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Effects of climate change in the Coastal Area of Centla, Tabasco

Efectos del cambio climatico en la Zona Costera de Centla, Tabasco

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Abstract

Coastal areas are vulnerable to different environmental variations as a result of climate change, mainly due to their geographical location. This research aimed to identify and analyze the main effects of climate change through satellite images in the coastal area of Centla, Tabasco, where natural and anthropogenic actions such as the loss of coastline, erosion and increase in sea level sea have been the main effects and coastal accretion has occurred to a minimum. The analysis of the coastline was carried out over a period of twenty-seven years (1995-2022), using a free-use geographic information system such as QGIS version 3.28; To create the current coastline (2022), Sentinel-2 satellite images downloaded from the COPERNICUS platform were obtained with a combination of bands 8, 4, 3 with a spatial resolution of 10 m and the coastline (1995) of the author Santana, Hernández. The results obtained indicate that there are notable changes in coastal erosion that have affected and will affect the human settlements that are located near the coasts, the most affected being the town of El Bosque, where it was shown that in the twenty-seven years they have lost around 19 to 20 meters per year of coastline. It is necessary that for the implementation of a strategy or alternative the degree of impact is evaluated, depending on the place and what is most suitable for the inhabitants; Actions such as restoration and protection of mangroves, accommodation or withdrawal, construction of structures, as well as; coastal monitoring.

Climate change, Erosion, Geographic information systems

Resumen

Las zonas costeras son vulnerables a distintas variaciones ambientales a consecuencias del cambio climático, principalmente por su ubicación geográfica. Esta investigación tuvo como objetivo identificar y analizar los efectos principales del cambio climático a través de imágenes satelitales en la zona costera de Centla, Tabasco, donde las acciones naturales y antropogénicas como lo es la perdida de línea de costa, erosión y aumento de nivel de mar han sido los efectos principales y en una mínima parte se ha dado la acreción costera. El análisis de la línea de costa se realizó en un periodo de veintisiete años (1995-2022), utilizando un sistema de información geográfica de uso libre como es el QGIS versión 3.28; para la creación de la línea de costa actual (2022) se obtuvieron las imágenes del satélite Sentinel-2 descargadas de la plataforma COPERNICUS con una combinación de bandas 8, 4, 3 con resolución espacial de 10 m y la línea de costa (1995) del autor Santana, Hernández. Como resultados obtenidos indica que existen cambios notables de erosión costera que ha afectado y afectará a los asentamientos humanos que se encuentran ubicadas cerca de las costas, siendo la más afectada la Localidad de El Bosque, donde se demostró que en los veintisiete años se han perdido alrededor de 19 a 20 metros por año de línea de costa. Es necesario que para la implementación de una estrategia o alternativa se evalué el grado de afectación, dependiendo del lugar y lo más apto para los habitantes; se consideraron acciones como restauración y protección de manglares, acomodo o retirada, construcción de estructuras, así como también; el monitoreo de las costas.

Cambio climático, Erosión, Sistemas de información geográfica

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Introduction

The climate change refers to a variation in the state of the climate identifiable in variations in the mean value or in the variability of its properties, which persists for prolonged periods, generally decades or longer periods; It can be due to natural internal processes or external forcing, such as modulations of solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or land use (IPCC, 2018). In Latin America, important changes in precipitation and increases in temperature have been observed. Furthermore, changes in land use have intensified the exploitation of natural resources and exacerbated many soil degradation processes in recent decades (Magrin *et al*. 2007).

Coastal areas are vulnerable to different environmental variations as a result of climate change, mainly due to their geographical location. These variations can be such as hurricanes, floods, rising sea levels, and loss of coastal ecosystems, which makes them alarming for the population. located in these areas, therefore, the analysis of the coasts from the ecological, fishing, industrial, tourist and social point of view is important for humanity (Botello, 2014).

Processes in coastal environments are subject to changes that vary widely in geographic scale, time and duration, which when combined create systems that are biologically productive but vulnerable to environmental pressures from various human activities (Botello *et al.* 2010).

The coast is a wide area that includes coastal reliefs, cliffs, marine terraces and coastal plains, which are constantly transformed by the action of waves, coastal currents, tides, tectonic movements, sea level oscillations, erosion, fluvial accumulation and human activity (Kokot and Chomnalez, 2012; Torresan *et al.* 2012).

Despite the importance of coastal areas, these; Like other ecosystems, they are one of the most disturbed on the planet. Pollution, eutrophication, industrialization, human settlements, change in land use in the agricultural sector to make way for towns and cities, agricultural production, overfishing, flooding, among other factors, continuously impact the sustainability of the environment. coastal (Botello, 2012).

Therefore, this project aims to carry out an analysis of the climatic effects in the coastal area of Centla, Tabasco, identifying those effects that have generated the most relevance; Its importance lies in knowing that these are dynamic and are in constant movement, making the coasts prone to modifications. through satellite images of specific periods, where use will be made of geographic information systems, which will allow us to gather, manage and analyze data.

Methodology

To carry out the stated objectives; in this research project; Search managers were used to obtain reliable information related to the research topic, thus being a compilation of research articles, studies carried out, theses, as well as sources such as INEGI, CONABIO and COPERNICUS.

Satellite image processing

To determine the coastline from satellite images, this consisted of searching and downloading satellite images. The images were downloaded from the Sentinel 2 satellite of the COPERNICUS Program of the European Commission with an acquisition date of 2022 corresponding to the month of May, the coastline from 1995 created by the author José Ramón Hernández Santana was used.

The cartographic projection used for the study area was the UTM Zone 15 North on the WGS84 ellipsoid. Another important step was the selection of multispectral bands, the images used for the digitization of the coastline were the combinations of bands, a false color infrared composition was obtained with the combination of bands 8, 4 and 3 with spatial resolution of 10 m. The satellite images were converted to raster format and a shapefile corresponding to the coastline to be generated was generated.

Coastline generation

The QGIS 3.28 software was used to generate the coastline of the study area for the proposed year (2022) in order to determine the changes that have occurred in the twenty-seven years of difference from 1995-2022. The generation of the coastline corresponding to the year 2022 was carried out by creating a line chain along the entire coastal area in shapefile format.

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Coastline digitization

The digitization process was the obtaining of digital geographic information regarding the coast composed of vector layers. The satellite images were obtained from the Copernicus program of the Sentinel 2 satellite and the band combinations were made, the digital material corresponds to the entire coastal area of the municipality of Centla, the spatial resolution of the image obtained from the Sentinel 2 satellite is projected at 10 meters.

The high-water line (HLW) was used, defining it as the wet/dry limit and interpreting it as the line defined by the difference in color that marks the retreat of the tide following authors such as Dolan et al. (1978) who consider this indicator stable.

Coastline analysis

The analysis was carried out manually by measuring the differences in position between both lines from the period 1995 and 2022 on profiles drawn perpendicular to one of them, in order to determine points of coastal erosion and accretion.

Map editing

Maps of the points where greatest coastal erosion and accretion were determined were created for visualization, in conjunction with the line drawings, as well as the meters lost between both proposed years and the annual loss.

Proposal of alternatives according to current regulations

To fulfill this objective, a documentary review was carried out regarding public policies that were related to coastal zones; as well as national programs and research carried out on the management of coastal ecosystems, and the adaptation of a comprehensive policy; Finally, the analysis of the most suitable alternatives was carried out in the coastal area of Centla, Tabasco.

Results

It was possible to determine the erosion points on the coastline, due to natural effects but at the same time anthropogenic actions over the years at a global and local level have contributed to destabilization.

Thematic maps were generated that are useful to visualize the loss of coastline using both lines in which they were measured and the measurements in meters that represent the loss were obtained, and how much has been lost annually in the twenty-seven years since 1995 was also presented. -2022.

The coastline that includes the year 1995 was made by the author Hernández, Santana;2008 and taken to carry out the following analysis. While for the digitization of the year 2022 using a satellite image. European Sentinel 2 rasterized with a false color infrared (RGB 8, 4, 3) the coastline was digitized at a scale of 1:250000, which includes the entire coastal area of the Municipality of Centla.

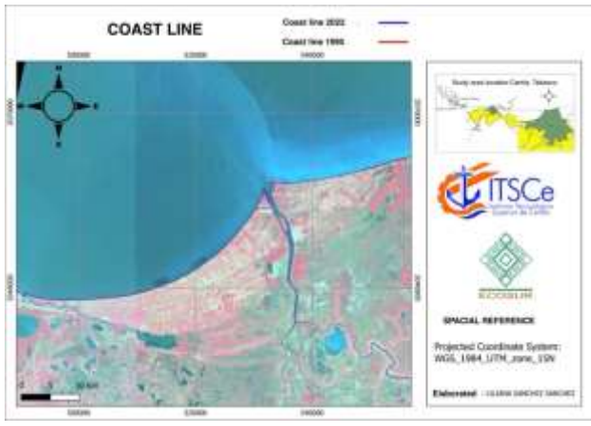

Figure 1 Coastline digitization 1995-2022, Centla, Tabasco, Mexico
Data: Information generated in the Geographic Information System Qgis 3.28

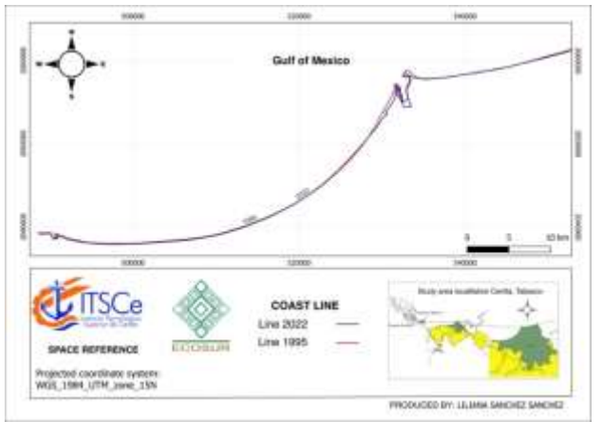

Figure 2 Union of coastlines 1995-2022, Centla, Tabasco, Mexico
Data: Information generated in the Geographic Information System Qgis 3.28

These are the main areas where erosion has had greater relevance throughout the established periods.

Coastline analysis due to erosion (1995-2022)

Derived from the influence of global climate change on the ocean level, which, in turn, are accelerated by human activities that consciously or not accentuate this indirect effect on the coastal system.

The erosion zones present retreat of steep cliffs with landslides, landslides and wear of the flat and shallow areas. In the accumulation zones, the sea deposits gravel and sand. The main driver of these dynamic transformations is the energy of the sea, through tides, waves and coastal currents.

The site with the greatest loss of coastline was identified as the coastal town of El Bosque. In what corresponds to the El Bosque Locality, two lines or transects were created considering the geomorphological changes it has had, and the amount of coast that has been lost and a transect in what corresponds to the river mouth.

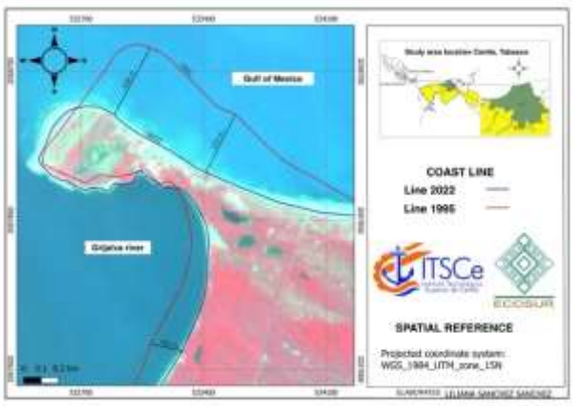

Figure 3 Coastal erosion in the El Bosque Locality to the mouth of the Grijalva River, Centla, Tabasco, Mexico
Data: Information generated in the Geographic Information System Qgis 3.28

In the first transect it is observed that there is a loss of 434.32 meters in a period of 27 years, which means an annual loss of 16.08 meters of coastline. In the second transect it is observed that there is a loss of 370.21 meters, which means an annual loss of 13.71 meters of coastline. While at the mouth of the Grijalva River it is observed that there is a loss of 186.16 meters, which means an annual loss of 6.89 meters of coastline.

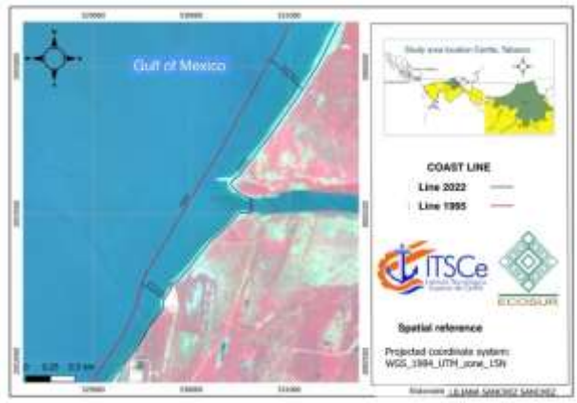

Figure 4 Coastal erosion in the Grijalva Delta., Centla, Tabasco, Mexico
Data: Information generated in the Geographic Information System Qgis 3.28

In the first transect it was determined that there is a loss of 442 meters in a period of 27 years, which means an annual loss of 16 meters of coastline. In the second transect it is observed that there is a loss of 273 meters, which means an annual loss of 10 meters of coastline.

The coast of Centla is a large area which is constantly transformed by waves, coastal currents, tides, oscillation of sea level and of course human activities, erosion by wave action has destroyed homes such as in the town of El Forest; which the erosion process has been very accelerated; The strong erosion on its coasts has caused a retreat of the coastline, it has brought with it in natural terms the penetration of the sea, losing a large part of the territory of the communities and therefore of their inhabitants. As coastal erosion progresses, space is limited, since the sea has been "gaining ground" by invading the coasts even more.

As they have been presented in front of the Carmen-Pajonal-Machona lagoon system and the communities of Ejido Sinaloa 1ra, El Alacrán 1ra and Alacrán Section Manatinero, in the municipality of Cárdenas; in the municipality of Paraíso the towns of Barra de Tupilco, Guano Solo, Unión 1ra and 2da. mentioned sites with high erosion rates (Hernández et al. 2008). Due to the force of hydrometeorological phenomena such as hurricanes or cold fronts.

Large coastal losses can be seen, for example, in the Grijalva Delta, the absence or limited width of the coastal plain, and the erosive forms, indicate low intensity of accumulation of marine sediments (Reyes, 2016).

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Another point to mention is that the rise in sea level leads to the loss of the coastline, since, in itself, the entire state, due to its flat topography, is susceptible to any increase in sea level that affects it. large surfaces.

Alternatives according to current regulations

For a country like Mexico, with highly vulnerable conditions, it is essential to address the issue of adaptation to climate change, which constitutes one of the central concerns that seeks to establish the necessary elements to identify, articulate and guide policy instruments, as well as as the actions and measures necessary to strengthen the adaptation capacities of society, ecosystems and productive systems (SEMARNAT, 2012a).

However, it is not easy to identify these adaptation processes since it is especially complex to define a baseline of reference or comparison (Angrist and Pischke, 2008), which is essential to develop strategies or alternatives that allow applying various public policies for adaptation to change climate.

Carmen Aurora Carmona Lara, an environmental specialist from the National Autonomous University of Mexico, highlighted the need to have a specific standard for the care of coastal areas; in which he has stated that current coastal ecosystems represent a very unstable equilibrium given by the sedimentary balance, which results in being vulnerable to alterations and modifications carried out by humans, either directly or indirectly, such as those They occur far from the coastal zone and whose morphodynamic response generally presents itself as erosion processes along the line of the coastal zones.

It should be noted that there is a lack of specific regulations for coastal protection, the legal instruments are not sufficient, but both the Coastal Law and the LAMMC present three management purposes a) Social participation in decision making, b) Monitoring or follow-up of key environmental variables and c) geographical scope of application (Lara, 2006). Therefore, at the moment the most that can be done is to use "criteria that are as well-founded as possible" such as those proposed below:

Mangrove restoration and protection

Since, with the destruction of mangroves, important areas of CO2 (carbon dioxide) capture and sources of oceanic carbon are reduced, the fauna whose habitats are linked to these ecosystems is endangered, and the protection that the Mangroves offer coastal communities resistance to rising sea levels (Duke et al., 2007).

Accommodation or withdrawal

This simple and logical solution is often socially traumatic as it involves moving people away from areas increasingly vulnerable to sudden disasters and areas that may become habitable due to rising sea levels. Planned relocation should be a solution of last resort, given its complexity and cost, when other options for in situ adaptation are not suitable, for example, when sea level rise makes areas uninhabitable; just as has happened with the El Bosque neighborhood; which the accommodation or withdrawal; Given the level of disaster it has caused, this becomes their only option every day.

Structure construction

It can help solve erosion problems, since they reduce the force of the waves and consequently retain sand. The problem is this captured sand is lost in the area that is downstream and then the erosion only moves to another area, but the problem remains. That is, the partial solution (Martínez., L. 2021). Therefore, it is important to develop specific schemes for each particular coast. as well as continuously monitor the efficiency of defense works, since coastal defense is an incessant iteration of adaptation-process.

Coastal monitoring

It is essential to maintain constant monitoring of the coasts, both in vulnerable areas and those that are not; since the coast is dynamic; not static. This must be strengthened as actions are developed in the territory.

Tabasco is an extremely vulnerable state and these types of situations will continue to occur, so control measures must be taken to reduce these impacts; Hydrometeorological phenomena, rising sea levels and waves form a chain of consequences.

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According to researchers, climate change has always existed, which is why we can say that they are of natural origin, but as a population we demand many services in terms of urbanization. and the satisfaction of our needs we have accelerated the rise in sea level, to an almost irreversible point.

Conclusion

9 maps were generated regarding coastal erosion, however, only the most important ones were taken into account, the same ones that were previously presented, these were based on the fact that the points at which the loss of coast ranges from 100 m to 400 m, which annually represents a loss of approximately between 10 m to 16 m of coastline, causing a retreat of the coastline.

The Grijalva-Usumacinta Delta is the largest river mouth in the country, since this is the one that discharges the most towards the Gulf of Mexico, which should contribute greater quantities of sediments, favoring coastal accretion; However, climatic variations such as rising sea levels, waves, and being a coastal plain make them more susceptible; without leaving aside anthropogenic activities, urbanization worldwide emits greenhouse gases which sometimes destabilizes the temperature, this variation in temperature triggers the thawing of the polar caps and this contributes to the increase in sea level, more that contributes to flooding and the loss of vegetation cover such as the mangrove, which is considered a natural barrier; All of these activities contribute to climate change and one of the effects that it has has been the loss of the coastline, under this context of climate change; It is of enormous importance to try to preserve the natural components of the coasts.

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