Dynamics of land use on the coast of delta Grijalva, Mexico, to generate development strategies

Dinámica de usos del suelo en la costa del delta Grijalva, México, para generar estrategias de desarrollo

VILLA-PERALTA, Ana del Pilar*†, RAMOS-REYES, Rodimiro, MONTERO-GORDILLO, Nayme and SUAREZ-GARCIA, Sandra Manuela

Instituto Tecnológico Superior de Centla. Academic Body in Formation Conservation and Preservation of Tropical Ecosystems, Mexico.

ID 1st Author: *Ana del Pilar, Villa-Peralta* / **ORC ID:** 0000-0001-5408-3209, **CVU CONAHCYT ID:** 1094994

ID 1st Co-author: *Rodimiro, Ramos-Reyes* / **ORC ID:** 0000-0003-3957-8160, **CVU CONAHCYT ID:** 93070

ID 2nd Co-author: *Nayme, Montero-Gordillo* / **ORC ID:** 0009-0008-1215-0248, **CVU CONAHCYT ID:** 549519

ID 3rd Co-author: *Sandra Manuela, Suarez-García* / **ORC ID:** 0000-0002-8573-6409, **CVU CONAHCYT ID:** 565464

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Abstract

The present investigation analyzed the change of coverage in the periods 2000-2018, through the digitalization and visual interpretation of orthophotos and satellite images, a comparative analysis was made between the digitization carried out in both years to identify the losses and possible strategies in the area of study and the coastline was analyzed. The results show that the loss of highest observance was the mangrove area, suffering a decrease of 4.78% and in profits the uses for hydrophytic vegetation, family gardens, urbanization and bodies of water, hydrophilic vegetation being the most profitable with a 5.24 %. For the analysis of the coastline, a loss of 262.2 meters in a period of 18 years was obtained in the area adjoining the Gulf of Mexico and, finally, by comparing the map of change of uses with that provided by the Program of Management Ecological State of Tabasco 2013, gives us a vision of the lack of compliance with the same program, which leads to poor application and use of land, generating environmental degradation and this in turn contributes to increased vulnerability to impacts caused by climate change.

Changes in uses, Vegetation cover, Coastline

Resumen

La presente investigación analizó el cambio de cobertura en los periodos 2000-2018, mediante la digitalización e interpretación visual de ortofotos e imágenes satelitales, se hizo un análisis comparativo entre la digitalización realizada en ambos años para identificar las pérdidas y posibles estrategias en el área de estudio y se analizó la línea de costa. Los resultados muestran que la pérdida de mayor observancia fue la zona de manglares, sufriendo una disminución del 4.78% y en ganancias los usos para vegetación hidrófita, huertos familiares, urbanización y cuerpos de agua, siendo la vegetación hidrófita la de mayor ganancia con un 5.24%. Para el análisis de la línea de costa se obtuvo en la zona colindante al Golfo de México una pérdida de 262.2 metros en un periodo comprendido de 18 años y por último, al comparar el mapa de cambio de usos con el proporcionado por el Programa de Ordenamiento Ecológico del estado de Tabasco 2013, nos da una visión de la falta del cumplimiento del mismo programa, lo que conlleva a la mala aplicación y uso del suelo, generando degradación del medio y esto a su vez contribuye al aumento de la vulnerabilidad a los impactos provocados por el cambio climático.

Degradación, Análisis, Vulnerabilidad

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* Correspondence to author: (E-mail: villaperaltaa@gmail.com)
† Researcher contributing first author.

Introduction

Human activities, primarily through greenhouse gas emissions, have unequivocally caused global warming, with global surface temperature reaching 1.1 °C above 1985 - 1900 in 2011-2020. Global greenhouse gas emissions have continued to increase between 2010-2019, with uneven historical and current contributions from unsustainable energy use, land use and land use change, lifestyles, and consumption and production patterns in all regions (IPCC,2023).

Land use change and loss of vegetation cover is one of the main problems of concern to humankind, as it directly affects biodiversity, contributes to local, regional and global climate change and is the primary source of soil degradation (López, 2006). The negative processes of land and vegetation use change have been documented as the second environmental problem at the global level, since they affect natural capital, microclimatic stability, the provision of environmental services and the increase in the concentration of greenhouse gases in the atmosphere, in addition to limiting at the local level the possibilities of sustainable management of the territory and its natural resources (Rosete, Pérez, Villalobos, Navarro, Salinas, & Remond, 2014).

México se encuentra dentro de las tendencias mundiales, presentando importantes procesos de cambio de uso y cobertura del suelo en sus casi dos millones de kilómetros cuadrados de superficie. En general se observan una gran cantidad de cambios que están por arriba de la media mundial en cuanto a tasas de deforestación, incremento de las áreas de cultivo y pastoreo, expansión urbana y muchos otros como la erosión a causa del aumento del nivel del mar efecto producido por el cambio climático (Rocha, WP, *et al*., 2017).

The cities and communities of the country do not escape this process, the population growth according to the press release of INEGI, 2000 showed for the year 2000 a total amount of 97.48 million inhabitants. In 2015 it passed to a total of 119, 530, 753 inhabitants which has meant not only a growth in the number of settlers if not also a physical growth and the continuous increase of its urban limits and consequently decrease of natural or semi-natural coverages (INEGI, 2015).

Under this approach, a large number of research initiatives have been promoted at global, regional and local scales, recognizing land use dynamics as an important component of the global environmental system and a precursor factor of global climate change. The studies carried out indicate that the monitoring and analysis of the urban expansion process and its resulting conversions of natural and semi-natural land cover is carried out through the study of land use and land cover changes (Sandoval, 2009).

Likewise, specific works have been carried out in different areas of the country that have indicated and quantified the impact caused by soil alteration processes; in this sense, in Tabasco, analyses have been carried out on land use change in several areas of the territory, such as in the municipality of Comalcalco, where the dynamics of land use change from 2000 to 2010 were identified (Ramos-Reyes et al., 2016a).

In the municipality of Centla in the Pantanos de Centla Biosphere Reserve, a study was carried out to evaluate the spatio-temporal vegetation and land use from 1990 to 2000 (Guerra, & Ochoa, 2006).

Given this problem, the main objective of this study is to study the dynamics of land use change, as well as the influence of anthropogenic activities as the main driver of change, to understand the causes, impacts and consequences that these transformations have on climate change, as well as the loss of the coastal coastline, and to identify possible development strategies, all this in a period between 2000 and 2018.

The use of Geographic Information Systems (GIS) and remote sensing (RP) tools was necessary to carry out this spatial monitoring study, since they provide transition information on the dynamics of land use over the years.

Methodology

In order to fulfill the proposed objectives, a methodological route was established that contemplates the preparation or pre-processing of the images, which consisted of cropping them to the study area.

June 2023, Vol.9 No.16 16-27

A polygon of approximately 20,000 ha was obtained with the cutout, which included the study area, and the study area was delimited with the ArcGIS 10.2 program. The 2000 map was generated with a black and white orthophoto of the same year, while the 2018 map was generated with an image obtained from the European satellite called Sentinel with a false color (RGB 1, 2, 3). The 2018 map was verified with information collected in the field using GPS equipment. Both maps were developed at a scale of 1:20 000, for the digitization and identification of land uses a visual interpretation was carried out on screen applying the criteria of tone, shape, size and texture (Chuvieco, 2008).

To identify the different land uses present in the study area, digital sources of information were used, such as maps from the 2000 National Forest Inventory and the State Ecological Management Program 2013-2018, in addition to information from the National Institute of Statistics and Geography and the National Commission for the Knowledge and Use of Biodiversity.

Land use change matrix

The temporal analysis of changes in land use will be carried out with the tools of the ArcGis 10.2 program in which the digitization was performed, in this digitization the different types of uses were categorized, which were necessary to locate to perform a standardization and achieve the matrix of land use change. To obtain this change of use matrix, it was necessary to convert the vector format (Shapefile) into a numerical matrix format (Raster) to perform the map algebra. A numerical value was assigned to each category from 1 to 9 for the 2000 map and from 1 to 90 for the 2018 map so that the map algebra could be obtained. To continue with the interpretation of the land use changes, the files should be imported from Raster format to Shapefile format.

Scale and pixel size

The scale at which the maps were digitized was 1:20 000, there is a direct relationship between cell size and scale and can be calculated using the following formula: where the scale is equal to the cell size multiplied by 96 and divided by 0.0254. Therefore, if the scale is 1: 20,000, the cell size is 5.29 meters.

Shoreline digitization

For the digitization of the coastline, ArcGIS 10.2 software was used to generate the coastline of the study area for both proposed years 2000 and 2018 to subsequently determine changes over time. An orthophoto was used for the year 2000 obtained from the National Institute of Statistics and Geography and for the year 2018 the Sentinel satellite image was obtained from the European Space Agency both digital materials corresponding to the entire coastal area of the municipality of Centla, the spatial resolution of the image obtained from the Sentinel satellite and the orthophoto are projected 10 m.

Once the spatial information on which to digitize the coastline was established, the indicator to be followed for its delineation was chosen. We chose to use the high water line (HLW), defining it as the wet/dry boundary and interpreting it as the line defined by the difference in coloration that marks the receding tide (Dolan et al. 1978). The digitization was carried out by a single person, valuing the ratio of time invested and accuracy obtained, the digitization scale was set at 1:5000, this line will be traced in an area of approximately 24 kilometers.

Comparison of the coastline

Already having the coastline of the year 2000 and 2018 will be analyzed to see if there is coastal erosion and accretion, and to determine possible indicators of climate change.

Strategies for land use

Based on the results obtained from the digitization of the study area, proposals for possible strategies for land use in the region will be determined in order to reduce the deterioration of the environment and thus ensure harmonious and sustainable development between society and the natural environment. These proposals should be based on the current State Ecological Management Program (PESOE, 2015).

Results

Analysis of land use changes on the coast of the Grijalva Delta, Mexico.

June 2023, Vol.9 No.16 16-27

Based on the work carried out in the ArcGis operating system for the digitalization of the orthophoto for 2010 and for the satellite image for 2018, the following results were obtained, where the surfaces in m2 are defined for the year 2000 and 2018 acquiring a classification of nine categories which are, acahual, coconut groves, water body, home garden, mangrove, pasture, urbanization, hydrophytic vegetation and oil zone (see Table 1).

	Surface 2000 (Ha)	%	Surface 2000 (Ha)	%	Profit	%	Lost	%
Acahual	5, 041.27	3.88	4, 839.41	3.69			201.86	**-4**
Coconut groves	1, 900.43	1.44	1, 182.28	0.90			718.15	**-37**
Water body	4,788.76	3.68	4, 796.11	3.65	7.35	**0.15**		
Family orchard	127.92	0.1	714.47	0.54	586.55	**82**		
Mangrove	15, 734.9	12.1	9, 603.47	7.32			6, 131.43	**-39**
Pasture	14, 484.8	11.14	14, 270.9	10.88			213.9	**-1.4**
Urbanization	578.44	0.44	723.05	0.55	144.61	**20**		
Hydrophytic vegetation	87, 349	67.18	94, 943.2	72.42	7, 594.2	**8**		
Oil area	42.63	0.03	28.04	0.02			14.59	**-34**
Total hectares	130, 019.19	100	131, 100.94	100				

Table 1 Land uses 2000 and 2018
Data: Orthophoto digitization in ArcGis 10.2 Geographic Information System

Land use for the year 2000 was distributed as follows, 67.18% (87, 349 Ha) of the surface was occupied by hydrophytic vegetation, 12.1% (15, 734.9 Ha) corresponded to mangrove surface, 11.14% (14, 484. 8 Ha) for grasslands, acahual 3.88% (5, 041.27 Ha), water bodies with 3.68% (4,788.76 Ha), coconut groves 1.44% (1, 900.43 Ha), 0.44% (42.63 Ha) for urban zone, .01% (127.92 Ha) for home gardens and 0.03% (42.63 Ha) of oil zone.

While for 2018 it was distributed as follows, 72.42% (94, 943.2 Ha) of the surface was occupied by hydrophytic vegetation, 10.88% (14, 270.9 Ha) corresponded to grassland surface, 7.32% (9, 603. 47 Ha) for mangroves, acahual 3.69% (4, 839.41 Ha), water bodies with 3.65% (4, 796.11 Ha), coconut groves 0.90% (1, 182.28 Ha), 0.55% (723.05 Ha) for the urban zone, 0.54% (714.47 Ha) for family orchards and 0.02% (28.04 Ha) for the oil zone. If we observe in the comparative table there are losses in some categories such as mangrove, coconut groves, pasture, acahual and oil zones; the land use with the highest loss is the mangrove zone with a decrease of 4.78%. And in terms of gains we have land uses for hydrophytic vegetation, home gardens, urbanization and water bodies, being hydrophytic vegetation the one with the greatest gain with 5.24% more surface area compared to the distribution of 2000.

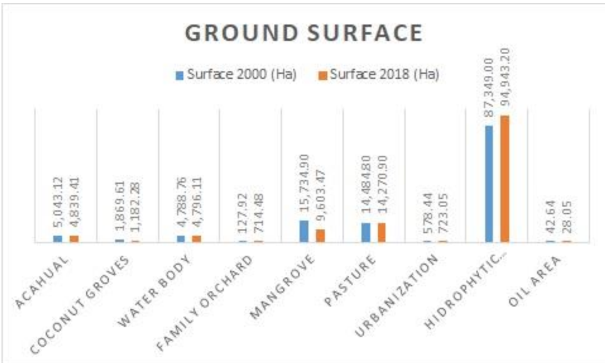
The hydrophytic vegetation category is predominant, with a total of 67.18% for 2000 and 72.42% for 2018, due to the fact that most of the territory to be studied is located in the area of the Centla Marshes, which have been considered as little altered areas. In the state of Tabasco there are extensive areas of wetlands, of which the Pantanos de Centla Biosphere Reserve (RBPC) stands out. This site, which is part of the 58 Mexican wetlands recognized for their international importance according to Ramsar and ranks fifth in extension in the Mexican Republic with an area of 302 706 ha covering marine-coastal and inland water wetlands (Barba-Macías, E et al., 2006).

According to De la Rosa, 2016 in his research in part of this same study area mentions the majority of the extensive and temporarily stable cover was hydrophytic vegetation, which only lost 2.8% of its area since the application of the decree as a reserve surface area designated as a natural protected area, a portion was allocated to agriculture (36,501 ha) and low flooded forests (20,122 ha). In contrast, the most transformed cover was low flooded forest, with 12% of its extension converted to hydrophytic vegetation (36,181 ha) and agricultural use (13,704 ha). The extension of water bodies increased (4.3%), while mangroves decreased (0.45%).

The area dedicated to agriculture doubled and replaced 16,209 ha of hydrophytic vegetation and 2,376 ha of low flooded forests; this transition was observed even in the core of the reserve. The greatest change was recorded in the core area, where 33% hydrophytic vegetation was eliminated and the buffer zone experienced the greatest loss of low flooding forest (De la Rosa, 2016).

The other land uses for the same period 2000 to 2018, had variations in losses or gains (Graph 1), home gardens with gains in occupied area of 586.55 Ha, urbanization with gains of 144. 61 Ha and water bodies 7.35 Ha; for losses, the mangrove area is notoriously decreased with a detriment of 6, 131.43 Ha, coconut groves with 718.15 Ha, pastures 213.9 Ha, acahual 201.86 Ha and the oil area with losses of 14.59 Ha.

Home gardens, urbanization and hydrophytic vegetation showed recoveries of 82, 20 and 8%, respectively. Mangroves, coconut groves and the oil zone showed a decrease of -39, -37 and -34%.



Graphic 1 Land area in the period 2000 - 2018
Source: Information generated in the ArcGis 10.2 Geographic Information System.

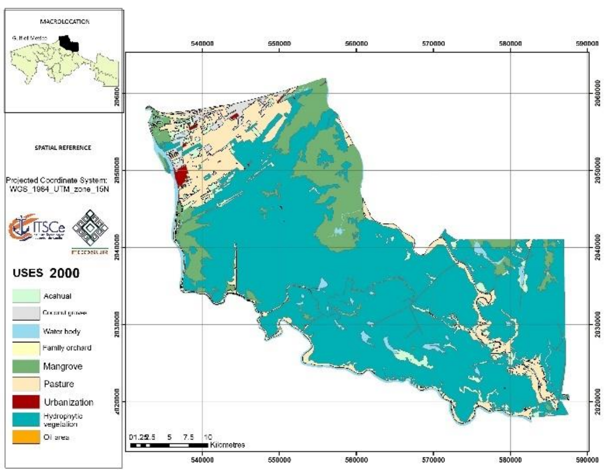


Figure 1 2000 land use on the coast of the Grijalva Delta, Tabasco, Mexico.
Source: Orthophoto digitizing in ArcGis 10.2 Geographic Information System.

Figure 1 shows the land use map of the Grijalva Delta coast in 2000, showing that the largest land uses are hydrophytic vegetation, mangroves and grasslands, while acahual is only found in small portions near the grasslands, as well as coconut groves, with an area of 1,900.43 ha (1.4%)

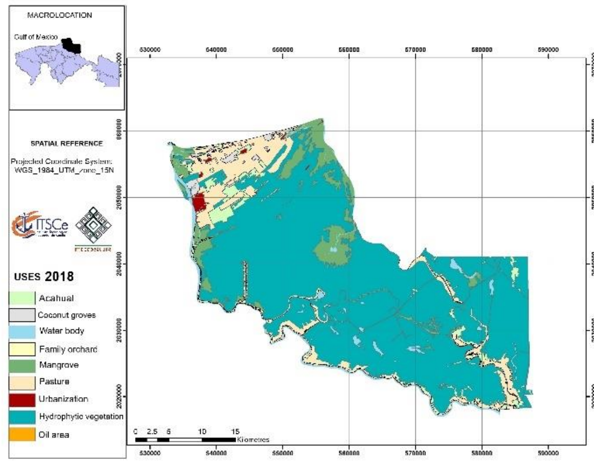


Figure 2 2018 land uses on the coast of the Grijalva Delta, Tabasco, Mexico
Source: Digitization of Sentinel satellite image from the European Space Agency in ArcGis Geographic Information System 10.2

The 2018 map (fig.2) shows that the most dominant uses continue to be hydrophytic vegetation (72.42%), pasture (10.88%) and mangrove (7.32%). Home gardens are the fastest growing with a surface area of 586.55 ha, which represents 82%.

Graphic 2 Gain and persistence of water bodies on the coast of the Grijalva Delta, Tabasco, Mexico
Source: Information generated in ArcGis 10.2 Geographic Information System

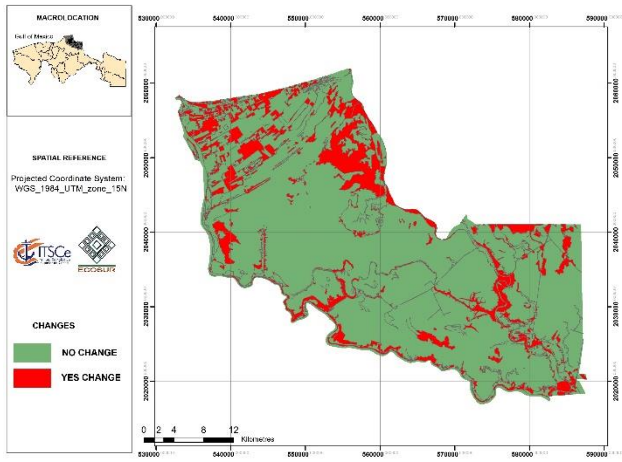
Ramos-Reyes et al. (2016b) have studied extreme events attributed to climate change that occur in coastal areas, such as intense hurricanes, severe flooding and sea level rise (SLR). According to Nicholls, 2002, these climatic events provoke irreversible changes causing loss of coastal lands that have been eroded and flooded.

In Figure 2 we observe the gains and persistence of land uses categorized as water body in which a notorious increase is defined in coastal areas and river margins resulting in losses in urban areas (4. 79 Ha), acahuales (41.95 Ha), pastures (129.54 Ha), coconut groves (23.34 Ha), home gardens (11.17 Ha), hydrophytic vegetation (232.25 Ha), oil zone (0.65 Ha) and mangrove area (90.78 Ha).

According to the PESOE, 2015, the regions most prone to be affected by flooding are those located in coastal areas, as is the case of the forest community in Centla, as well as the populations located on the banks of the Grijalva, Mezcalapa and Usumacinta rivers, mainly.

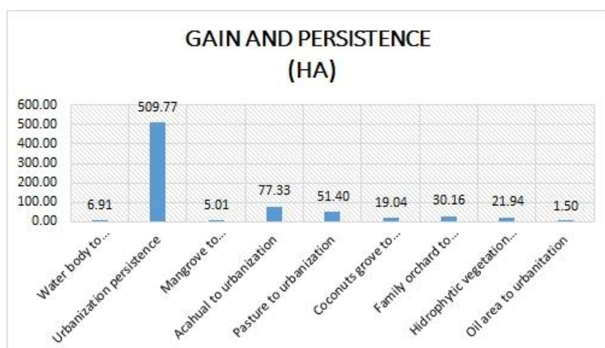
Mangroves are a type of land use with significant losses, with a specific gain towards water bodies totaling 90.78 ha. Based on research by Yáñez et al, 2014, mangrove forests are considered among the most vulnerable ecosystems in the tropical/subtropical band of the planet and subjected to diverse environmental stressors at the continent/ocean interface, placing mangroves at severe risk to the impacts of climate change, particularly in terms of geomorphological, sedimentological, biogeochemical processes, geographical distribution, morpho-physiological resilience and the uncertainty of the sustainability of the environmental services provided by these amphibious forests, among other aspects.

In the same context, the PESOE, 2015 mentions that important modifications are likely to occur in mangroves that may be affected by sea level rise projecting where seawater could enter up to 40 km inland in extreme cases. In terms of plant formations that are in these risk conditions are coastal wetland ecosystems and dune vegetation and marsh vegetation or hydrophytic vegetation.



Graphic 3 Gain and persistence of mangrove land uses on the coast of the Grijalva Delta, Tabasco, Mexico
Source: Information generated in ArcGis 10.2 Geographic Information System

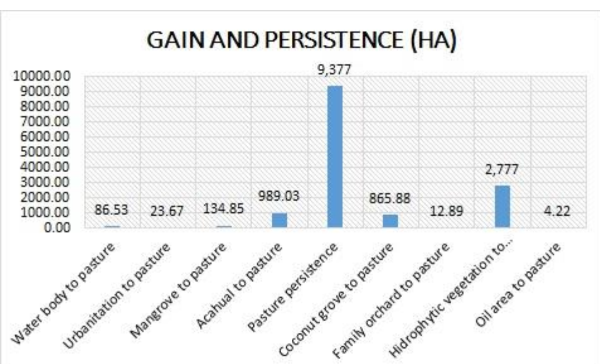
The scarce and almost null increase in land uses destined for mangrove areas is analyzed (Graph 3), (Hernández-Melchor et al, 2016) states that in the state of Tabasco 19,922.9 ha of mangrove have been lost, due to land use change originated by activities such as the oil industry, the establishment of cultivation areas and grazing areas. Mangroves are of great environmental importance, as this ecosystem is characterized by its rich biodiversity, and also serves as protection against saline intrusion into the soils bordering the coast and protects the population from storms and hurricanes (Ramos-Reyes et al., 2016a).



Graphic 4 Gain and persistence of urban land uses on the coast of the Grijalva Delta, Tabasco, Mexico
Source: Information generated in ArcGis 10.2 Geographic Information System

Figure 4 shows the loss of various uses such as acahual (77.33 ha), which were increased in uses destined for urbanization, pastures are also in decline (51.40 ha), being replaced by the expansion of urban development, areas of lower population identified as home gardens were also replaced by the increase in population re-categorized as urban. Based on the publications of Capdepont-Ballina J. & Marín-Olán P., 2014 in which he mentions that in the administration of Mario Trujillo García (1971-1976) began the economic transformation of the entity, which became evident towards 1980, bringing with it an increase in population who demanded more and better services, calling it modernization, understanding it as an improvement in the material life of Tabasco, which was boosted by the exploitation of hydrocarbons, but to the detriment of social and ecological life; In 1970 the rural population was greater than the urban population and the primary sector economy predominated, but in 1990 this situation was already different due to the rebound of secondary activities such as hydrocarbon extraction and the urban growth of the headwaters of the municipalities impacted by this sector, which could be proven for the study area of this project that in the year 2018 the increase of urban zoning and the loss of areas for the development of family orchards is interrelated with the oil boom in our state.

In 1990 Centla had a total population of 70,053 inhabitants, occupying the seventh place from highest to lowest number of inhabitants, while in 2010 there was an increase of 102,110 inhabitants, occupying the eighth place in growth (INEGI, 1990 and 2010).



Graphic 5 Gain and persistence of pasture land use on the coast of the Grijalva Delta, Tabasco, Mexico
Source: Information generated in ArcGis 10.2 Geographic Information System

In Tabasco, economic activities have been conditioned by the natural environment and markets. A series of stages characterize a product throughout its economic history: 1) traditional crops, cocoa, copra; 2) banana monoculture (late nineteenth century to mid-twentieth century); 3) livestock expansion (1950-1970) and the oil stage (1976- 2013).

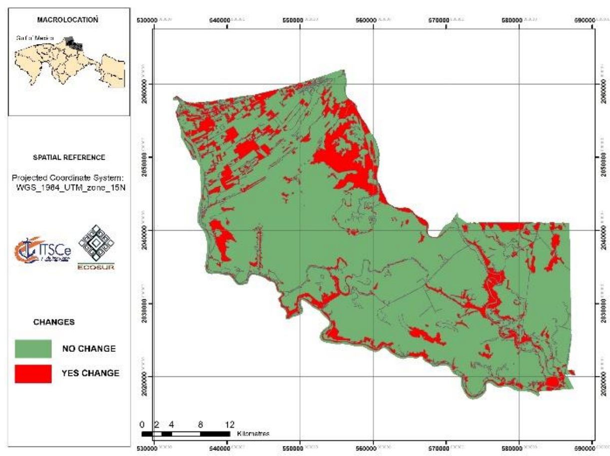


Figure 3 Matrix of land use changes from 2000 to 2018 on the coast of the Grijalva Delta, Tabasco, Mexico
Data: Information generated in the ArcGis 10.2 Geographic Information System

The results of changes in the period analyzed from 2000 to 2018 showed changes in 23,064.2 ha and the majority of the area remained unchanged with a total of 106,857 ha.

According to De la Rosa 2016, the reduction in natural cover reflects the extractive pressure on natural resources and a marked process of land use change within Pantanos de Centla Biosphere Reserve, even in restricted protection zones and core zones. Observing the change matrix map (Fig. 3), it is clear that changes occur more rapidly in areas that are even considered natural protected areas. It is likely due to poor management and the growth of community zones that exert pressure on natural resources, changes in land use, changes due to poorly designed public policies, and changes that have developed naturally (hurricanes, temperature variations, etc.) whose scope surpasses conservation efforts within the protected area and its surrounding area.

Analysis of the coastline (2000-2018)

According to the results obtained by digitizing the lines for the year 2000 through an orthophoto and for the year 2018 using a SPOT image from the European satellite called Sentinel with a false color (RGB 1, 2, 3), the coastline was digitized at scale 1:5 000, which includes part of the coastline of the municipality of Centla (Fig. 10) starting in the town of El Bosque to the mouth of the San Pedro river with a total length of 23, 858.34 meters.

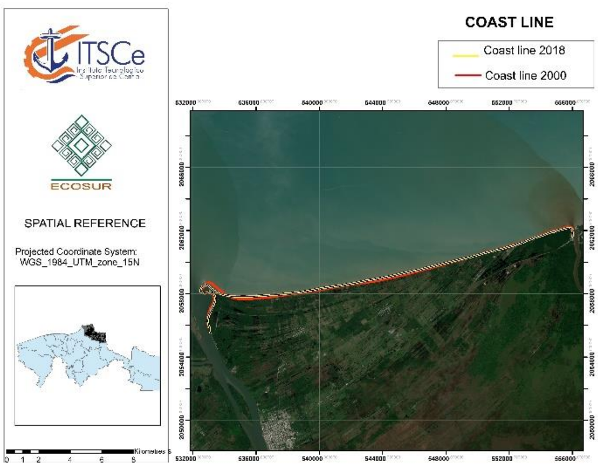


Figure 4 Digitization of coastlines 2000 - 2018
Source: Information generated in ArcGis 10.2 Geographic Information System

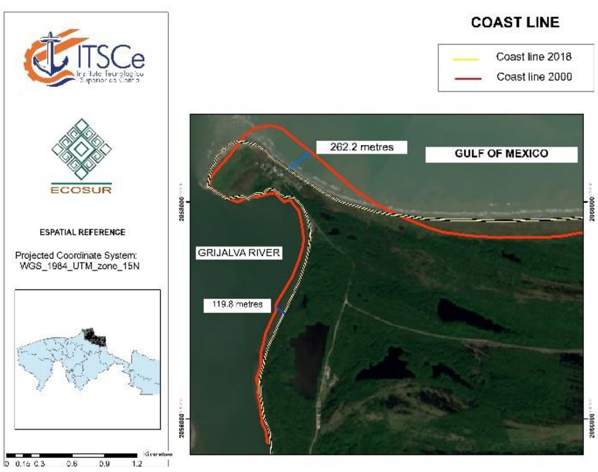


Figure 5 Erosion of the Grijalva river mouth
Source: Information generated in ArcGis 10.2 Geographic Information System

The coastal areas of the state of Tabasco are highly susceptible to being flooded by extreme phenomena as a consequence of Global Climate Change (GCC) in the municipalities of Cárdenas, Paraíso and Centla, with soils being more susceptible to flooding due to the poor drainage of the gleysols that are associated with wetlands and swamps (PESOE, 2015).

According to the same PESOE 2015, it indicates in an analysis during 40 years between 1950 and 1990 an increase in the Gulf level of around 13 cm in its Mexican part and in a linear projection determines that the sea level rise would reach 90 cm by the year 2100, putting at risk by the effects of the tide considerable portions of the State, however, recent studies point out that it could reach in some areas a meter and a half.

The site with the greatest loss of coastline was identified in the regions that present peninsular forms, as is the case of the locality of the forest, which is mostly surrounded by water from the Gulf of Mexico, and another area of the same locality that is located around the mouth of the Grijalva River.

Figure 5 shows that in the area adjacent to the Gulf of Mexico there is a loss of 262.2 meters over a period of 18 years, which means an annual loss of -14.5 meters. Other studies that address the same topic have reported annual losses, such as the case of Sánchez Magallanes and El Alacrán, with retreats of -4 and -7, respectively (Hernández-Santana et al., 2008).

Ramos-Reyes et al. (2016b) in coastal areas of the same state of Tabasco, in the municipality of H. Cárdenas located sites where coastal vulnerability is present according to vulnerability parameters, concluded that the Villa de Sánchez Magallanes presents red focus on an extreme scale before the phenomena of climate change, reaching up to 5m per year, reaching serious problems of erosion and loss of the coast, affecting citizens living along the entire coastal coastline.

If we relate the results obtained in (fig. 5) with the previous predictions of sea level rise, we can consider that what was described by the authors of the PESOE are not wrong, generating already in the forest community a conflict for the loss of territory and gain of the sea, affecting not only human localities but also populations of coastal wetlands, dune vegetation and marsh vegetation.

Sustainable development strategies

Comparative analysis of land use with that established in the State Ecological Management Program.

To determine the activities carried out in the study area and consider whether these activities contribute to and comply with the territorial ecological management plan, an intersection of the map indicating the environmental management units and the digitized map was carried out to determine the change in land use, and the following result was obtained (Fig. 6).

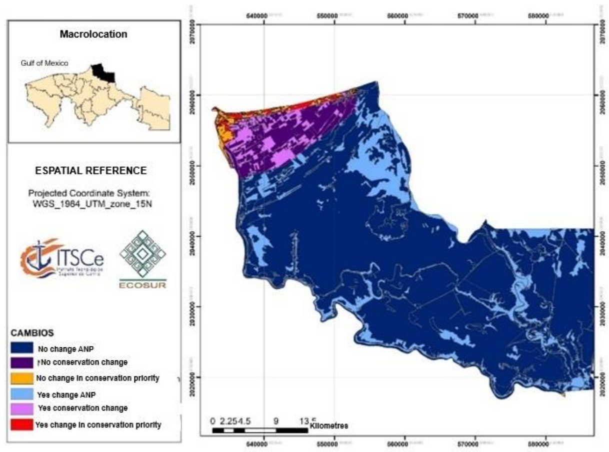


Figure 6 Comparative map of land use and the Environmental Management Unit of the POEE
Data: Information generated in the ArcGis 10.2 Geographic Information System.

According to the PESOE, the study area is categorized into three Environmental Management Units (UGA's), which are natural protected area, conservation area and priority conservation area, with the main one accounting for approximately 90% of the territory corresponding to natural protected area, 4% for the priority conservation area and 6% for the conservation zone.

Priority conservation zones are those areas of state or federal jurisdiction that must be protected or conserved because the reduction or loss of their natural properties would increase the risk to the population and its heritage, the loss of endemic species or risks, as well as the loss of strategic natural resources for the social and economic development of the state. Some of these, among others are, coastal areas, dunes, mangroves, river margins, gallery forests and mountain slopes (PESOE, 2015).

The environmental management units (UGA's) of conservation are the areas of the state territory that present little altered ecosystems, since they maintain in good condition their structure, function and ecological processes.

In addition, they may or may not contain species that are in a risk category according to the Mexican Official Standard. The environmental services provided by these parts of the state territory are strategic to reduce the risks to the human population and its heritage in the face of hydrometeorological phenomena, coastal erosion and the effects of climate change. The use of natural resources in this area must be evaluated technically, legally and economically by trained personnel and the corresponding environmental authorities (PESOE, 2015).

Protected natural areas are the areas of the state territory, decreed as protected natural areas of federal, state or municipal jurisdiction, based on the General Law of Ecological Balance and Environmental Protection and the Environmental Protection Law of the States of Tabasco, or equivalent (PESOE, 2015).

The results of the comparative map show that within the protected natural area there are modifications to the soil for productive activities, with the same intensity as the modifications observed outside of the natural area, which indicates that although there is a management plan for Pantanos de Centla Biosphere Reserve, it is not being implemented or does not have the necessary improvements to counteract the effects of land use changes.

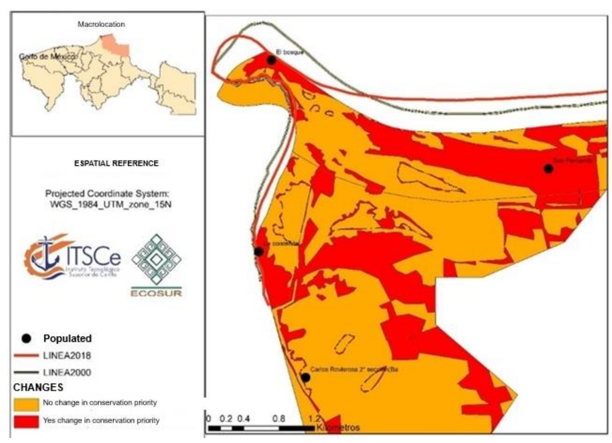


Figure 7 Coastal zone map of the municipality of Centla
Source: Information generated in ArcGis 10.2 Geographic Information System

The increase in population causes greater demand on natural resources, as well as an increase in the area suitable for industrial and housing developments, regardless of the filling of some bodies of water. The areas with more changes are those linked to the presence of high population density.

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If we observe Figure 7. We will notice that the areas with population presence are the ones that have had the greatest changes as is the case of the coastal communities of El Bosque, San Fernando, La Costeñita and Carlos Rovirosa 2nd Section, which contributes to the conclusions given in the (PESOE, 2015) where it mentions that the greater the population, the greater the changes in land use and population affectations.

According to the PESOE, 2015, there are several vulnerable areas throughout the state of Tabasco due to population growth and the activities that this growth entails, it can be observed that there is great vulnerability in the coastal zone, especially at the mouth of the Grijalva-Usumacinta river, In general terms, population growth is concentrated in areas of greater vulnerability to flooding, with the Grijalva basin region being the most vulnerable, including in some cases the Chontalpa region (Paraíso, Comalcalco, Cunduacán and part of Cárdenas). This in turn represents a conflict in inappropriate land use, since the areas of greatest conflict are being populated at an accelerated rate due to inappropriate human settlements.

Development strategies according to the State Ecological Management Program

One of the main primary activities in the municipality of Centla is fishing, which is considered a source of income for many families. However, due to the various oil activities and the decrease in free fishing, these families have been affected, so based on the PESOE, 2015, it is proposed as a strategy for this area to promote productive actions through the reactivation of the capacity of primary activities according to the agricultural, livestock, fishing and forestry vocation, so it is proposed to develop in this area the activity of aquaculture, with aquaculture projects that favor the use of native species over exotic ones.

Ecological guidelines	Strategy	Description	Production activity
Promote productive activities	Reactivate the capacity of primary activities according to the agricultural, livestock, fishing and forestry vocation.	Aquaculture projects must favor the use of native species over exotic species, the latter being restricted by the corresponding authority.	Aquaculture

Table 2 Proposed strategy for sustainable development in the study area
Source: PESOE, 2015

Conclusions

For the analysis of land use changes, the study area was digitized with orthophotos for 2000 and a satellite image for 2018, in which nine land uses were identified in the Delta coast, Tabasco, Mexico, for both dates, which were: coconut groves, pasture and mangrove, acahual, hydrophytic vegetation, home gardens, urban area, bodies of water, and oil zone. Hydrophytic vegetation was found to cover the largest area, with a total of 87,349 ha in 2000 and 94,943.2 ha in 2018.

Anthropogenic activities are the main factor in the loss of biodiversity in the Grijalva Delta Coast and the effects generated by climate change due to the increase in sea level invading land areas, since most of the changes in land cover occur near the coast and river banks, in addition to the mismanagement of natural resources and ignorance of the consequences that their daily activities cause to the ecosystem, which lead to degradation and desertification. This contributes to the erosion and deterioration of the coastline.

The coastline was also spatially evaluated with orthophotos from 2000 and a satellite image from 2018, finding greater erosion at the mouth of the Grijalva River and on the coast of the community of El Bosque, and observing coastal accretion, due to sediments from the river that are dragged and deposited in the first meters of the coast. The coast of the Grijalva Delta is vulnerable to the effects of climate change, mainly the mouth of the Grijalva River, in the community of El Bosque, with losses of great importance and concern with about 262.2 meters in a period of 18 years, which means an annual loss of -14.5 meters.

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