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Analysis

# Land use change and its effects on the value of ecosystem services along the coast of the Gulf of Mexico

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ABSTRACT

In the central region of the Gulf of Mexico, urban growth occurs mainly to support tourism and results in loss of natural ecosystems and ecosystem services. Our objectives were to analyze land use changes and calculate the value of these changes in terms of lost ecosystem services. We selected three study sites with contrasting infrastructure for tourism: Boca del Río, Chachalacas and Costa Esmeralda. From 1995–2006, we found that urban sprawl was predominant, and occurred over mangroves, grasslands, croplands and the beach. Using the benefit transfer method, we calculated a net loss ($US 2006/ha/year) of $1.4\times10^3$ in Boca del Río, $7\times10^5$ in Chachalacas and $1\times10^5$ in Costa Esmeralda. Because the value of urban land is higher (from 45,000 USD/ha (2006) in Costa Esmeralda to 6 million in Boca del Río) than the total estimated Ecosystem Services Value (106,000 USD/ha, including all ecosystems and ecosystem services), land use change may seem economically profitable. However, after losing ecosystem services such as coastal protection or scenic value and recreation, the apparent gains from urban development are lost. Land use and policy making should consider ecosystem service losses so that ecosystems are preserved and society benefited.
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## 1. Introduction

Natural ecosystems provide a variety of direct and indirect services and intangible benefits to humans and other living organisms (Costanza et al., 1997; Daily, 1997). Because of their relevance to society, these ecosystem services, as well as their economic value have become a focus of interest for scientists, policy makers and stakeholders over the last decade (Troy and Wilson, 2006). The provision of ecosystem services is directly related to the functionality of natural ecosystems upon which ecological processes and ecosystem structures depend (de Groot et al., 2002). Nevertheless, because of population growth, economic pressure, and urban sprawl, natural ecosystems are continuously being altered, destroyed or transformed, especially during the last decades (Vitousek et al., 1997). Globally, land use changes from natural ecosystems to croplands, grazing lands (grasslands), and urban areas have increased over time, resulting in reduced or modified biodiversity, altered functional processes and diminished provision of ecosystem goods and services to society (Balvanera et al., 2006; de Groot et al., 2002; Díaz, 2006; Li et al., 2007; McIntyre and Lavorel, 2007; Metzger et al., 2006). For instance, it has been observed that land use change into urban sites and agriculture is detrimental for several ecosystem services such as a) nutrient cycling, climate regulation, erosion control and genetic resources (Li et al., 2007; Peng et al., 2006; Wang et al., 2006; Zhao et al., 2004), b) recreation opportunities (Kreuter et al., 2001), c) climate regulation and erosion control (Portela and Rademacher, 2001) and d) soil fertility, water availability and increases the risk of forest fires (Schroter et al., 2005).

Although the impact of human activities is pervasive to all natural ecosystems in the world, the coasts have been particularly affected. For millennia humans have been attracted to the coastal areas and at present nearly 40% of the global population live within 100 km of the shoreline (Martínez et al., 2007). The impact of human activities near or at the coast is, therefore, intense. Mexico is no exception to this global trend: here, tourism has developed rapidly along the coast, especially during the last decades. In particular, the coast of the state of Veracruz (745 km long) is socially very important, with nearly 20% of its cities and 27% of its population (1,898,013) located less than 20 km away from the shoreline. Land use change has occurred rapidly in the state, which has lost more than 36% of its original forest cover since 1980 and more than 40% suffer from serious soil erosion (SEFIPLAN, 2005). Public and private investments in agriculture activities increased dramatically between 1940 and 1970; but have since changed to promote cattle ranching (CONABIO, 2006). State programs in Veracruz support and promote livestock activities in natural areas, thus exacerbating deforestation and pollution, and consequently, a degraded landscape

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(SEFIPLAN, 2005). Recently, tourism activities have increased along the coast, resulting in additional degradation and loss of natural ecosystems.

These development policies do not consider the environmental impacts of land use change in terms of ecosystem services. Indeed, the ecological relevance and the social pressure on the coastal ecosystems of Veracruz make it evident that there is an urgent need to: a) assess the current status of the natural ecosystems located along the coast of the state of Veracruz; b) to evaluate the ecosystem services provided by natural ecosystems located at the coast and c) assess how they have been altered with land use change. Because tourism and urban sprawl along the coast of Veracruz are increasing rapidly, in this study we aimed at assessing land use change in three coastal locations with contrasting tourism activities and later evaluated the impact of these changes in terms of ecosystem services. We used ecosystem service values to estimate the impact of regional land-use change associated with tourism development that has occurred over the last decade (1995–2006).

## 2. Methodological and Ideological Options

### 2.1. Study Sites

The state of Veracruz is located midway along the Gulf of Mexico between Tamaulipas and Tabasco (Fig. 1) and occupies 3.7% of the total surface of Mexico. The state's high weather and topographic diversity support a diverse array of atural ecosystems, ranging from tropical rain forests to alpine needle leaf forests (SEFIPLAN, 2005). Veracruz is the third most populated state in the country with nearly seven million inhabitants. The shoreline of Veracruz (745 km) represents 6.42% of the national coastline (11,593 km) (INEGI, 2007). In Mexico, the port of Veracruz is one of the most important ports for commerce between America and Europe. The state of Veracruz has a rather high agricultural productivity because of the abundant rivers interconnecting within the watersheds, which flow through the municipalities downhill and into the coastal zone (SEFIPLAN, 2005). The coastal ecosystems are highly diverse, and include mangroves, coral reefs, sea grasses, coastal dunes, tropical rain forests, among others. All along the coast, disorganized urban growth has generated deterioration, pollution and overexploitation of these diverse natural resources. As human conflicts compete for space and resources, coastal dunes and wetlands are transformed and degraded by human settlements (SEMARNAT, 2006).

The coast of Veracruz is an important destination for national and international tourism. We selected three study sites with contrasting tourism activities and infrastructure (Fig. 1), all located in the central region of the Gulf of Mexico in the state of Veracruz: Boca del Río, Chachalacas and Costa Esmeralda. The three study sites cover similar areas, although Costa Esmeralda was marginally larger (Table 1). They all share a hot-humid weather with mean annual precipitation ranging from 1018 mm/year in Chachalacas to 1694 in Boca del Río. Boca del Río is located to the south and adjacent to the Port of Veracruz. It is mostly urbanized and includes large hotels and urban infrastructure. Here, commercial activities are predominant. This is the most densely populated location from our three study sites. Chachalacas is located in the municipality of Úrsulo Galván, it is the least urbanized area and offers suburban infrastructure in a more natural setting. Costa Esmeralda encompasses 3 municipalities: Tecolutla, San Rafael and Nautla. It is a farming area with limited urban infrastructure. Fishing, cattle ranching and croplands are more important in Chachalacas and Costa Esmeralda. All three study sites have popular beaches that are frequently visited by tourists. Natural ecosystems and habitats in all study sites have been fragmented owing to land use change and the increasing impacts of human activities.

### 2.2. Land Use Changes

We used high resolution aerial images of the same areas from different time periods (1995 and 2006), to assess the changes that have occurred in each site over a decade. Land use polygons were created based on 1:75,000 orthophotos from 1995 that were obtained from the National Institute of Statistics, Geography and Informatics (INEGI, 2007). Polygons were also created over high resolution aerial photography of 0.80 m of pixel from 2006. ArcView 3.2 was used to digitize by hand two vector maps for each study area. In each location, the study area comprised the alongshore political limits of the municipalities, and a 2.5 km wide band inland from the shoreline. Land use was classified for two time periods (1995 and 2006), and was verified in the field. Finally, we calculated transition matrices of land use change, by summarizing the cover of each land use type from 1995 and calculating how each one changed in the following decade (2006).

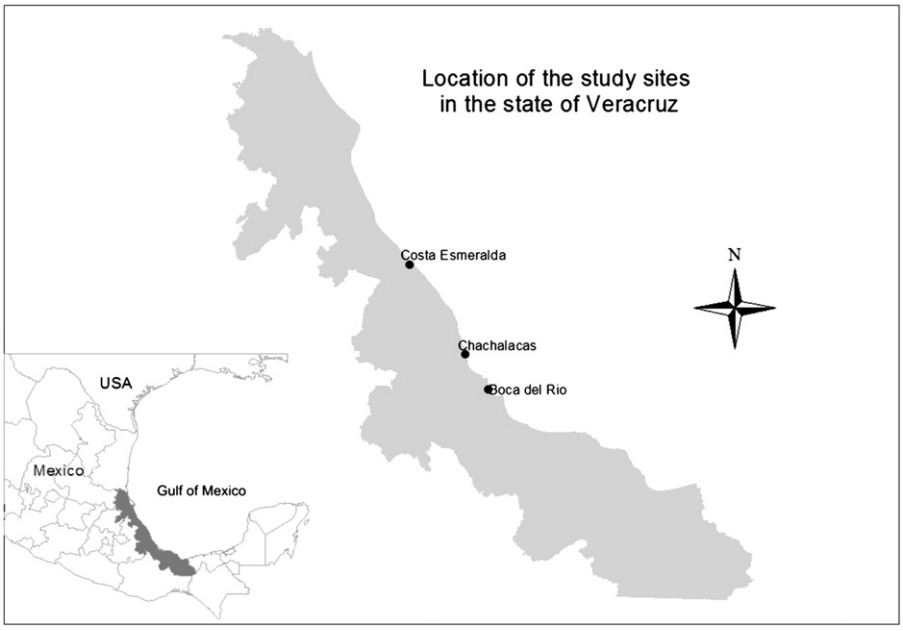


**Fig. 1.** Location of the study areas in the state of Veracruz.

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