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Assessment of land-use change in coastal areas through geographical information systems

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ABSTRACT

Objective: This article describes and analyzes the main concepts of coastal ecosystems, these as a result of research concerning land-use change assessments in coastal areas.

Design/Methodology/Approach: Scientific articles were searched using keywords in English and Spanish. Articles regarding land-use change assessment in coastal areas were selected, discarding those that although being on coastal zones and geographic and soil identification did not use Geographic Information System (GIS).

Results: A GIS is a computer-based tool for evaluating the land-use change in coastal areas by quantifying variations. It is analyzed through GIS and its contributions; highlighting its importance and constant monitoring.

Limitations of the study/Implications: This research analyzes national and international scientific information, published from 2007 to 2019, regarding the land-use change in coastal areas quantified with the digital GIS tool.

Findings/Conclusions: GIS are useful tools in the identification and quantitative evaluation of changes in land-use in coastal ecosystems; which require constant evaluation due to their high dynamism.

Keywords: GIS, vegetation cover, anthropogenic deforestation, urbanization, coastline.

INTRODUCTION

Coastal areas contribute to the socioeconomic evolution of humanity (Gómez *et al.*, 2016) due to their productive potential, where fishing, industry, tourism, and transport are developed as economic activities that address conflicts arising from the use and exploitation of their natural resources, such as soil, water, and landscape (Lara-Lara *et al.*, 2008).

Changes in coastal geomorphology increase when phenomena caused by population growth and socio-economic development coincide with environmental factors of aquatic ecosystems (De la Lanza *et al.*, 2013). In this sense, urban expansion entails an important land-use change in coastal areas (Barragán & de Andrés, 2016) causing effects that deteriorate its ecosystem resources.

Geographic Information Systems (GIS) are technological tools that display spatial information on land-use changes, providing quantitative information related to geographic information on coastal areas.

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Therefore, this research analyzes national and international scientific information, published from 2007 to 2019, regarding the land-use change in coastal areas quantified with the digital GIS tool, through integration, selection, and comparison of scientific articles available in databases of specialized data; to recognize and define knowledge gaps in the dynamics of these ecosystems.

MATERIALS AND METHODS

Scientific articles were searched using keywords in English and Spanish such as "land-use change in coastal areas", "geographic information systems in coastal areas" and "GIS in coastal areas" in Google Scholar and databases of scientific journals, as a network of Scientific Journals of Latin America and the Caribbean (Redalyc), Elsevier, Scopus, Web of Science, Scientific electronic library online (Scielo).

Articles regarding land-use change assessment in coastal areas were selected, discarding those that although being on coastal zones and geographic and soil identification did not use GIS. Thirty articles were selected, in which the aim of the study, and the main results were identified. Subsequently, a matrix was integrated with the variables: year, author, research institution, DOI/URL, place, title, contribution, line of research, objective, variables, cartographic inputs, type of analysis, GIS program, formulas, and method. Finally, the spatial distribution of the investigations was identified by georeferencing the reported coordinates.

RESULTS AND DISCUSSION

General features: coastal areas

Coastal areas have extensive interaction between the marine and terrestrial environment, where "dry" and "wet" portions of the territory interact through the coastline (Ortiz *et al*., 2010). This, derived from environmental, social, and economic services that this territory provides, having a wide demand for occupation, due to the development of food production, through fishing or aquaculture, transport, urbanization, construction and administration of ports, and industry, among others. Consequently, its growth and expansion directly affect associated ecosystems (Ponce & Botello, 2005).

Coastal lagoons

Diverse coastal ecosystems make up the Mexican coastline, such as lagoons, estuaries, swamps, and bays established in 11,592.77 km Among these, the coastal lagoons cover an area of 15,000 km^2 and, according to their hydric dynamics, there were identified between 125 and 130 bodies of water (Lara-Dominguez *et al*., 2011).

Coastal lagoons are semi-closed bodies of water, parallel to the coastline, with a permanent or seasonal marine communication, protected from the sea through of a bar, while sometimes a river flows into its headwaters (De la Lanza *et al*., 2013). A lagoon can integrate several bodies of water, including the estuary and one or more swamps originated as abandoned beds, which form a chain of bodies of water closed by modification of the channel of rivers or low dynamics lagoons and/or flooded by tides (De la Lanza *et al*., 2013).

The origin of the lagoons is recent and short-lived geological phenomena. The constant interaction with external phenomena, such as erosion, sediment deposition, fluctuations in sea and land levels, as well as river discharges and tidal ranges, prevent these complex, short-lived systems from reaching a final state of equilibrium (Farrera, 2004).

Lagoons are open systems with high primary productivity. Naturally, they are areas of refuge, feeding, and reproduction of around 50% of the species that constitute littoral fisheries (Toledo, 2005). In this sense, they are economically important by providing food resources, in addition to tourism and communication resources (De la Lanza *et al*., 2013; Farrera, 2004).

Vegetation

Mangrove forests or mangroves stand out as abundant vegetation of coastal lagoons, estuaries, and bays (Toledo, 2005). This vegetation includes perennial, bushy, or arborescent plants that reach up to 25 m in height (Ellis & Martínez, 2010). Around 64 mangrove species are known worldwide (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, 2008). Spalding (2010) presented the book "World Atlas of mangroves" where he recognized 73 species including some hybrids. The representative families of species from the Pacific Northwest are *Avicenniaceae*, *Combretaceae*, *Meliaceae*, *Rhizophoraceae*, and *Sonneratiaceae*. The Eastern Pacific species are *Avicenniaceae*, *Combretaceae*, *Pellicieraceae*, and *Rhizophoraceae*.

López *et al*. (2010) mentioned that mangroves develop in flooded soils, periodically or permanently with waters ranging from brackish to saline. Yáñez-Arancibia *et al*. (2014) pointed out that the function and environmental quality of tropical estuarine ecosystems depend on the variety of their biodiversity components.

Seagrasses (*Halodule beaudettei*, *H. wrghtii*, *Syringodium fiiforme*, *Thalassia testudinum*, and *Ruppia maritima*) are other vegetation associated with coastal areas (Toledo, 2005). These grasses are a functional group of approximately 60 species of underwater plants (Green & Short, 2003). Den Hartog (1970) carried out a worldwide geographic distribution and regionalization of seagrasses, identifying seven genera in tropical coasts, mainly *Thalassia*, *Halophila*, *Syringodium*, *Haladla*, *Cymodocea*, *Thalassodendron*, and *Enhalus*. The first four genera have representatives in both the tropical Atlantic and the Indo-Pacific, the remaining genera are restricted to the western Indo-Pacific. The high productivity and ecological value of seagrass meadows classify them as important ecosystems within coastal areas (Millán *et al*., 2016).

Hydrophilic vegetation, popal, and tular type is another type of abundant vegetation in coastal ecosystems.

The first is a community of herbaceous plants from 1 to 3m in height composed of geniculata and plants of the genera *Calathea* and *Heliconia*, which cover swampy or stagnant freshwater surfaces from 0.5 to 1.5m deep (Ellis & Martínez, 2010; Rzedowski, 2006). The second is made up of herbaceous plants rooted on the shores of lakes, lagoons, or marshy lands, which have long, narrow leaves known as tulles; the genera present are *Typha*, *Scirpus*, and *Cyperus*, as well as the species *Phragmites communis* and *Arundo donax* knew as "reedbeds" (López *et al*., 2010). Also grouped as hydrophilic vegetation are those plants that float on the surface of fresh and brackish water such as *Pistia stratiotes*, *Salvinia*, *Eichornia crassipes*, and different species of the genus *Nymphaea*, *Brasenia*, and *Nymphoides*, as well as small plants such as *Lemna*, *Spirodela*, and *Wolffia* (Ellis & Martínez, 2010).

Economic activities

The ecosystems of the coastal area play a historical and cultural role in the development and support of world societies. The wealth in natural resources of the coasts develops diverse activities of economic importance (Tovilla *et al*., 2010). In the municipalities, along the coast, fishing predominates as a productive activity, in addition to being combined with agriculture, livestock, tourism, and industry (Ortiz *et al*., 2010).

Fishing

Artisanal, riverine, or small-scale fishing is carried out in coastal waters, lagoons, and rivers; using artisanal fishing gear on smaller vessels equipped with outboard motors or artisanal propulsion systems (Marín, 2007). Among the fishing gear are gill nets, hand lines, longlines, and traps; built with a variety of materials, dimensions, and operating systems according to the species being fished (Jiménez, 2006).

Small-scale fishing is characterized by low investment in equipment and low potential for the catch. This activity is often referred to as "artisanal," meaning that the fishermen make their fishing gear. However, "small scale" describes fishing carried out in small boats, with or without a motor, with fishing gear manufactured outside their communities or handcrafted (McGoodwin, 2002).

Small-scale fishing is a productive activity that generates food and employment. In 2016, the Food and Agriculture Organization (FAO, 2016), reported a world fish catch of 90.9 million tons obtained through the work of 40.3 million fishermen, estimating participation of small-scale fishing in 90% of the catches and the jobs created (FAO, 2019). In 2018, 40.3 million people participated (full-time, part-time, or occasionally) in the primary sector of capture fisheries (FAO, 2018); reducing unemployment and alleviating poverty in some developing countries and regions (Soto & Quiñones, 2013).

A long chain of intermediaries responsible for the supply of inputs, transformation, and commercialization of the product, such as boat builders, outboard motors, fishing implements, fishing equipment, and filleting or processing industries (Jiménez, 2006; Ortiz *et al*., 2010) depend indirectly on fishing.

Land-use change

The accelerated development of economic activities encourages disorderly growth in the coastal area, competition for space and the use of resources creates environmental conflicts that reduce the quality of services (Lara-Lara *et al*., 2008).

The change in land-use is defined as the territorial use and controlled anthropic exploitation of coastal ecosystems that, due to the productive intensification processes carried out in the territory, are manifested in changes in the modes of productive use, followed by changes in land use (Fernández & Prados, 2010).

The main causes of habitat loss in coastal areas of Mexico are deforestation, land-use change for the urban, port, and tourist developments, as well as extraction of materials used as fill in construction (Lara-Lara *et al.*, 2008). The different environments and their services are maintained on adequate conditions by applying effective and efficient policies, based on evaluation according to the speed of the change that has occurred (López *et al.*, 2015).

Evaluation methods

One way of evaluating land-use change is to measure variations in vegetation and non-vegetation cover. Traditionally, the measurement of changes in vegetation cover and land-use is carried out superimposed on documents generated by remote sensing or thematic coverage mapping (Bocco *et al.*, 2001).

Technological advances in remote sensing equipment determine the precision in the analysis of changes in coverage and land-uses. Aerial photographs gave way to satellite images, which were enhanced using orthophotos and high-resolution satellite images (Fernández & Prados, 2010).

Three methods are available for interpreting remote sensing images: visual interpretation, pixel-based digital image processing, and image segmentation. In visual interpretation, analysts draw polygons around visible differences in satellite images on the computer screen (Puig *et al.*, 2002). Polygons are related to a land cover legend class. An advantage of this method is the possibility of updating recent images, using a base map starting with the initial date, while a disadvantage of this method is its subjectivity because it depends on the criteria of the analyst.

Pixel-based digital image processing performs supervised and unsupervised classifications of soil categories with computer algorithms. Each pixel is considered a unit of soil and is added to groups of similar pixels. When clustering is based on the digital number of the pixel it is called "unsupervised classification", whereas in "supervised classification", an analyst assigns representative pixels of a land cover to a class in the legend, also considering the knowledge that the analyst has of the unit.

In image segmentation, an algorithm assembles groups of pixels based on spectral responses and the set of rules established by the analyst. However, to avoid large-scale errors, careful linking of land cover with land-use field verification information is required (Hyman *et al.*, 2011).

Finally, the evaluation of the dynamics of land-use (time in years) is carried out using cartographic maps modifiable with Geographic Information Systems (GIS) constructed with interpretation of information from images produced by remote sensing (Ramos-Reyes *et al.*, 2004).

Geographic information systems

Geographic Information Systems (GIS) are digital programs that spatially identify and represent areas that are more susceptible to change, and also help to understand processes and dynamics of change that occur in land cover and land-uses of a specific territory (Camacho-Sanabria *et al.*, 2015).

Killeen *et al.* (2005) mention that a GIS integrates geographic spatial referential information, identifying related patterns between different sources of information, applicable to any work with geographic representation. A GIS is a base of information related to the coordinates of the shape X (longitude), Y (latitude), and Z (depth), which improves the user's decision-making capacity on research, planning, and management (Bhardwaj, 2009). Through GIS, changes in land-use are evaluated with the support of cartographic inputs, such as aerial and satellite photographs. The error in maps of changes in the classification of images is minimized by corroborating current land-uses in the field.

Trends in GIS research

The articles included in the database are (43%) in Spanish and (57%) in English; (27%) at the national level and (73%) at the international level. The cartographic inputs used are mainly images from the Landsat satellite (44%), followed by territorial maps (23%), and high-resolution aerial images (14%), the remaining percentage is made up of images from the Spot satellite, various satellite images, orthophotos, printed and digital cartography.

Managed GIS evaluate information through visual interpretation analysis

(57%), pixel-based digital image processing (30%), and image segmentation (13%). The most used programs are ArcGIS (47%), ENVI (12%), ArcView (10%), IDRISI (8%), in addition to QGIS, Quantum GIS, PCI Geomatics, ERDAS, ILWIS. The formulas applied are: FAO deforestation rate (10%), vegetation improvement indices (10%) location stability, and residence stability (7%), among others; the formulas were not specified in 47% of the articles.

The general process identified for quantifying land-use changes using GIS was:

- Data collection: obtaining cartographic inputs to be used in each study and supports for land-use change maps, such as cartographic maps, satellite images, or national maps.
- Image pre-processing: geometric, atmospheric corrections, or georeferencing with GIS.
- Image classification: identification of soil classes, image interpretation, and selection of methods: visual interpretation, pixel-based digital image processing, and image segmentation.
- Maps of change: once the land-uses have been classified in the images, maps of the period to be analyzed are obtained.
- Change map precision evaluation: verification of control points in the field to determine map reliability.
- Changes matrix: list of quantitative changes of soil classes when comparing in the evaluation period.
- Statistical analysis or rates of change: calculation of deforestation rates by type of class or some relation of the degree of fragmentation, or other formulas.
- Changes in land-use and land cover: obtaining results in changes and percentages of losses and gains.

GIS evaluate land-use change in all types of regions, however, this research focused on coastal areas, identifying the lines of research developed (Table 1).

Table 1. Research lines developed on the evaluation of land-use change in coastal areas.

1.	Land-use change and ecosystem services
2.	Land-use change on the shoreline
2.1	Land-use change and coastal vulnerability
2.2	Land-use change in coastal dunes and its relationship with water resources
3.	Land-use change on the mangrove surface
4.	Dynamics of land-use change
5.	Land-use and Land Cover (LULC)
6.	Land-use change and infrastructure

Geographical distribution of land-use change studies in coastal areas, through Geographic Information Systems

The geographical distribution of studies in coastal areas is concentrated in tropical regions with ideal climatic conditions for the establishment and development of mangroves; it is where five studies of land-use change were established. Most of the articles and lines of research are located in the Gulf of Mexico, meanwhile, two other studies are presented in the Pacific Ocean. The dynamics of land-use change are the line of research with the most published articles (11), due to the interest in knowing processes that generate changes in land-use and their feasibility of evaluation in any region.

In Asia, studies of the value of ecosystem services and land-use change are prioritized (3), while in the Gulf of Mexico there is an information gap, as there is only one article in this line. Coastline assessment studies are concentrated in Spain (2) and the Gulf of Mexico (1). In South America, two studies that evaluate the coastline with other aspects, one the coastal vulnerability in Peru and the other, the coastal dunes and their relationship with water resources in Argentina. The coastline is an issue to be evaluated, considering the studies described, the decrease in the coastline and its impact on it, coupled with modifying climatic and geomorphological conditions. Changes in the infrastructure of the Havana Malecón in Cuba, related to climatic, geomorphological, and anthropic conditions were studied. This highlights the usefulness of GIS in the evaluation of coastal areas, considering them a facilitating tool for their spatial analysis.

According to institutions of origin of the corresponding author (Figure 1), Geography is the main science applied to these studies in 40% of the participating institutions, Environmental Sciences have 30% of the studies, followed by Ecology, Geomatics and Informatics with 7% each and to a lesser percentage are Agronomy, Aerospace and Civil Engineering with 3% each.

Research lines developed

Land-use change and ecosystem services

Most articles referring to land-use change in coastal areas compare this with its relationship with ecosystem services and effects derived from anthropic changes in natural covers. The Millennium Ecosystem

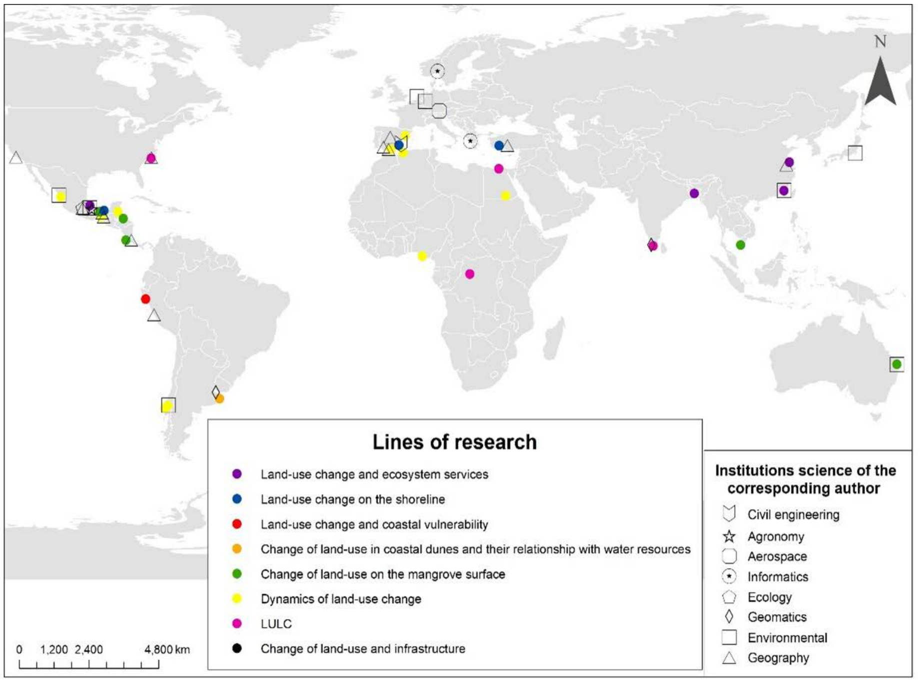

Figure 1. The geographical location of the lines of research and science related to the evaluation of land-use change in coastal areas.

Assessment program (Hassan *et al*., 2005) states that ecosystem services benefit the existence of humanity on the planet, being classified as *Provision*, goods produced by ecosystems; *Regulation*, services obtained from the regulation of ecosystem processes; *Cultural*, non-material benefits enriching quality of life, and *Support*, services necessary to produce all other services.

Lin *et al*. (2013) identified the dynamics of the environment on Xiamen Island, southeast China, by analyzing changes in land-use between 1973 and 2007, impact on ecosystem services and landscape patterns. The urban spatial expansion of the island was maintained using large areas of forests, farmlands, bodies of water, and coastal wetlands; continuously increasing land-use changes, decreasing the value of ecosystem services, and significant fragmentation in the landscape pattern.

Huq *et al*. (2019) conducted an assessment of ecosystem service values in southern Bangladesh from 1973 to 2014, where they analyzed land cover and how its variations affect ecosystem services. They identified 14 ecosystem services (Provision: agricultural inputs, economic benefits, fisheries and aquaculture, food production, medicinal plants, raw materials, water, and biodiversity. Regulation: local climate regulation, soil management, water purification and treatment, regulation of the water flow, extreme event management, Cultural: recreation); in addition to three soil classes (agricultural land, rural vegetation with human settlements and wetlands). The authors concluded that there is an increase in land-use in the first two classes and a decrease in the value of services derived from poor rural agricultural planning.

Xu *et al*. (2016) evaluated, between 1977 and 2014, ecological security, due to changes in land-use in the coastal area of Jiangsu, China; concluding that the land-use types most affected by the increase in the surface of urban areas (area in 2007 from 9.45% to 207.33% in 2014) are the intertidal zone and halophilic vegetation.

Mendoza-González *et al*. (2012) evaluated the effects of land-use change on the Gulf of Mexico coast and its relationship with the decrease in ecosystem service values, between 1995 and 2006. They concluded that the expansion of agriculture, livestock, along with urban expansion directly impacts on ecosystem services and their economic values. The ecosystems with the smallest surface area were beaches, dunes, and wetlands, being, however, the ones with the highest ecosystem value.

Considering the research described, agricultural and urban expansions reduce ecosystem services. Vegetation areas such as forests or wetlands when transformed into land-use, such as urban, agricultural, or livestock areas, do not provide ecosystem services of great value; in this context, the identification of viable maintenance areas in coastal planning will conserve the value of their ecosystem services.

Land-use change on the coastline

Pagán *et al*. (2018) analyzed trends of change in the past, the current state, and the future progression of various sandy beaches of the Levant Mediterranean, between 1956 and 2016. They concluded that historical anthropic pressures reduce the regression of the coastline, affecting its trend. As for artificially regenerated beaches, the original beach width has yet to be reached, showing a lack of adequate beach regeneration techniques.

In México, Hernández *et al*. (2008) determined Spatio-temporal variations of the coastline of the state of Tabasco (1973-2004), caused by variations in the mean sea level and the magnitude of the geographical changes in its territory. They concluded that the morphodynamic processes of the coastal area revealed a predominance of the retreat of the coastline over the effects of accretion processes.

Temiz and Durduran (2016) stated that the changes in the coastline in Lagos can be evaluated, in their study they estimated the changes in Lake Acigöl in Turkey between 1985 and 2015, where they reported a decrease of 129 to 42 km^2 in surface areas of water, losing 67.4% over a period of 30 years. The factors causing the changes were: evaporation of lakes due to heating, reduced rainfall, excessive consumption of water for agricultural use, and formation of other soil covers.

Land-use change and coastal vulnerability

Rondón and Tavares (2018) evaluated erosion vulnerability in the Peruvian coastline, classifying it into three categories, low, medium, and high, under a sea-level rise scenario in a Climate Change context, between 1962 and 2015. They developed four physical variables: *geomorphology*, *beach type*, *beach slope*, and *shoreline* changes and three anthropic variables (*land-use, beach width, and coastal settlement*). The variables with the highest vulnerability were *beach type* (72.2%) and *shoreline changes* (62.6%). Average vulnerability predominated in *beach slope* (50.7%) and *geomorphology* (51.1%). In the *beach width* variable, the situation is similar between medium vulnerability (43.2%) and high vulnerability (44.4%). In *coastal settlement* (81.9%) and coastal land-use (75%) variables, predominated low vulnerability. Using the *beach width* variable, related to the creation of beach infrastructures, a predominantly high or medium vulnerability was identified in all inhabited areas.

Land-use change in coastal dunes and its relationship with water resources

In Argentina, Carretero *et al*. (2014) analyzed the changes in recharge possibilities of the coastal aquifer in the Partido de La Costa, Buenos, Aires, according to the changes in land-use between 1973 and 2010, classified four types of land-use: *mobile dunes*, *semi-fixed dunes*, *fixed dunes*, and *urbanized areas*. The *mobile dune* was reduced, being replaced by settlements of cities located in front of the sea. The *fixed dune* replaces the *semi-fixed dune* in small sectors. A slight advance of a *fixed dune* on *mobile dune* was observed, interfered in certain sectors with *semi-fixed dune*, which is part of the natural process of evolution of the dune barrier. Urbanization and population growth have generated changes in the coastal dune environment. In the *mobile dune*, the infiltration of excess water through the sand is more significant, whereas in the *fixed dune* it is less due to its impermeable, vegetated, or compacted cover.

Considering the above, we point out that coastline vulnerability increases due to urban development expansion. The transformation of coastal dunes to urban areas are geographical modifications reflected in the decrease of the coastline and the reduction of the recharge of aquifers by infiltration.

Change in land-use on the mangrove surface

Sanabria-Coto *et al*. (2018) proposed a comprehensive geographical delimitation of the Mangrove of Nosara, Guanacaste, Costa Rica between 1944 and 2016, through the analysis of physiographic elements typical of the marine/continental context that favor the adaptation and distribution of the mangrove forest, composed of the red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*) and majagua shrubs (*Hibiscus pernambucensis*). The area was associated with topographic reliefs, hydrographic patterns with obvious lateral changes, and unconsolidated sediments.

Hernández *et al*. (2016) in Tabasco, Mexico, evaluated the change of land-use in the period 1995 to 2008, identifying and quantifying the changes in location and mangrove areas. They identified three types of agroecosystems (AES) surrounding mangroves: coconut, coconut-pasture-livestock, and grass-livestock. In 1995 the mangrove area was 568.49 ha, for 2008 such surface showed an increase of 148.72 ha replacing part of the hydrophytic vegetation that occupied 543.48 ha in 1995 and was reduced to 355.10 ha in 2008. In 1995 the pasture-livestock agro-ecosystem had an area of 487.07 ha, in 2008 it lost 21.19 ha replaced by mangrove. In 1995 the coconut AES had 226 ha, reduced in 2008 to 36.37 ha, of which 189.73 ha were associated with the AES coconut-pasture-livestock and in some cases with mangrove swamps. The increase in the mangrove surface resulted from anthropic disturbances favoring its colonization, negatively impacting the grass-livestock AES.

Tuholske *et al*. (2017) determined the effects of the expansion of urban areas and tourism development in the mangroves of Roatán in Honduras, quantifying the land-use and change of coverage between 1985 and 2015. They concluded that at the end of the period the total coverage of mangroves decreased by 28.21%. The pixel-by-pixel comparison of the classified images indicated that 352.9 ha of *tropical forest*, 486.52 ha of *mixed agriculture*, and *tropical forest* (AMB), and 224.1 ha of *mangroves* were converted into *urban areas*. The conversion of 10% (486.5 ha) of AMB measured in 1985 to an urban area in 2015, suggested that urban development reduced the old agricultural areas. The *tropical forest* 4.3% (271 ha) in 1985 was converted to an *urban* area by 2015. The *urban* class expanded at an annual rate of 22.59 ha for the total of islands between 1985 and 2015. Mangroves throughout the island decreased by 7.50 ha per year. They found a significant relationship between urban growth and loss of mangroves between 1985 and 2015, the model indicated that an increase of 3 ha of an *urban* class is correlated with a loss of 1 ha of mangrove class.

In Australia, Brown *et al*. (2018) described, holistically and in the long term, drivers and processes of change in mangroves of the Maroochy River, Queensland between 1988 and 2016, evaluating the change in mangroves with remote sensing and traditional ecological knowledge. They interviewed seven key participants to describe and identify extensive changes in the distribution and extent of mangroves in the river system. According to participants, mangrove forests extended within the study area before European colonization (1860). Between 1988 and 2016, the total mangrove area decreased by 683 ha in the study area of 5,795 ha, representing a loss of 30%. Drivers of mangrove change in the study area include farming, urbanization, pollution, sewage discharge, and boating.

Hauser *et al*. (2017) mapped the dynamic fragmentation of central mangrove forests in the Ca Mau Peninsula, Vietnam between 2004 and 2013, based on a post-change analysis of land cover. They concluded that mangrove forests decreased from 44% in 2004 to 37% in 2009. The origin of the forest loss was the productive conversion to aquaculture areas from 2004 to 2009. Between 2004 and 2013, around 7,849 ha were reforested and rehabilitated, constituting, in 2013, around 31% of the total mangrove forest cover. For the subsequent years, 2009 and 2013, these "restored" forest patches were established by conversion of aquaculture land cover (6,933 ha).

By the above, irrational forest exploitation, hydrological modification due to deviations of river channels, dredging, or filling of mangrove areas for port construction, aquaculture, and tourism infrastructure, are highlighted among the causes of the physical destruction of the mangrove habitat (Beltrán *et al*., 2005). Since anthropic factors affect the ecosystem services of the environments, their evaluation and monitoring become even more relevant.

Dynamics of land-use change

In Spain, Ramírez-Cuesta *et al*. (2016) explained changes in the mouth of the Ebro River, between 1957 and 2013, establishing evolutionary trends determined by a modification of various geomorphological units. They concluded that the geomorphological units with the greatest increase in area in the period 1957-1984 were those occupied by *anthropized deltaic plain* (ADP) and *sandbar*, *active spit* (S), the diminished class was *fixed dune & vegetated Aeolian mantle* (FD). In the 1984-2013 period, the *littoral ridge* (LR) and FD categories increased, while *interdune depression* (ID), *beach* (B), and S decreased. The most significant processes during the study were marine erosion and agricultural expansion, whose greatest magnitude was during 1957-1984. Concerning to geomorphological changes, the period 1957-1984 was more active than during 1984-2013.

Peña-Cortés *et al*. (2011) analyzed the relationship between geographical distribution, environment, and anthropogenic factors, in the coastal area of the Araucanía Region, in Chile, between 1968 and 2009. They identified 427 fragments of swamp forest with sizes between 0.25 ha and 936 ha, representing a total area of 7,675 ha, equivalent to 4.6% of the evaluated territory. The small size and irregular shape of the vegetation fragments, in addition to the use of surrounding agricultural land, place high pressure on most of the forest distribution.

Berlanga *et al*. (2010) analyzed patterns in vegetation cover and land-use change in the north coast of Nayarit, Mexico, in the period 1973-2000, the percentage of change was 30% at the regional level. The dominant class was the forests, covering in 1973 (48%) and in 1990 (40%) of the total area, this condition changed in 2000, where agriculture dominated by 41%.

Concerning to natural wetlands, these covered 19% of the total area every year, while artificial wetlands, represented by shrimp farming (they were recorded from 1990) covered a small percentage of the region, the same as in 2000. The secondary vegetation class had a lower capacity to stay in the same place during the analyzed periods.

In Kenya, Were *et al*. (2013) characterized land cover dynamics, between 1973 and 2011, in the eastern Mau forest and the Lake Nakuru basin. They concluded that the main land cover types in the lake's drainage basin were forest-shrublands, grassland, croplands, built-up land, bare land, and water bodies. The first period was from 1973 to 1985, the second from 1985 to 2000, and the third from 2000 to 2011. Forest- shrublands, grassland, and cropland had higher magnitudes of change compared to built-up land, bare land, and water bodies during the three periods. Forest- shrublands and grasslands decreased, 428 km^2 and 258 km^2 respectively, at annual average rates of 1% each, while cropland and built-up land expanded by 660 km^2 and 24 km^2 at average annual rates of 6% and 16% respectively. Built-up land was the most dynamic, growing at average annual rates of 2%, 17%, and 5%, in the three periods, respectively.

Fernández and Prados (2010) evaluated land-cover and land-use changes in the Guadalfeo river basin, Spain (1975-1999). The results of which are as follows: in 1975, the dominant categories were shrublands-grassland and conifers with an area of 78,395.81 ha, which represents 60% of the total area. The rainfed and irrigated categories with 43,032.14 ha, followed by rainfed olive groves (2,372.69 ha) and vineyards (770.96 ha) made up the second group. In 1999, the dominant category in coverage and land-use was shrublands-grassland, representing 66% of the surface, with an area of 84,875.14 ha. In 1975 the area of this category doubled to 44,739.18 ha. The next category in order of extension is dry land, with an area of 15,708.69 ha and representativeness of 12%. The rest of the categories, up to eleven different coverage, were dispersed in the basin with less than 5% representation. The southwestern area was more dynamic and prone to the introduction of changes in agricultural land-uses, in turn, the northeast strip tends to the stability of uses in by the conservation objectives. However, progressive shrublands were observed at the expense of the coniferous patches existing in 1975.

In Mexico, Rosete *et al*. (2009) analyzed land-use and vegetation change in the Baja California Peninsula (1978 to 2000), at the level of vegetation types and a 1:250 000 scale. They identified that 92.3% of the territory remained unchanged between 1978-2000, while 7.7% presented some change in vegetation cover. At the regional level, the main land-use and vegetation changes are of anthropic origin caused by urban growth and the expansion of agricultural activities, mainly in the extreme north and south. Types of vegetation and land-use with the greatest decrease were xerophilous scrub, grasslands, rainfed agriculture and irrigation, and humidity agriculture. Most of the changes were in the coastal plain, associated with agricultural areas and human settlements, as well as in adjacent areas with arboreal vegetation (forests and low forests).

Meanwhile, Peña-Cortés *et al*. (2009) geospatially evaluated the change in land-use (1980 and 2004), on the coastal edge of the La Araucanía region in Chile. The most important land-use categories in 1980 were native forest and agricultural matrix (with 21% and 44% respectively). In 2004, forest plantations underwent the most important factor of change, starting at 1% and reaching 9% of the surface with the growth of over a thousand percent. The original land cover of the coastal edge of La Araucanía changed dramatically; initially, as a result of the authorization of land for agricultural-livestock activity and later, due to the impact of forest plantations.

Kuenzer *et al*. (2014), between 1986 and 2013, characterized the geography of the Nigerian Delta using variables such as land surface dynamics, coastline, creation of channels for oil exploitation, and gas flaring. They concluded that urban areas expanded 1,516 km^2 from 1986 to 1,730 km^2 by 2013 and the agricultural area increased 31,700 km^2 to 33,895 km^2 respectively. The area of forests and swamps decreased from 18,325 km^2 to 15,408 km^2, while the mangrove forest remained with 10,311 km^2 in 1986 and 10,072 km^2 in 2013, with a period of decline until 2003 and stabilized afterwards thanks to protection activities and rehabilitation. Analysis of shoreline dynamics revealed that annual accumulation rates were slightly higher than erosion rates, however, starting in 2003, they increased in almost all coastal states. Annual rates of coastal change at discrete locations vary from 64.8 m of coastal erosion to accretion rates of 59.8 m. Highlighting that the impact of the oil industry activities in the Delta is remarkable.

The network of access channels, within the mangrove ecosystems of the three, affected Delta states, expanded from 230.4 km in 1986 to 269.5 km in 2003, and 349.3 km in 2013.

For their part, Díaz-Gallegos and Acosta-Velázquez (2009), in the Chetumal Bay in Mexico, determined the magnitude, dynamics, and distribution of processes of land cover and use changes in the landscape surroundings of the bay from 1990 to 2005. The natural covers dominated the distribution of land-use and vegetation around the bay, with the natural vegetation class being the largest (291,305 ha), followed by wetlands and mangroves. Agricultural and livestock activities were concentrated in the south-western part of the Bay. The medium and lowland semi-deciduous forests decreased about 950 ha each year, with a rate of −0.32% during the analysis period. Mangroves that registered the highest annual change rate (−0.65%), decreased approximately 300 ha each year, being concentrated in the south of the Bay. During the study period, the agricultural / livestock classes, human settlements, and secondary vegetation increased their areas. The secondary vegetation class was less stable in its location (51%), so most of its patches were not spatially maintained in the area; this class displaced natural vegetation (8,225 ha) and agricultural / livestock (1,907 ha) classes. Likewise, the agricultural / livestock class was displaced by the natural vegetation and secondary vegetation classes, showing the temporal dynamics of agricultural activity in the study area.

Gordillo-Ruiz and Castillo-Santiago (2017) recognized factors causing changes in the Sabinal river basin in Chiapas, between 1992 and 2009, based on socioeconomic trends and landscape patterns, through the evaluation of the change in coverage of land-use. Their results showed that 72% of the basin territory has the same type of land cover and 28% had some type of change. The forests showed a decrease of 663 ha, which represents 8.7% of the original area and a deforestation rate of −0.5%. Human settlements expanded by 4,331 ha, equivalent to a growth of 63%. The most important land-use change processes in the basin were the forest for agricultural land and the expansion of the urban area in areas of secondary vegetation and crops.

Ramos-Reyes *et al*. (2016) identified the dynamics of land-use change, between 2000 and 2010, in Comalcalco, Tabasco, Mexico. In 2000, the authors identified 6 land-uses: *grasslands*, *agriculture*, *hydrophilic vegetation*, *mangroves*, *bodies of water*, and *urban areas*. There were specifically located, to the north, mangroves and lagoon bodies; to the northeast, a small portion of *hydrophilic vegetation*, *agricultural use*, and *grasslands*; the central and southern portion was less diverse in terms of land-uses, it is limited to *grasslands*, *agricultural*, and *urban areas*, while the most extensive uses are grassland and agriculture. In 2010, the same six land-uses of 2000 and a greater number of urban centers were identified, highlighting the expansion of the municipal seat in places corresponding to agricultural and livestock use. The main land-uses were conserved both in number and in area, although the change in the use of *grasslands* in *agriculture* and *urban areas* and from *hydrophilic vegetation* to *grasslands* stands out.

We consider that the dynamics of land-use change is the area where the most published articles were found, due to the interest in identifying patterns or transitions of land-use change that generate these transformations. In them, the substantial negative effect exerted by the dynamics of agricultural activity in the study regions is argued, precisely due to the increase in the use of areas of natural vegetation or grasslands as areas of agricultural use; in addition to identifying secondary vegetation as a substitute for other types of vegetation due to its historical displacement capacity.

Land-use and Land Cover (LULC)

In India, Kaliraj *et al*. (2017) evaluated the decadal changes and their transformations of Land-Use and Land Cover (LULC) features, on the South West coast of Kanyakumari, where they identified 12 LULC. The areas of each face land cover, cultivable lands, plantation, fallow land, and barren land are converted into built-ups, the latter with an area of 17.54 km^2 in 2000 and represented 6.01% of the total study area increasing to 39.22 km^2 in 2011 occupying a surface area of 13.43% of the total area. Most of the land cover features were transformed into built-ups and settlements without considering the negative impacts on coastal systems.

In the United States, McCarthy and Halls (2014) evaluated changes on Masanboro Island in North Carolina between 2002 and 2010. Screening results indicated that nearly 20% of the study area experienced change. The soil class intertidal marsh underwent the greatest change among the smallest habitat classes, while the upland scrub underwent 84% changes. The net change (absolute value of the difference in profit and loss) of the Island was 5%, but the swap change (the difference between total change and net change) represented more than 14%.

On the northern Egyptian coast, Shalaby and Tateishi (2007) analyzed changes in land cover and land-use over a 14-year (1987-2001). They concluded that the study area underwent a severe change in land cover as a result of multiple agricultural or tourism development projects. Also, urban settlements and agricultural lands increased in extension considerably, while the area of natural vegetation decreased. The degradation of natural vegetation due to overgrazing, the inter-annual variation in the amount of rainfall, the water record due to poor irrigation management and wind erosion were identified as land degradation processes.

In Greece, Kolios and Stylios (2013) investigated the LULC changes in the southwest part of the Epirus region, called Preveza, between 2000 and 2009. They concluded that the *Barren land and Urban fabric-beaches-roads* classes increased by 4.18% and 1.76% respectively. On the other hand, *Forest-high vegetation* (0.68%) and *Low vegetation* (5.2%) decreased. The *Water land* class remained almost unchanged. The 16.15% and 7.62% classified as *Barren land* in the initial state year (2000), were changed to *Low vegetation* and *Urban fabric-beaches-roads* classes respectively. However, 76.03% of the *Barren* land in the initial state remained in the final state (2009) without changes, determining that the change 16.15% of the spatial change of the *Barren* land class to *Low vegetation* is overestimated due to possible irrigation from agricultural areas, which changed humidity levels on the earth's surface; consequently, their spectral signatures mislead the classifier. There is also a notable change from the *Barren* land class to the *Urban fabric-beaches-roads* class that shows a clear trend towards LULC changes.

By previous works, the LULC verifies the change from natural covers to those transformed to land-uses and the percentage of each one in the study area. Land covers such as vegetation, secondary vegetation, and grasslands are transformed into urban or agricultural land-uses, although the latter use tends to transform from agricultural to urban land.

Change of land-use and infrastructure

In Cuba, Remond *et al*. (2018) mapped the infrastructure of the Havana Malecón and analyzed meteorological events and geographic variables most influential in its deterioration, between 1990 and 2012, using remote sensors, as well as spatial and statistical analysis. The variables analyzed (depth of the sea, the surface of the reef, and distance from the Malecón to the coastline, the height of the Malecón above mean sea level, and orientation of the coast) followed the direction of the prevailing winds on the coast. The Malecón presented some signs of deterioration in 56.9% of its surface, while the most deteriorated areas were located in the northwest of the sector. The orientation of the coast and deteriorated areas showed a high correlation, indicating that the deteriorated areas are perfectly oriented concerning the wave trains caused by the arrival of cold fronts, subjecting the Malecón to an incessant process of wear and tear. The distance from the Malecón to the coastline exerted some influence, since, in sectors of the Malecón separated from the coastline, the energy of the wave trains is dissipated during seasons of cold fronts.

The foregoing shows that the evaluation of coastal areas serves for the preservation or improvement of maritime infrastructure, since environmental factors deteriorate it rapidly, in addition to being applied in determining future impacts with projections of sea-level rise.

CONCLUSIONS

Uncontrolled urban growth and human pressure constantly affect coastal territories, due to the economic, environmental, and social importance of all the ecosystem services provided. Urban settlements and agricultural use are the changes in land-use that cause the greatest impacts on coastlines, whose dynamics begins with the conversion of land from natural vegetation to agricultural use and later to urban or anthropic use; where there is hardly a transition to another use, as in agriculture, which can change to vegetation or mangroves according to the presence of suitable geomorphological conditions.

Environmental impacts in coastal areas are minimized by identifying areas more suitable for different land-uses. These areas often lack a coastal order; if they exist, due to the performance of economic activities, they prioritize the transformation of the territory without considering impacts on the habitat, reducing the quality and value of the ecosystem services provided.

Geographic Information Systems are useful tools in the identification and quantitative evaluation of changes in land-use in coastal ecosystems; which require constant evaluation due to their high dynamism. Updated information is obtained, from baselines or monitoring through change behavior studies, useful in decision-making by those responsible for carrying out adequate mitigation, territorial planning, protection, and preservation actions for ecosystems.

RECOMMENDATIONS

Geographic Information Systems are a tool for evaluating change in study areas of coastal ecosystems. However, to perform more efficient analyzes, technical improvements are required by incorporating statistical analyzes or appropriate extensions to various approaches.

Coastal areas offer diverse ecosystem services that favor urban expansion; however, the anthropic activities carried out affect such services. Various studies evaluate the change in land-use relating to the decrease in the value of these services; China, for example, established the importance of this line of research, unlike Mexico, where studies of this type are needed, as well as the integration and spatial analysis of information through GIS.

After the filling of wetlands or mangroves, the natural habitats of the coastal areas are reduced, changing to urban or agricultural land-uses, causing loss of viable subsistence spaces for native or migratory species. Therefore, it is necessary to identify the relationship between the decline in species of fauna and flora with the change in land-use, since its information is limited.

Climatic and geographical conditions, coupled with the increase in transformations to urban areas, rapidly modify the coastline of coastal areas. According to the studies analyzed, there is a decrease in accretion effects on the coastline; this reduction can affect nearby human settlements. This change is visualized by analyzing the demographic increase and the climatic and geographical conditions that affect the coastline; in addition to serving to carry out a correct territorial organization. Likewise, through GIS, coastal vulnerability indices can be built and areas of a high risk of flooding due to sea-level rise can be detected.

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