

Causes that provoked floods in Baracoa municipality after passing over of Hurricane Oscar

Factores que provocaron inundaciones en el municipio Baracoa luego del paso del Huracán Oscar

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Abstract: This paper discusses the reasons causing the floods that were generated by Oscar hurricane in Baracoa city in October 2024. The existing risks and vulnerabilities in the region were also identified based on the physical-geographical and geological conditions. Identifying and vulnerabilities will facilitate efficient risk management and more effective land management, ensuring the long-term sustainable development. The paper highlights the importance of resilient infrastructure, adequate urban planning and community awareness as vital steps for reducing vulnerability to future climate events to ensure a sustainable development of the region.

Keywords: climate change, tropical storms, natural disasters

Resumen: Se analizaron las causas que provocaron las inundaciones generadas por el huracán Oscar en octubre de 2024 en el municipio de Baracoa. Se identificaron las vulnerabilidades y los riesgos existentes en la región, teniendo en cuenta las condiciones físico-geográficas y geológicas. La identificación de peligros y vulnerabilidades facilitará una gestión de riesgos eficiente y un manejo del territorio más eficaz, asegurando un desarrollo sostenible a largo plazo. El estudio destaca la importancia de la infraestructura resiliente, la planificación urbana adecuada y la conciencia comunitaria como pasos vitales para reducir la vulnerabilidad ante futuros eventos climáticos, asegurando un desarrollo sostenible en la región.

Palabras claves: cambio climático, ciclones tropicales, desastres naturales

Introduction

The coastal floods in Cuba, depend on the meteorological system causing them, as well as the particularities of the affected geographic area (Hidalgo-Mayo & Mitrani-Arenal, 2022). The floods caused by rain represent one of the recurrent natural disasters in América (Guerrero *et al.*, 2025). The climatic change is influencing on the frequency of torrential rainfalls caused by rains due to atmosphere warming (Anchía & Quirós, 2022).

The abundant rainfalls in a short time period is one of the most frequent reason causing floods. Paucar, Paucar & Onofre (2024) likewise recognize the sea level increase, as well as the sea waves, systems or hydraulic structures failures, lakes floodings, as causes of floods. Other reported causes of floods are the geomorphology (Popolizio, 1986; García *et al.*, 2021), the damage of natural drainage systems (Fernández *et al.*, 2023), rivers floods (Anchía & Quirós, 2022) and deforestation or modification of the vegetal cover (Guerrero *et al.*, 2025).

At Cuba's eastern seashores, the meteorological systems that generate floods are the tropical hurricanes and the combination of high migratory pressures, combined with the the low extratropical events (Hidalgo-Mayo, Mitrani-Arenal & Pérez-Rivas, 2017). Baracoa's municipality floods have been documented by authors such as Hernández, Vega & Casals (2002), Hidalgo-Mayo, Mitrani-Arenal & Pérez-Rivas (2017), Perigó *et al.* (2020), Hidalgo-Mayo & Mitrani-Arenal (2022), Mitrani-Arenal y Cabañal-Infante & Hidalgo Mayo (2024).

Oscar hurricane of category SS-1, moved over Cuba's eastern region on October 20 and 21, 2024. It was characterized by a high volume of rainfalls at the intermountain zones (Ramos, 2025). Oscar hurricane caused coastal heavy sea and floods of between 3.7-5.0 m at Baracoa city.

This paper discusses the reasons that caused the floods in Baracoa's municipality, Guantánamo province due to Oscar hurricane in October 2024.

Materials and methods

Baracoa's municipality is located at Guantánamo province north seashore, at the eastern part of Cuba. It is Maisí municipality at the eastern region, at the south it is limited by

Imías and San Antonio del Sur municipalities and it is limited at the western region by Yateras and Moa municipalities (Figure 1).

Baracoa is characterized by an impressive diversity, based on physical-geographical, geological, geomorphological tectonic, climatic and hydrogeological terms.



Figure 1. Geographical location of Baracoa, Guantánamo province, Cuba.

Baracoa's topography is abrupt, with very few flat zones, about 95 % of the municipality's total area has a height relief, that is classified as premountains as, of small and low mountains. The relief is characterized by the existence of blades with slopes greater than 15 %, as well as the formation of several geological structures. The remaining 5 % is made up by a small coastal strip of 2 km width.

The distinctive feature of Baracoa's coastal morphology is the *tibaracones*, a raised area formed by a large bar or curtain of sand and sediments that the lively waves of the sea raise at the mouth of the rivers, parallel to the beaches; when the rains break, the rivers descend in floods whose waters are temporarily dammed by the curtain (Castellanos, 2021; Rodríguez, 2021; Acosta Abad, 2023).

Cuba's eastern territory morpho structural maps were consulted for Baracoa's characterization (Hernández-Santana *et al.*, 1001, Hernández-Santana *et al.*, 1995), Cuba's geological map (Baracoa sheet) (Instituto de Geología y Paleontología, 2011) and the hydrographical map proposed by Domínguez-González (2005).

The field work was performed in order to determine the effects caused by the floods associated Oscar hurricane.

Information was requested from CITMA's office in Baracoa, in order to obtain relevant data about the soil, vegetation and the climate of the area under study.

Discussion of the factors associated to the floods taking place at Baracoa's municipality

The vulnerability of the coastal regions before natural phenomena, such as hurricanes, is a topic of increasing concern globally (Rodríguez & Oreilly, 2023; Nájera *et al.*, 2023; Martínez, topography and, geography, vegetation, altitude over the sea level, as well as the human activities. As a whole, these elements interact in a complex manner by increasing Baracoa's susceptibility to floods.

Climatic change

The climatic change is one of the greatest catalysts of the floods, altering the meteorological conditions and increasing the frequency and intensity of the extreme climatic events. The global increase causes the evaporation of big quantities of water, increasing humidity that increases moisture in the atmosphere and causing more intense rainfalls. The climatic change greatly affects Cuba's seashore (Pérez-Parrado, 2019; Perigó *et al.*, 2020; Lam, Casas & Garea, 2024) causing the sea level increase and increasing the vulnerability of these zones before adverse climatological events.

Oscar hurricane caused torrential rainfalls, water volumes that oversaturated the soil, causing severe floods. Also, sea warming provides more energy to the hurricanes, which intensifies their destructive capacity.

Topography and geography

Baracoa's topography is essential in order to understand the vulnerability of the region. Its location in a basin surrounded by mountains causes the rain water to build up quickly and effectively. During Oscar hurricane, the intense rainfalls, generated by the meteorological system, combined with the slopes, caused an accelerated water runoff towards the valleys and populated areas. This phenomenon caused sudden floods, that affected both infrastructures, as well as the people's daily life.

Baracoa's geography that is characterized by its direct access to the sea and its exposition to hurricane winds, was also a determining factor. The proximity to the ocean increases the impact of the storms, increasing not only the risks of heavy seas but also cyclonic waves. These conditions exacerbate the effects of flooding, as seawater can mix with rainwater, hindering the natural drainage of wastewater and causing significant damage to urban and rural infrastructure.

Rainfall

During Hurricane Oscar, Baracoa experienced extraordinary rainfall over a 24-hour period. This volume of rain was not only exceptionally high but also occurred in a short time, causing the soil and drainage systems to be unable to adequately handle the excess water. Low-lying areas and the Duaba and Miel river basins were particularly affected, with rivers rapidly overflowing and sweeping away infrastructure, farmland, and homes.

The impact of these intense rains was exacerbated by Baracoa's topography. The presence of mountains and hills facilitates the rapid runoff of water into low-lying areas, where it accumulates and causes flooding.

Rainfall also has a significant impact on soil and vegetation stability, which can increase the risk of landslides. In Baracoa, where deforestation has reduced the soil's capacity to absorb water and stabilize slopes, the rains from Hurricane Oscar triggered several landslides. These events not only blocked vital routes and destroyed homes but also added an additional layer of danger to the already complex flooding situation.

Soil permeability

Soil permeability is a crucial factor for water management. In Baracoa, it varies depending on the soil type, which is primarily alitic, ferritic, and ferralitic. These soil types are characterized by their high iron and aluminum content, giving them a denser, more compact texture. Due to their composition and structure, their water absorption capacity is limited, leading to increased surface runoff. During heavy rainfall events, rainwater does not easily infiltrate the soil but tends to accumulate on the surface. This surface water accumulation increases runoff, leading to rivers and streams overflowing and causing widespread flooding.

The passage of Hurricane Oscar caused the soil's capacity to absorb water to be rapidly exceeded, resulting in a massive accumulation of water on the surface. The Duaba and Miel rivers overflowed, flooding residential and agricultural areas and causing significant damage to infrastructure.

Deforestation

The vegetation plays an important role to reduce the damages. The forest areas and the mangroves may act as natural absorbers of big volume of water and retain big volumes of rain water. Losing vegetation due to deforestation or change of soil use, reduces the absorption capacity that increases the floods.

In Baracoa, deforestation for agricultural and other uses has reduced the vegetal coverage, which reduces the soil capacity for handling intensive rainfalls caused by hurricanes such as Oscar hurricane. The mangroves in particular, are essential to protect the coastal zones from the erosion and the cyclonic heavy seas but its degradation left these areas unprotected

Altitude over the sea level

The altitude plays an essential role in the flood's dynamics. The relationship between the sea level and the altitude is complex, mainly in less altitude areas and close to the seashore just as Baracoa city where the flooding risk is greatly increased.

The torrential rainfalls associated to the hurricane, caused rivers and brooks, increasing the situation in low zones. At the same time, the high areas, although they are less exposed to direct floods, they faced land displacement and quick water streams, that added other damages. As soon as Oscar hurricane got closed to the eastern seashores, the atmospheric conditions caused an increase in the sea level, combining it with the strong storm surge that accompanies these phenomena.

Human activity

The human activities such as urbanization and intensive agriculture, also greatly contribute to floods. The construction of waterproof infrastructure such as roads and buildings, limits the water infiltration into the soil, increasing the flow and overloading the drainage systems.

Also, the agricultural practices that requires to remove the vegetal coverage, as well as the intensive use of the soil, reduce the capacity to use water and makes water use more susceptible to erosion. The combination of compacted soils and without suitable drainage creates the required conditions for the floods, when heavy rains occur.

Effects of the floods caused by Oscar hurricane in Baracoa

One of the main effects of the floods was farming destruction, which were covered by water for several days. The soil saturation and the lack of a suitable drainage, caused excessive hydric stress on the plantations, resulting in the loss of banana, cocoa and other agricultural product harvests that are essential for the local economy. The loss of agricultural products did not only affect the agricultural production, but it also impacted negatively on the region feeding safety, because many agricultural workers depend on their crops for their daily feeding.

Besides, the floods in the crops, the stagnated water created the required conditions for the development of pathogens and plagues that damaged the plantations even more, which makes the existing problems more difficult. The mobilization of agricultural workers, as well as the access to their fields, were affected by the floods, which delayed the recovery and replantation works.

Another negative impact was the soil erosion, as the loss of essential nutrients. The strong rainfalls and the surface flow, removed the surface layers of the soil, that were rich in nutrient, leaving a less fertile land and unable for future crops. This erosion also affected the soil structure, making water retention more difficult and increasing the vulnerability for future floods.

Likewise, the hurricane caused a lot of trees falling, as well as the destruction of forests, particularly in areas where deforestation had already weakened the ecosystem resistance. The loss of fire coverage, does not only reduces the biodiversity, but also it increases the soil vulnerability to erosion, creating a difficult situation that may last years to be recovered.

On the other hand, waste handling, became an immediate objective and the plastics are removed by the floods that contributed to soil pollution and water bodies, which affects both public health as well as the surrounding areas. The late response and the lack of a

suitable infrastructure for wastes collection and deposition after hurricane may worsen the situation.

Resiliency, mitigation actions and adjustment

Based on the hurricane impact magnitude, it is essential to implement resiliency actions and mitigation actions in Baracoa. Improving the infrastructure, a suitable urban planning and enhancing community's awareness, are essential steps to reduce vulnerability, based on future climatic events. So, it is necessary to:

- Implement safer construction standards and infrastructures that must be resistant to climate, including effective drainage systems, are essential steps to minimize the damages for future events.
- Protecting the mangroves in order to use the beaches as natural barriers against the storms.
- Enhancing the education about risks and adapting strategies, may empower the local population to be properly trained before these natural events.
- Designing evacuation plans, as well as performing periodic training, are essential in order to assure that the community is properly protected

Conclusions

Oscar hurricane caused intensive floods due to the incapacity of the water drainage systems to handle the water volumes. The risks indicators for water floods in the study, show a high flooding probability of floods in low zones, as well as in the zones that are located close to rivers.

The physical-geographical and geological of the study area are unfavorable in a flooding event. So that it is evidenced that in the case of the soils which are mainly alitic and ferrallitic, they show a low permeability that worsen their occurrence.

Among the main elements causing the floods in Baracoa, due to Oscar hurricane, the climatic change, the abundant rainfalls, as well as soil permeability and deforestation and the human activities are observed.

The analysis of the present vulnerabilities in the municipality, has identified several critical points such as: poor drainage systems, buildings that have been constructed

without considering the resiliency standards, lack of suitable emergency plans, as well as resources for the fast response.

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