Effects of the Sea Level Rise, a product of global warming, on the Cadastraland Population conformation of the Colombian Caribbean

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Key words: Climate Change, Sea Level Rise, Property, Multipurpose Cadaster, vulnerability.

SUMMARY

Progressive rise in average sea level due to anthropogenic climate change in the forty municipalities of the Caribbean coast will suffer the impacts of both marine transgression and an acceleration of coastal erosion (INVEMAR, 2017) where cities such as Cartagena and Santa Marta already suffer impacts such as flooding, and disappearance of beaches intensified by a drastic intervention in the natural coverage of the coast. This leads us to show strong socioeconomic inequalities in departmental capital cities, as well as physical ones, in areas with economic concentration that increase the vulnerability of properties and the effects on housing, real estate investments or the tourism sector, the impact on conservation areas as well as exacerbate the problem of land ownership and living costs. The area with the greatest vulnerability on the Caribbean coast is concentrated in the northern area of La Guajira and to the south in the municipalities of the department of Antioquia. Even so, the municipalities with the largest affected area or densely populated were chosen, showing particularities regarding the several types of effects. For example, the municipality of Coveñas (Sucre) where 1,199 properties would be affected by ANM by 2100, which represents 30% of the urban area, or the municipality of Sitio Nuevo, Magdalena, where more than 50% of the municipality is affectedby SLR by 2040.

RESUMEN:

El aumento progresivo del nivel medio del mar debido al cambio climático antropogénico en los cuarenta municipios de la costa Caribe sufrirán los impactos tanto de la transgresión marina como de una aceleración de la erosión costera (INVEMAR, 2017) donde ciudades como Cartagena y Santa Marta ya sufren impactos como inundaciones, y desaparición de playas intensificadas por una intervención drástica en la cobertura natural de la costa. Esto nos lleva a evidenciar fuertes desigualdades socioeconómicas en las ciudades capitales de departamento, así como físicas, en las zonas de concentración económica que incrementan la vulnerabilidad de los predios y las afectaciones a la vivienda, las inversiones inmobiliarias o el sector turístico, el impacto sobre las áreas de conservación así como agudizan el problema de la tenencia de la tierra y los costos de vida. El área de mayor vulnerabilidad en la costa Caribe se concentra en la zona norte de La Guajira y al sur en los municipios del departamento de Antioquia. Aún así, se escogieron los municipios con mayor área afectada o densamente poblados, que presentan particularidades en cuanto a los diversos tipos de afectaciones. Por ejemplo, el municipio de Coveñas (Sucre) donde 1.199 predios estarían afectados por ANM para el 2100, lo que

representa el 30% del área urbana, o el municipio de Sitio Nuevo, Magdalena, donde más del 50% del municipio está afectado por SLR para el 2040.

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1. INTRODUCTION:

The Institute of Geography Agustín Codazzi (IGAC), taking into account the National Development Plan (NDP) "Colombia World Power of Life" and the Sustainable Development Goals (SDG), seeks to analyze the possible territorial consequences (physical and economic) in the coastal urban area in the future due to the progressive increase of the SLR phenomenon generated by Global Warming and its probable consequences on human resettlement in coastal areas from the dynamics of community resilience.
Due to the progressive rise of the average sea level as a result of anthropogenic climate change, the 40 municipalities of the Caribbean coast will suffer the impacts of both marine transgression and an acceleration of coastal erosion, where cities such as Cartagena and Santa Marta are already suffering impacts as flooding and the disappearance of beaches, intensified by drastic intervention of natural cover of the coast. This leads us to evidence of strong socio-economic inequalities in the both capital cities as well as physical inequalities in areas with economic concentration that increase vulnerability and the effects on housing, real estate investments or the tourism sector, the affectation of conservation areas as well as exacerbating the problem of land tenure and living cost.

The most vulnerable area of the Caribbean coast is concentrated in the northern part of La Guajira and to the south in the municipalities of the department of Antioquia, even so, the municipalities with the greatest area affected or densely populated were chosen, showing particularities with regard to the different types of effects. For example, the municipality of Coveñas (Sucre), where 1199 properties would be affected by ANM by 2100, representing 30% of the urban area, or the municipality of Sitio Nuevo (Magdalena), where more than 50% of the municipality will be affected by ANM by 2040.

In conclusion, in the urban area there is a high impact of flooding, erosion and pollution. Which in some way is constantly being generated, as well as projects in coastal areas such as hotels and infrastructure to avoid the loss of beaches. Even so, over the years, urban areas will be destined to adapt their forms of habitat or being displaced to higher areas and inland. This work represents the possible replication of Multipurpose Cadaster data management to understand the spatial dynamics that the nation will face, with the knowledge of the territory, updating and sustaining the cadastral base being the pillars to face Global Warming and improve the resilience of the inhabitants of the Colombian Caribbean coast.

2. SOCIAL CONTEXT, CARIBBEAN COASTAL MUNICIPALITIES:

The area of the Caribbean coast since before the Spanish Conquest was populated extensively, evidenced by the chronicles where observations of culture, censuses and environmental descriptions, coasts and the great mountains of the Andes or plains and jungles of the “New World” (Arciniegas, 1862) marked the first information of the first settlers, which shows a broad interaction with the territory. Currently in the 40 municipalities of the Caribbean coast there are more than four million people according to DANE in the 2018 census, where the majority of the population is located in its three main cities of Barranquilla, Cartagena de Indias and Santa Marta. In the coastal areas there are also different zones of strategic importance for agricultural production and environmental conservation, as well as most of the densely populated areas that generate high demand for resources and critical cases of socio-environmental conflicts, especially in the areas of the swamps and the coal ports in Santa Marta.

Figure 1. Diagram representing the variations of the different moments of the beach formation due to the intervention of spurs in the Salguero Beach area (2023).

Figure 1, shows another problem that, together with erosion, could be the main cause of the loss of coastline in the future, together with ANM. It is the installation of infrastructure to preserve the beach service in the vicinity of condominiums or real estate investments, altering the dynamics of the beaches by confining the sediments to the opposite direction of the coastal drift current and increasing erosion in the direction of the current. In the image we can see different moments of erosion according to the moment of the construction of the spur, where it can be seen that it solves the problem of beach loss by transferring the problems of erosive processes to other sectors.

To explain the Geographical and Physical Context, it is valid to mention that, the Caribbean coast is located in the confluence zone of three plates: The Caribbean, Nazca and South American. As a consequence of this interaction, the regional macro-tectonic structure is governed by the Santa Marta - Bucaramanga fault, as part of the transforming edge on which the two plates are in contact. The fault has a lateral displacement of about 110 km and generally maintains a plane close to 90° (1993; in Royero and Clavijo, 2001), which in turn contributes to the orogeny of the Sierra Nevada de Santa Marta.

The Isthmus of Panama Formation which in turn conditions the circulation of the Panama gyre that distributes waters to the north and the Sinú prism extends from south to north from the Gulf of Urabá to the Magdalena sediment fan (Flórez, 2003), Regionally, the accretionary prism is the result of the subduction of the Caribbean plate to the South American plate and the beginning of the closure of the Central American isthmus since the Cretaceous, which generates a complex system of folds and thrust faults that condition the flow of sediments from the eastern side of the Caribbean basin.

3. THEORETICAL FRAMEWORK:

Risk is the state of a system to cope with a possible disaster situation, occurring within the geographical space, in the interaction of society with nature for a given period of time. Risk, therefore, is not limited to the magnitude or severity of a natural event, but depends on which elements of the whole are exposed to the phenomenon, how much it can affect them independently and how capable the elements of the system are of coping with the impact and overcoming it.

3.1 Risk Management:

Hazard is understood as the condition in which a phenomenon can negatively affect the elements of a system, in this case the phenomenon is the differences in sea level and the elements of the system that comprise the urban and rural areas of the Caribbean coast, which are the population including rural communities and the infrastructure, both housing and public works, roads, electricity and sewage networks, among others.

3.2 Climate change:

In the first decade of the 21st century, governmental organizations developed different manuals and guidelines to comply with the 2005 Yokohama Risk Framework and its subsequent UN Hyogo 2005 and Sendai 2015 versions in order to collaborate and strengthen climate change mitigation and adaptation. In the subject of risks and hazards in Colombia, some approaches to the study are made by different disciplines, from engineering (Darío, 2001) with the understanding of vulnerability, in geography (Hernández Peña & Vargas Cuervo, 2015) linking the perspectives of risk and its management in Colombia with development, Land use planning (González Largo, 2014) with the objective of incorporating GIS in the delivery of hazard categories from the category of land use plans and geology (Portilla, 2017) from the technical theoretical framework of risk among others, who have developed or supported different terms of reference documents.

This is to introduce climate change as the variation in the state of the climate, identifiable, for example by statistical evidence, in variations in the mean value or in the variability of its properties, that persists over long periods of time, usually decades or longer. Climate change may be due to natural internal processes or external forcing such as modulations of solar cycles, volcanic eruptions or persistent anthropogenic changes in the composition of the atmosphere through increased concentrations of greenhouse gases or land use. Climate change could modify the characteristics of extreme weather and hydroclimatic events in their average frequency and intensity, which will gradually be expressed in the spatial behaviour and annual cycle of these events. (Ley 1391 de 2018 Gestión Cambio Climático).

The main basis for understanding the different scales of the atmospheric and climate system comes from (Hays et al., 1976) and (Emanuel et al., 1985) and unified by (von der Heydt et al., 2021), added to the guidelines of (IPCC, 1992) for the analysis of climate change give us theoretical tools to understand the climate system from the temporality. Climate change simulations emerged as a measure of adaptability and the creation of projection scenarios (Jones et al., 1995). On the other hand, in Colombia there was interesting evidence of the effects of climate variability recorded by (Pabón, Jose Daniel; Montealegre, 2000).

3.3 Sea Level Rise (SLR):

The phenomenon of average SLR is caused by the average warming of the planet, which increases the presence of liquid water due to the melting of ice caps and thermal expansion, which allows the volume of water to increase and generates the phenomenon of marine transgressions. From a geological perspective, transgressions have occurred frequently due to abrupt changes in climate; in the case of the Cretaceous, they were characterized by increases in sea level, which generated different shallow water zones or epicontinental seas, according to (Boudagher, 2018). The same is true for the last interglacial periods, where static changes are evident in marine and terrestrial terrace geo-forms, one of the most evident examples in Colombia is the island of San Andrés, where the different changes of increase and decrease in sea level rise can be seen.

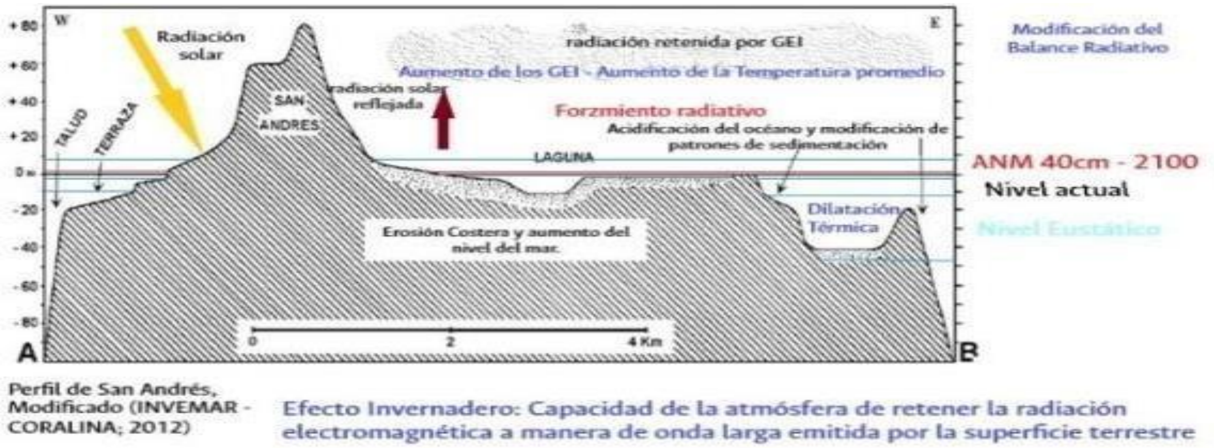

Figure 2. Diagram of SLR modifying the profile of the Island of San Andrés.

4. METHODOLOGY:

To characterize the extreme phenomenon from the physical perspective, spatial data from the INVEMAR sea level rise scenarios of 2040, 2070 and 2100 were used, giving the intensity of 18cm, 29cm and 40cm respectively. In addition to the physical, economic and environmental information treated from a holistic model. Economic, land value and estimation of the value of geo-economic homogeneous zones = 10%, socio- economic socio-economic strata and absolute population = 30%. Physical location with respect to the different hazard scenarios and number of floors = 10% and environmental change of coverage close to the coastline - mangrove = 50%, indicating the social conditions of resilience and vulnerability by commune, in the face of the extreme event.

5. DISCUSSION:

CO2 is the most studied variable to understand the climate change in the region. From the perspective of millions of years, climate changes triggered by volcanism or anoxic events can be similar to current climate change due to the modification of greenhouse gas concentrations, but with the difference of origin and speed in which it is evidenced as the cost erosion or melting of tropical glaciers, we will now look at how it can impact in the specific case of Cartagena (Bolivar) the rise in the average sea level.

Figure 3. Planet scope image with SLR scenario (2100).

Figure 4. Cartagena Aerial Photography (1954).

The historic city of Cartagena de Indias is one of the most important cities on the Atlantic coast of Colombia, and is a historical, tourist and cultural reference point for the region.

It has a population of over one million inhabitants according to DANE projections for 2023. In Figure 4 we can see an image of the city of Cartagena in the 1950's where a high level of human intervention is evident, and when compared with Figure 3, the strong urban growth is evident both in area and its interventions in the northern part of the marsh and the spurs in the coastal area. The large human intervention is evident, but how much would it affect the possible rise in sea level in the Cartagena area? Furthermore, which areas would be most vulnerable to sea level rise according to socio- economic or physical criteria, and how much would a new urban expansion of the city of Cartagena be favorable? In socio-economic terms, the north of the city is the most vulnerable area in terms of the phenomenon, as it is the area with the most in the north of the city, in socio-economic terms, it is the area most vulnerable to the phenomenon, as it has the least economically favorable neighborhoods.

Conversely, in the western area, although it has the best living conditions, the main economic resource is the beach service, which has a strong tendency to disappear, as well as being one of the areas with the highest property and commercial value of property in Colombia. Cartagena de Indias for the 2040 scenario will have a total of 166480 properties with a total of Medium Threat = 5830 properties and High Threat = 12525 properties. However, in order to define the likely future distribution of the urban sprawl in the city of Cartagena, it is necessary to consider both land tenure and environmental conditions that will allow for an increase in urbanization in the north-west of the city of Cartagena, as well as a likely acceleration of informality in areas such as the Popa hill.

6. CONCLUSIONS:

The updated multi-purpose cadaster base could be the first and essential measure of adaptability to climate change. To reduce these negative impacts, it is necessary to incorporate a variety of actions in the different instruments and levels of territorial and sectoral planning. Thus, for example, in the long term, such a reduction would be achieved by incorporating, or complementing and strengthening specific actions in the Land Management Plan, in the Watershed Management Plans, in the Integrated Water Resource Management Plans, in the Disaster Risk Management Plans and in the sectoral plans, among others. At the level of the four-year administration plans, consider the execution of these actions and ensure that the goals are met as progress is made through the Annual Operational Plans.

Vulnerability in the Caribbean coastal region in 20240 is high, where the main areas affected are urban areas with a population with little adaptive capacity, in addition to areas with little planning for these flooding events or heavy rainfall that would be intensified by ANM. In the different maps of both Hazard and Vulnerability it is possible to see the probable modifications in urban areas, where new locations can be seen both in an informal and planned way.

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