among the ten poorest municipalities in the country, three are found in the RBJBE: Cristóbal with 86.2% of households living in multidimensional poverty, Postrer Río with 82%, and La Descubierta with 78.8% [21]. Although general poverty in the Enriquillo Region is the highest among the four macro-regions of the country (30.2%), the aggregated data of the southern macro-region of the country, which includes the Del Valle, Enriquillo, and Valdesia regions, suggests a slight decrease in extreme poverty, going from 4.5% of the population in 2019 to 3.8% in 2020 [24]. It contrasts with the behavior from the other three macro-regions, in which extreme poverty increased because of the COVID-19 pandemic. The Eastern macro-region was the most affected one, where extreme poverty went from 2.8% to 4.9% of the population in the same period [24].

Despite the lights and shadows of the economic and social situation of the Dominican Republic, it contrasts substantially with the situation of the Republic of Haiti, the poorest country in the Western Hemisphere. With a history characterized by intense political, social, and economic instability and highly complex environmental problems, the Republic of Haiti constitutes a complex scenario to approach the climate vulnerability analysis, given its territory's political fragmentation in terms of governance [3]. Nevertheless, the two countries of the island share similar challenges in terms of the vulnerability to the effects of climate change and the sensitivity of their most essential ecosystems and primary economic activities, especially along the border of the two countries [3,25,26]. In this regard and returning to the sensitivity of the primary economic activities to climate change in the DR and the island, it should probably be pointed out that this sensitivity is more significant in poor rural communities around protected areas, which directly depends on the resilience of their ecosystem services, given the complex dynamic interactions at the local level between climate change, adaptation, and ecosystem services [27,28]. That is the case of the settlements around Lake Enriquillo and the communities in the Reserve of La Selle, where Lake Azuei is located, and which borders Lake Enriquillo on the Dominican side.

The socio-economic and political differences between the two countries also provoke different responses to the challenges of adaptation faced by communities and families [29], which in the Dominican case translated into a more significant presence and action of the state and local authorities in response to the flooding of Lake Enriquillo, unlike what happened in Haiti with the flooding of Lake Azuei. It is not about a better or a worse response, but about the existence of asymmetric capacities (governance, basic infrastructures, essential public services, financing, among others) on the two sides of the border that make a difference in the adaptive response to the challenges of climate change at the local level [3,16].

3.2. Biosphere Reserves and Protected Areas around Boca de Cachón

From the point of view of conservation, ecosystems, and the management of biological diversity, Boca de Cachón is located within the limits of the RBJBE. In collaboration with the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and its Man and Biosphere Program or MAB [30,31], the Dominican government created the biosphere reserve in 2002. It has an area of around 4858 sq. km, of which approximately 900 sq. km corresponds to the marine area [6,32]. Figure 2 shows the location of RBJBE in the DR territory.

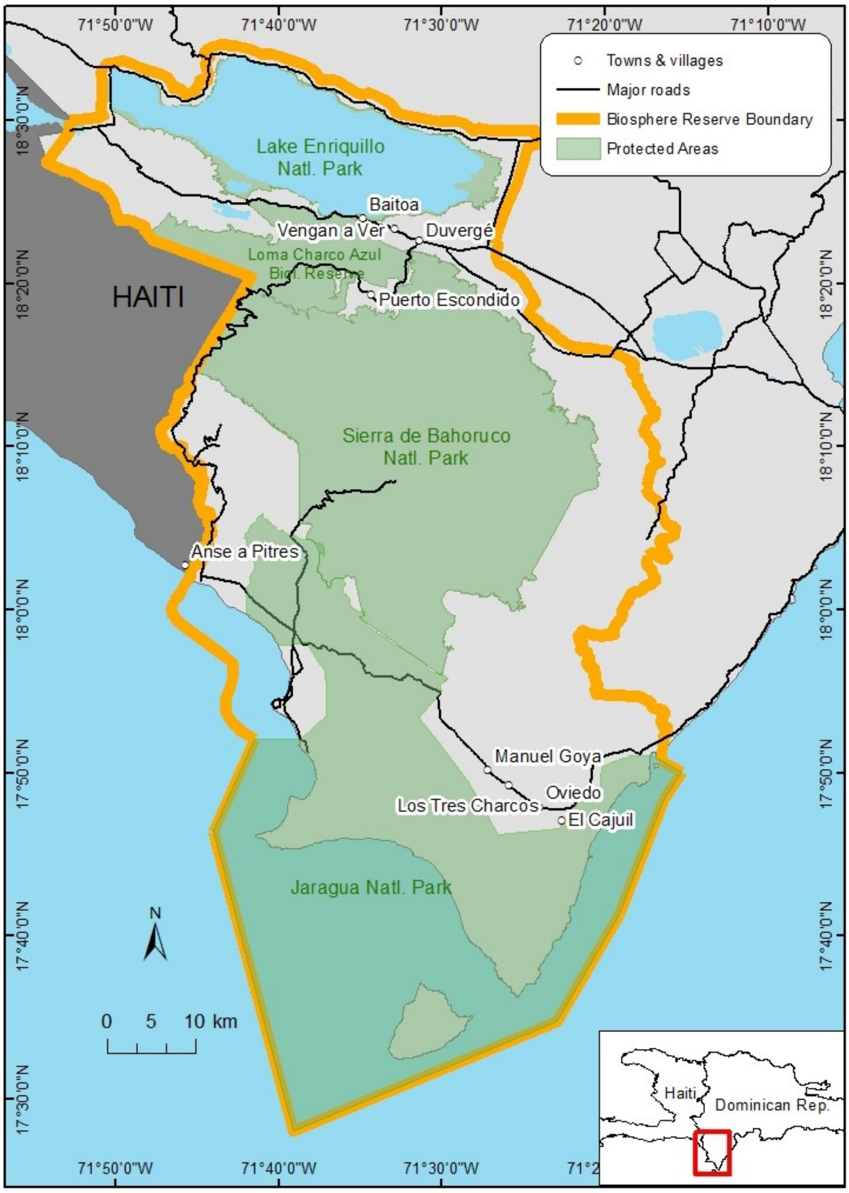

Figure 2. The Jaragua-Bahoruco-Enriquillo Biosphere Reserve in the DR. Source: Gómez-Valenzuela et al. (2021) [6].

The RBJBE has three main conservation zones. The first one comprises the national parks Lago Enriquillo and Isla Cabrito, where Boca de Cachón is located. Sierra de Bahoruco National Park and its surroundings comprise the second conservation area. Finally, the third conservation area is integrated by the Jaragua National Park, to the south of the Sierra de Bahoruco, occupies a substantial portion of the Barahona territory, and has a critical marine area that includes the Beata and Alto Velo islands, the southernmost points of the Island of Hispaniola and the Dominican territory [32]. Within the RBJBE is the Loma Charco Azul Biological Reserve, of high importance due to its biodiversity and other conservation spaces, natural resources, and high diversity of genes, species, and landscapes [33].

The RBJBE includes unique ecosystems and threatened species and islands, coastal-marine habitats, wetlands, dry forests, broadleaf forests, and pine forests [32]. The RBJBE also has a height gradient in the Hispaniola that ranges from 40 m below sea level (in Lake Enriquillo) to 2367 m above sea level (in the Loma del Toro of the Sierra de Bahoruco). Lake Enriquillo is the largest wetland in the Caribbean (about 330 sq. km.) and the first RAMSAR site in the region [34]. Lake Enriquillo and Isla Cabrito were created as national parks by Law 664 of 14 May 1974. The Lake contains archaeological heritage dating back to the pre-Hispanic settlements of different aboriginal cultures. Its surroundings contain important biodiversity that includes more than 65 native, endemic, and migratory birds, the endemic species of iguanas (*Cyclura cornuta* and *Cyclura ricordii*) [35,36], and the American crocodile [37]. Figure 3 shows some pictures with *Cyclura cornuta* around Lake Enriquillo.

Figure 3. The Lake and its iguanas. Pictures (**1**,**2**) show different perspectives of the scenic beauty of Lake Enriquillo, and pictures (**3**,**4**) captures two scenes of the interaction of *Cyclura cornuta*, one of the two endemic iguanas of the Hispaniola. Photo credit: VGV.

Based on a recent economic valuation of ecosystem services provided by the RBJBE [6], the provisioning and regulating ecosystem services were the most valued by the Dominican society, indicating the dual role of the biosphere reserve in providing natural resources for both primary economic and subsistence activities at the local level, and the recognition of its richness and unique biodiversity. There is no doubt that poverty constitutes a complex situation from the point of view of the management of protected ecosystems since controversial evidence points to benefits and costs in both directions, that is, in favor of the net benefits in terms of conservation derived from the establishment of protected areas [38,39].

3.3. Climate Variability and Socio-Economic Impact

Between 2003 and 2014, the surface of Lake Enriquillo began a period of expansion that resulted in its water level increasing from around 42 m below sea level in 2003 to 29 m below sea level in 2014, causing the flooding of cultivated land and human settlements around it [4]. As a result, the Lake's surface went from an average range of between 195–265 to 354–391 sq km in 2003–2014, reaching a maximum level in 2012–2013 [3,26]. Figure 4, from Moknatian et al. [40], shows the increase of the Lake's surface from 2003 to 2014. Between 2011 and 2013, the socio-economic impact was extensively discussed, and public intervention was initiated [40,41]. Since 2013, a gradual reduction in the area devoted to the Lake has been documented [42].

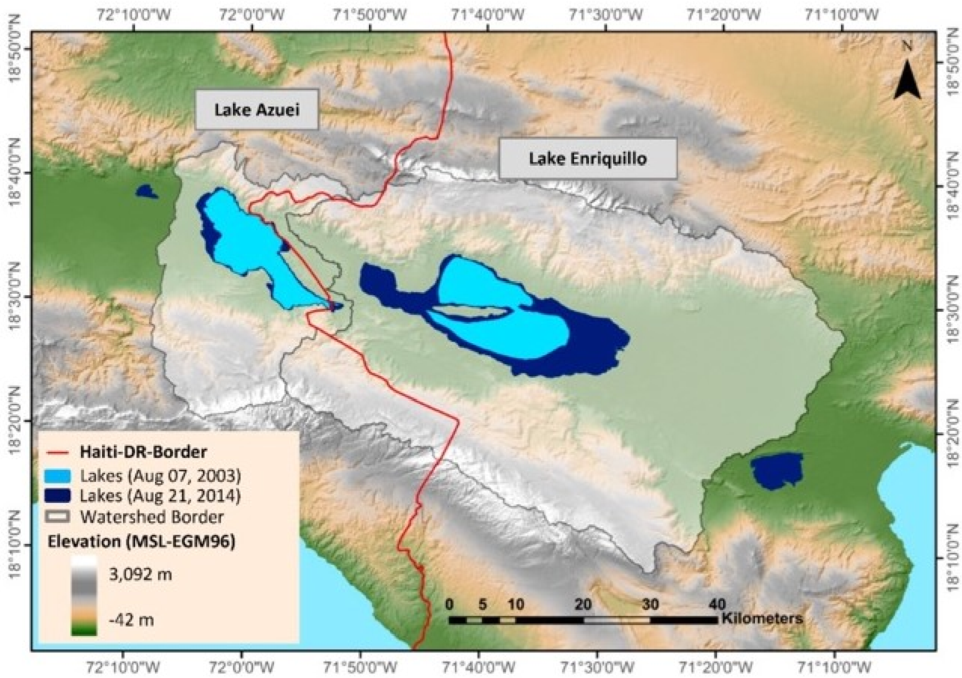

Figure 4. Increase of Lake Enriquillo Surface 2003–2014. Source: Moknatian et al. (2017) [40].

The causes of the increase in the Lake's surface are attributed to the accumulated effects of rainfall in its basin, the tropical storms and hurricanes that occurred throughout the decade, and the contributions from the Yaque del Sur River through the Cristóbal channel [4]. According to Herrera et al. [43], the projection of future hydroclimatic changes in the coming decades, especially at the end of the twenty-first century, indicates a significant and relatively homogeneous general trend favoring increased aridity Hispaniola due to a significant decrease in the average annual rainfall. Although these projections are made at a high level of resolution and require calibrations to adjust the local projections, these medium- and long-term projections point out an intensification of the vulnerability of regions and communities that are currently already suffering from climatic stress, as is the case in the region hosting Boca de Cachón. In sum, the climatic variability, and the change in the precipitation patterns in the basin, combined with the socio-economic vulnerability of the communities of the Lake's belt, may explain the Boca de Cachón climatic crisis. Figure 5 depicts yearly climatic data from the meteorological station of Jimaní located at 18°29′ LN and 71°5′ LW, provided by the National Meteorological Office (ONAMET). It shows the total rainfall in millimeters (mm) and the annual temperature average 2000–2020.

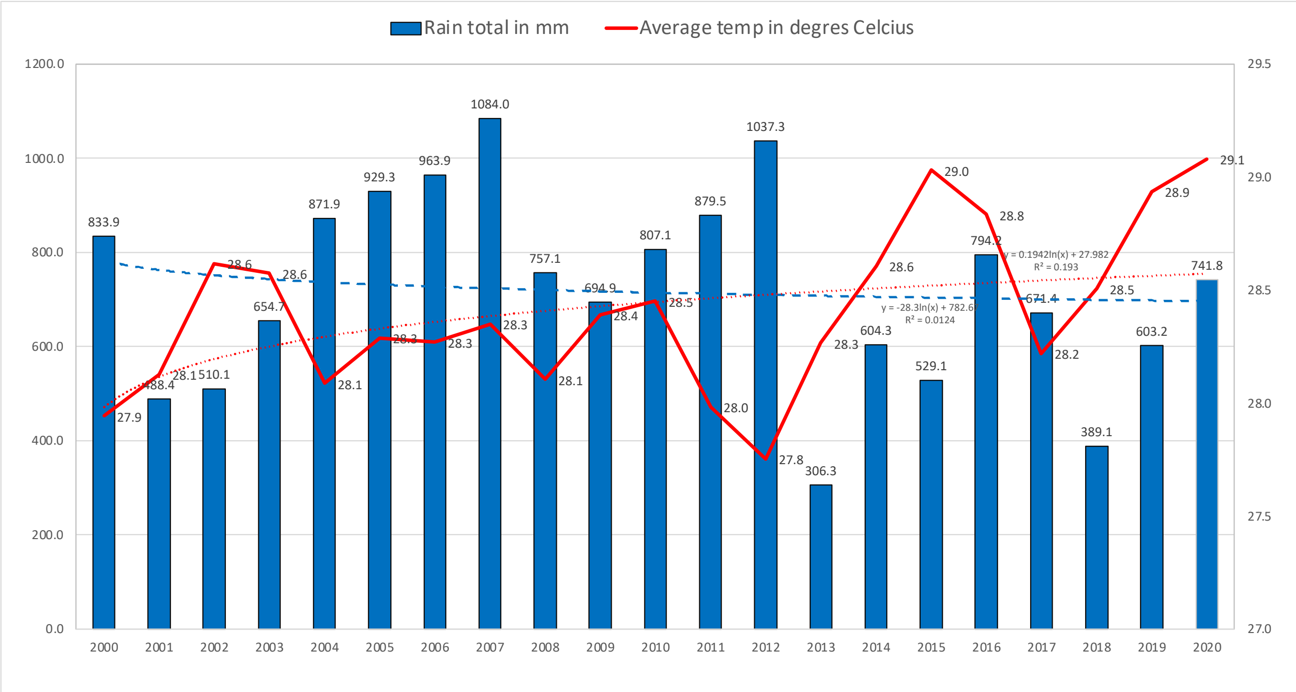

Figure 5. Climatic chart 2000–2020 rain total in mm and average temperature. Source: own elaboration with data provided by ONAMET.

It appears at first glance that the temperature and the precipitation data in Figure 5 refer to a dynamic of indetermination that hides the complexity inherent in each temporal sequence in which the temperature or precipitation event occurs, as it is recorded in the meteorological station of Jimaní. It constitutes something much more extensive than the data itself. It does not define a situation of analytical impossibility but encourages us to approach the case of Lake Enriquillo with a much more open and rigorous mentality. In general terms, the climatic data of Figure 5 coincides with the patterns indicated by different authors regarding the change in the long-term precipitation pattern predicted for Hispaniola and for the region in which Boca de Cachón is located [43], as well as the increasing trend of temperature [44], as can be seen in the logarithmic trend lines of both precipitation and temperature. A detailed review of the change in the precipitation pattern at national scale and its influence at the regional level (regions of the Dominican territory) can be found in Izzo et al. [44], highlighting the specific contribution of an accumulation effect derived from extreme climatic phenomena such as the Noel storm in 2007 [45]. The year 2007 was the year with the highest rainfall recorded by the Jimaní meteorological station in 2000–2020, as shown in Figure 5. The climatic evidence suggests that the year 2007 could be a turning point in the climate crisis of Lake Enriquillo due to the combined and synergic effect of the local impact of the rainfall caused by the storms Noel and Olga and its socio-economic impact.

In terms of the socio-economic impacts, the crisis caused by the flooding generated several social, economic, and political problems, both at the local and the national levels, given the considerable effects on traditional activities, such as agriculture, livestock, families, and communities. The situation led the government to issue a Presidential Decree (Decree 674-11) declaring a “state of emergency” for the communities in the Lake’s belt [46]. Figure 6 shows a composition of images giving an idea of the magnitude of the impact of the flooding of Lake Enriquillo.

Figure 6. Flooding in the lake belt. Pictures showing the rising waters of Lake Enriquillo. Photo credits: Eladio M. Fernández.

The socio-economic impact of the lake Enriquillo flooding has been challenging to estimate. However, based on restoration costs available, it has been globally estimated at between US $50 and the US $70 million [5,6,47]. The estimation considers the substantial losses in agricultural and livestock, with around 17,000 productive hectares affected, and private and public properties with severe damage. It has directly impacted the 22,000 inhabitants in the settlement surrounding the lakes, with an extended impact over the 122,000 inhabitants of the nine municipalities in the provinces of Bahoruco and Independencia [5]. This global estimate includes the Dominican government's responses to resettle and relocate Boca de Cachón, with an estimated investment of US $24.4 million [48]. Figure 7 shows pictures from the Old and the new Boca de Cachón, as well as some phases of the resettlement process.

Figure 7. New wines in old wineskins. Images of Boca de Cachón before and after. Picture (**1**) shows the effects of the Lake's rising waters in Boca de Cachón, and Picture (**2**) illustrates the situation before the population movement in "Viejo de Boca de Cachón," where most affected houses were destroyed. Picture (**3**) shows the housing project's final stage before its inauguration in 2014, and pictures (**4**–**6**) were taken in the summer of 2021. Image 6 shows the Boca de Cachón local spa, with sulfur water, cultural reference, and identity construction. Photo credits: (**1**): [49]; (**2**): [50]; (**3**): [51]; Photo credits pictures (**4**–**6**): V.G.V.

The consequences of this climatic crisis are numerous and extend beyond what is visible. First, there is the problem of floods, their tremendous socio-economic impact, and the associated uncertainties. Second, political action often leads to the physical destruction of memory, exacerbated by the mobilization of families and assets to a new location. Undoubtedly, and regardless of the attention given to the resettlement processes, like the one given to Boca de Cachón, we are in the presence of a profound social impact whose resolution requires a long-term commitment of the public institutions [52]. The inhabitants of Boca de Cachón have not been the first to move due to climate variability in the DR. The stories of thousands of refugees from Hurricane David and Storm Federico of 1979 still resonate like those of Hurricane George of 1998 and Storm Noel of 2007, among other more recent ones. However, the inhabitants of Boca de Cachón will possibly take with them the idea of climate refugees more clearly than the previous ones.

Finally, it was estimated that 575 households in Boca de Cachón were affected by the Lake's flooding at the local level. It includes 283 farmers, around 630 hectares of flooded cropland, and 135 cattlemen who indicated vast livestock loss [5] (pp. 16–17). Nonetheless, perhaps one of the most critical impacts may have occurred in a more intangible way, by splitting the local memories into two spaces: the Old Boca de Cachón and the New Boca de Cachón, the first remaining as a permanent memory of their loss under the Lake Enriquillo waters and the latter as a permanent reminder of the present and future uncertainties [53,54].

4. Discussion: Ecosystem Services and Local Interactions in a Rural Environment

In Boca de Cachón, agriculture and livestock were the activities most impacted by the flooding of the Lake, but also commercial and transport activities [5,41]. The impact of the flooding is directly related to the inability of producers to capture the benefits of the ecosystem services that sustain the affected economic activities such as agriculture, livestock, and others [28,55]. It also directly refers to the ecosystem services provided by the protected areas in the surroundings of Boca de Cachón, including provisioning services, such as the provision of fresh water for people and animals, animal feed, fibers for the manufacture of inputs, and various raw materials, among others; the regulating ecosystem services, including climatic stability, flood control, erosion control, soil conservation, regulation of water flow, among others; supporting ecosystem services, which include nutrient cycling, hydrological cycle, soil production, hatchery and habitat of species, among others, and finally, cultural services such as tourism, recreation, spirituality, scenic beauty, landscape, sense of belonging, and others [56]. The referred ecosystem services were severely affected by the lake flooding, an impact directly linked to the efficiency of productive activities and the welfare of the inhabitants of Boca de Cachón, affecting their social formation, economic structure, cultural identity, and sense of belonging, due to the intertwined relation between ecosystem services and welfare [57]. The literature suggests that in the case of agriculture and livestock in the Caribbean [19,58], especially in the insular developing countries, climate change and climate variability already have and will continue to have a significant impact on agriculture, fisheries, and other activities, primarily due to changing climate patterns, air surface temperatures, and factors such as water availability.

It is essential to highlight that in a context of high climatic stress, such as one characterizing the Lake Enriquillo basin, a complex local socio-economic-environment relationship tends to generate a complex interaction dynamic, positive and negative, between the different types of ecosystem services [17,59]. There could be synergistic or compensation effects or trade-offs in both cases, with the first consisting of the mutual benefit generated by the interaction of ecosystem services. The latter implies a possible win-lose situation or vice versa since the ability to obtain the benefits of a given ecosystem service reduces the possibility of obtaining other services [60,61]. Figure 8, taken from Power [17], shows the interactions between ecosystem services in terms of their synergies and trade-off (ecosystem disservices) based on a conceptualization of rural agroecosystem environment. The interactions and synergies indicated by Power in Figure 8 show a continuous cycle in which not only the different ecosystem services interact and generate synergies, but also trade-offs that could negatively affect ecosystem services, generating a state of imbalance that prevents local economic actors from capturing the benefits of agroecosystem services, thus affecting not only productive activities but also the well-being of communities. This description fits very well with the complex panorama experienced by Boca de Cachón.

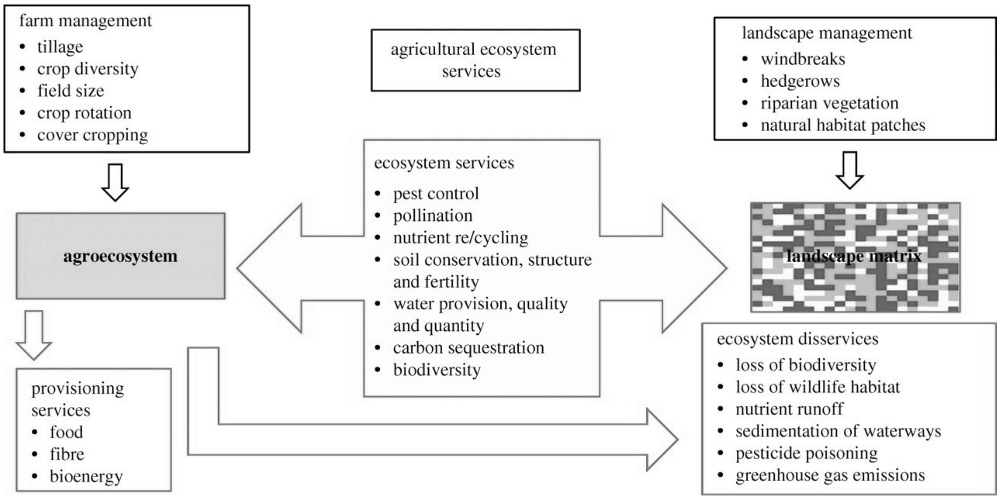

Figure 8. Synergies and trade-offs (disservices) in the rural farming environment ecosystem services. Source: Power (2010) [17].

From Figure 8, it is clear that interactions and feedbacks between ecosystem services at the scale of an experience such as Boca de Cachón, in which climate variability acts as a stressor combined with socio-economic pressure on natural resources, and the effects of the Lake's flooding, constitutes an opportunity not only for the development of future research lines but also to create a learning space on sustainability and resilience in rural environments related to protected areas and biosphere reserves [30]. In these spaces, the interactions climate, ecosystem services, socio-economic, and pressure, vulnerability create a highly complex warp. These elements create a perfect storm generating the climate crisis of Boca de Cachón. However, Boca de Cachón could serve as a rural living laboratory that provides a learning opportunity to better design public policies that strengthen local capacities for adaptation and mitigation. The message is simple: ecosystem services are not independent. They relate to each other in a non-linear way, understanding for non-linear interactions those in which the different components and services of the agroecosystem at the local level are "not directly proportional" [62] (p. 359).

The non-linearity of the local responses of the agroecosystems impacted by the Lake's rising waters constitutes a complex phenomenon based on unforeseen dynamics whose causes are not only climatic. It may occur as an aftermath of minor variations between the thresholds in which plants and animals and other agroecosystem components respond to environmental and climatic stressors [62]. Factors such as a change in the temperature patterns account for around 80% of the changes in ecosystem components, including its complex effects in moisture available for complex regulatory and supporting ecosystem services [62]. These responses could be found in specific areas of sensitivity and interaction between environmental, climatic, and socio-economic factors. Therefore, understanding the complexity of the interactions between the components and the ecosystem services and their reaction to variations in temperature and humidity is essential for the actors, especially the decision-makers, to maximize the opportunities and minimize the risks of climate vulnerability [16,17]. In the case of rural agricultural and livestock activities, the literature suggests that the problem can be analyzed as trade-offs between provision and regulation services [17], without neglecting other interactions with cultural and support services, which in the case exposed here are of high interest, given the socio-environmental context in which Boca de Cachón is embedded. Moreover, in the context of Boca Cachón, despite the need for further research, everything seems to indicate that the interactions of adverse effects occur between provision and regulation services, and it also includes cultural services, without ruling out other types of adverse interactions.

In any case, at the local level, the ability to capture the benefits of positive ecosystem services and minimize adverse offsetting effects will depend on the local adaptive capacity, which is a multiscale phenomenon for a much more medium-long-term perspective, accounting for the economic resources, technology, information and skills, infrastructure, institutions, and equity in supporting processes of adaptation to climate change, with sensitivity drivers in the connection zones in which individuals, families, productive systems, and social structures and networks overlap [18,59,61]. Figure 9 shows a primary perspective on the complexity perspective developed in this article concerning the Boca de Cachón case.

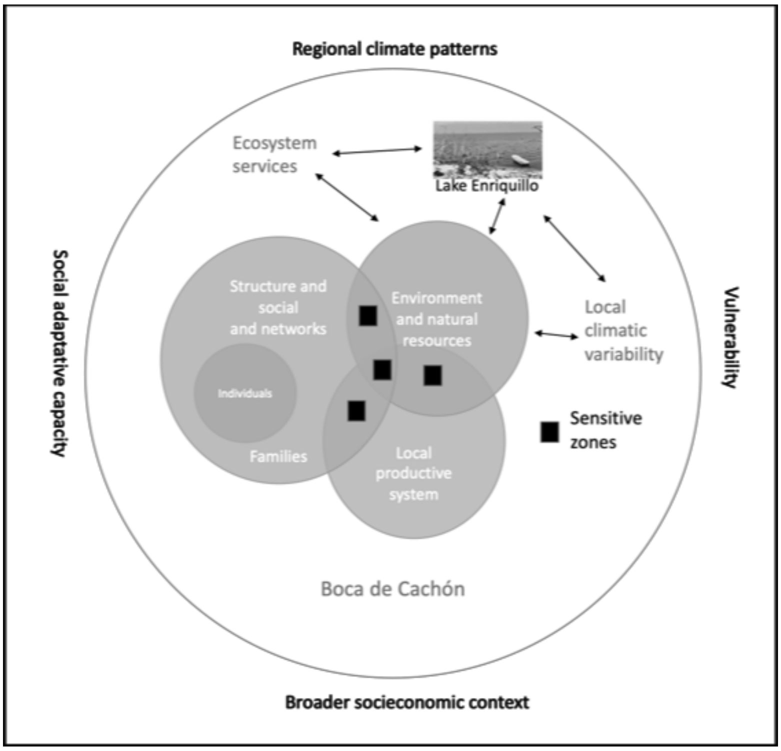

Figure 9. Boca de Cachón's complexity perspective. Source: own elaboration based on the conceptual review carried out through this article.

To conclude and in addition to the above considerations and given that Boca de Cachón is located within a Biosphere Reserve, the combined effects of social and economic pressure on biodiversity and natural resources relate climate variability with both provisioning and regulating ecosystem services, putting much more stress on the community coping capacity to deal with the crisis unleashed by the Lake Enriquillo floods. Coping capacity represents the social and physical resources available to face an emerging shorter-term crisis [63] (p. 351), which in the case of Boca de Cachón likely was increased and magnified due to resource limitations and probably a low local social adaptive capacity, unleashing high-stress drivers in sensitive areas where social, economic, and environmental factors overlap, as can be seen in Figure 9.

5. Concluding Remarks

The case of Lake Enriquillo as a study subject reveals it an incredible and insightful story hiding a highly complex local phenomenon. Its memory contains a cumulative, non-linear, and synergistic nature, whose measurable expression has accumulated drop by drop in the rain gauge of the Jimaní meteorological station, as well as degree by degree with each fluctuation in temperature throughout the days, weeks, months, and years, even prior to 2003 and 2004. All this is in an elusive game with an initially ambiguous but intuitive ending and with emergent connections between disconnected phenomena of social and human nature. Boca de Cachón has lived, currently live, and will continue living for the next decades amid a climate-based crisis. Thus, it is necessary to prepare and continue preparing the community for a transition and social transformation process, helping them become more resilient for inevitable future climate shocks in the Lake's belt.

From the first moments of the rise in the water level of Lake Enriquillo, between 2003 and 2004, to the accumulated effects of extreme events, such as Storm Noel in 2007, to the exacerbation of the problem in 2010, there was time to at least pay attention. Given the latter, it could be argued that the social costs of the relocation process of the Boca de Cachón could have been lower. However, that is not easy to pin down. The Boca de Cachón experience suggests that the biophysical and socio-economic-environment conditions combined in Boca de Cachón continue to be present in the Lake's belt, pointing out a possible increase in soil erosion and desertification accompanied by relevant changes in precipitation patterns. This experience should provide a learning space to advance in the readiness process and strengthen adaptative capacity at the local level. In this local context, adaptation could be defined as a learning process that is a function of the ability of individuals, families, communities, regions, and economic activities to adapt to the effects or impacts of climate change. Based on the climate future scenarios for the following decades, the socio-economic problem caused by the rising water of Lake Enriquillo, combined with the social vulnerability at the local level in the Lake's belt, could be one of many episodes of the climate crisis to come. Thus, to support a more inclusive, sustainable, and resilient economic growth model with impact at the local level, at least a medium-long term strategy is required, including strategic multiscale planning for local development, covering national and regional policy actors and local level. Becoming resilient goes together with a capacity-building process for local institutions and the human capital around the Lake's belt, creating new opportunities for technology transfer and innovative solutions for local challenges.

From the social point of view, a pending task will be to analyze the current situation of Nueva Boca de Cachón, considering general levels of satisfaction with the resettlement experience and the public investment in infrastructure and services aimed at improving their quality of life. It is a relevant point given the subversion effect that local political processes can have on the level of success of resettlement, to minimize unfair and maladaptive results, which can quickly occur in cases such as that experienced by the inhabitants of Boca de Cachón. A resettlement experience is usually traumatic at the level of individuals, families, and the community. Creating new spatially referenced identities (the new Boca de Cachón versus the old Boca de Cachón) can exacerbate inequality and fracture the social capital at the local level. Given the future possibilities that climate variability and climate change could exacerbate, by excess or by default, the socio-environmental problems in the Lake's belt, it is now necessary to accompany the communities in a capacity-building process that incorporates the lessons learned from Boca de Cachón. It is necessary to assume Boca de Cachón as a learning space for adaptation processes in rural environments in the Caribbean region.

A point of interest that will require further and a more specific research focus is the eventual interaction between the ENSO (El Niño Southern Oscillation) with the local climatic variability that contributed to the increase in the waters of Lake Enriquillo. ENSO is a complex phenomenon whose duration and intensity, as well as its alternation with La Niña as part of the same complex event, is affected by multiple factors such as the onset moment, the oceanic feedback of the temperature and evapotranspiration cycles, the temperature adjustments of the tropical Atlantic, and the cooling of the tropical Pacific, among other factors [64,65]. For now, this appreciation will require a very rigorous validation process. However, the facts could be interesting if the available climatic data in Figure 5 are compared with ENSO records of the first two decades of the twenty-first century. In the years 2004–2005 and 2005–2006, the ONI (Oceanic Niño Index) estimates two weak ENSO phenomena [66] (p. 5807), while in the years 2007–2008 and 2010–2011, two strong La Niña phenomena occurred, with the latter likely related to changes in the average conditions of the tropical Pacific, probably in response to global warming, as Marjani et al. point out [66]. Are these possible interactions just spurious coincidences? To what extent and scale could there be some interaction between the ENSO phenomenon and what happened in Lake Enriquillo? The answers to these questions are undoubtedly beyond the scope of this review article. However, it certainly opens the door to continue exploring the interactions and effects of highly complex phenomena, such as climate change and ENSO, concerning the non-linear effects on the local climate variability [67].

Some limitations derived from the scope and nature of the present study are as follows. First, it is necessary to exhaust a socio-environmental and economic evaluation of the current state of the Boca de Cachón resettlement from the perspective of the family units and their livelihoods. Second, the analysis of the synergies and compensations of the ecosystem services concerning local climatic stress and considering the environment as part of a biosphere reserve deserves more detailed attention, contributing to the territory's planning and management initiative along the Lake's entire belt. These lines of research are expected to be developed in the short term.

To conclude, the title of this article makes a literary reference to "La increíbe y triste historia de la cándida Eréndira y su abuela desalmada" (The incredible and sad tale of innocent Eréndira and her heartless grandmother) published in 1972 by the Colombian Gabriel García Marquez, Nobel Prize in Literature 1982 [68], one of the most influential authors of the Latin American boom and possibly the most conspicuous representative of the so-called "magic realism." The story of innocent Eréndira takes place across interwoven stories that have the Caribbean as a background, the same Caribbean Sea so close and far from Boca de Cachón at the same time. According to some authors, the Candid Eréndira narrates the complex relationship between an oppressor (the grandmother) and an oppressed (Eréndira) [69]. A predictable story like what happened in Boca de Cachón can turn into a drama with unforeseen consequences for individuals, families, and communities. Has Boca de Cachón been trapped in the no man's land of uncertainty? Is the Nuevo Boca de Cachón an attempt at emancipation or a new prison that traps the souls of its inhabitants? It is not easy to tell.

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