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Floristic composition and soil characteristics of tropical freshwater forested wetlands of Veracruz on the coastal plain of the Gulf of Mexico

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A B S T R A C T

We studied the influence of geomorphological setting and soil properties on the vegetation structure, composition and diversity of five forested coastal wetlands in Veracruz on the Gulf of Mexico. These swamps are located on floodplains and in dune depressions. We recorded 109 woody and herbaceous species. The most frequent species were the trees *Pachira aquatica*, *Annona glabra*, *Diospyros digyna* and *Ficus insipida* subsp. *insipida*, the lianas *Dalbergia brownei* and *Hippocratea celastroides* and the hemi-epiphyte *Syngonium podophyllum*. The Shannon-*H* diversity index varied from 2.659 to 3.373, density from 1750 to 2289 stems ha^{-1} and basal area from 32.7 to 76.42 $m^2\ ha^{-1}$. The classification analysis defined two groups: one corresponded to forested wetlands along the floodplain (Apompal, Cienaga, Chica) and the other included Mancha and Salado, in dune depressions. PCA ordination of soil parameters during the rainy season explained 67.0% and during the dry season 69.1% of the total variance. In the rainy season Mancha and Salado samples remain close together because they have lower Mg, Na, K, % Total C and % Total N values. Apompal and Chica samples remain close to each other because of their high levels of % Total C, % Total N, Mg, Na and high soil water content. Cienaga samples are separated from the others because of high values of P, Ca and Eh as well as high water levels. In general, soil parameter ordination during the dry season showed that redox potential, P, water level and water content decreased in the forested wetlands and Na values increased in Chica. The soil textures identified were clay, sandy clay loam, sandy loam and clay loam; clay texture dominated alluvial processes in the floodplain (e.g., Cienaga). The forested wetlands in the floodplains had similar vegetation and the same happened in the dune depressions but soil characteristics were more variable in both cases. Plant diversity in floodplains tends to be relatively high, and the presence of adjacent tropical forests probably increases its richness, except in cases in which there are stressing factors, such as salinity. The forested wetlands studied showed dominant floristic elements, which extend north into Florida such as *A. glabra* and *Ficus aurea*. Other dominant elements such as *P. aquatica* are also found in Central and South America. The forested wetlands studied are subjected to continuous deforestation to transform the land into farming or ranching activities, this being a common practice throughout the distribution range of these forests.

1. Introduction

Tropical forested wetlands provide connectivity between coastal ecosystems, which is critical in flood control and storage of organic matter, sediment retention, among other functions (Ewel, 2010). These forested wetlands are located in extensive floodplains such as the Amazon (Kubitzki, 1989; Teixeira et al., 2011), in depressions where the water table is exposed as in dune lakes (Moreno-Casasola et al., 2009), on the periphery of coastal lagoons (Lot and Novelo, 1990), as small patches of vegetation in the Everglades (Gunderson and Loftus, 1993), forming Petenes in the Yucatan Peninsula (Olmsted and Durán, 1986), or in narrow plains as in the case of the Pacific islands (Allen et al., 2005; Ellison, 2009). Many of these swamps in subtropical and tropical areas and in coastal tropical plains are frequently found upland from mangroves, and they have received little attention (Ewel, 2010).

Forested wetlands are characterized by the presence of tree elements with morphological adaptations (buttresses, knee roots) to

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scarcity of oxygen, and the presence of palms, which can become the dominant elements and lianas. The height of these forests usually ranges from 10 to 25–30 m. Despite the physiognomic similarities among forested wetlands in each region, each is characterized by a particular plant composition: for example in the southern United States dominant species are *Taxodium distichum* var. *nutens* and *Nyssa sylvatica* var. *biflora* (Brown et al., 1984), in the coastal Gulf of Mexico *Pachira aquatica* and *Annona glabra* (Lot and Novelo, 1990), in the Yucatan Peninsula *Bucida spinosa* and *Haematoxylum campechianum* dominate (Olmsted and Durán, 1986), in the Guyanas and Caribbean region, including Puerto Rico the most conspicuous species are *Pterocarpus officinalis* and *Symphonia globulifera* (Alvarez-Lopez, 1990; Migeot and Imbert, 2011), in the Pacific Islands one can find *Terminalia carolinensis*, *Campnosperma brevipetiolatum*, *Calophyllum vexans* (Allen et al., 2005; Ellison, 2009) and in the southern part of Australia *Melaleuca* spp. (Finlayson et al., 1993; Zoete, 2001). The description of the structure of these forests and their relationship with environmental parameters such as soils, hydrology and geomorphology has established the characteristics of the main types of forested wetlands and their functions (Chimner and Ewel, 2005; Hupp et al., 2009; Klimas et al., 2009; Middleton, 2009), but there are still few examples in the tropical and subtropical regions. Knowledge of the structure and species composition of these ecosystems will set the basis for determining and comparing their diversity (Myers, 1990; Zoete, 2001), connectivity and interactions with adjacent ecosystems (Mitsch and Gosselink, 2000), and will permit the establishment of guidelines for their conservation (King et al., 2009) and restoration (Middleton, 2002; Toth et al., 2002), role in carbon storage and productivity rates which is exported to mangroves and adjacent water bodies.

Historically, the main human activities that have transformed these ecosystems are flow alteration by dams (De la Lanza-Espino and Cáceres-Martínez, 1994; Jansson et al., 2000; Millennium Ecosystem Assessment, 2005), water contamination (Keddy, 2002; Tockner and Stanford, 2002) and changes in land use (MacKenzie, 2008; Ewel, 2010) that have reduced their distribution and altered the function and quality of the environmental services they provide.

Coastal tropical wetlands of the Gulf of Mexico are supplied with freshwater flowing from the highlands (and rainwater) and, in some cases, saltwater intrusion from the coastal lagoons. This mixture of salt- and freshwater creates a salinity gradient that facilitates the establishment of diverse types of wetlands. From high to low levels of salinity, mangroves (*Rhizophora mangle*, *Laguncularia racemosa*, *Avicennia germinans*, *Conocarpus erectus*), freshwater forested wetlands (*P. aquatica*, *A. glabra* and *Ficus* spp.) and freshwater/brackish marsh species (*Sagittaria lancifolia*, *Pontederia sagittata*, *Thalia geniculata*, *Cyperus giganteus*, *Typha domingensis*) can be found in this region. The freshwater wetlands in Veracruz have been severely degraded, mainly by a transformation of all of these types of wetlands into flooded pastures and the introduction of exotic species such as the African grass *Echinochloa pyramidalis* (López-Rosas et al., 2005, 2006; Moreno-Casasola and Infante, 2010; Moreno-Casasola et al., 2010). More recently, urbanization has also become an important cause of wetland transformation.

Regional forested wetlands have received little attention. Emphasis has been on the study of different aspects of mangrove ecology (Rico-Gray and Lot, 1983; López-Portillo and Ezcurra, 2002; Hernández-Trejo et al., 2006; Utrera-López and Moreno-Casasola, 2008). There is some information describing the floristic composition of the freshwater forested wetlands (Orozco and Lot, 1976; Lot and Novelo, 1990) and less on their functionality (Infante, 2004; Yetter, 2004; Infante and Moreno-Casasola, 2005; Moreno-Casasola et al., 2009). Today, there are few remnants of forested wetlands, and there is a growing need for more detailed study on their composition and vegetation structure, seed and seedling ecology, productivity, hydrology and soil characteristics.

Wetlands exist on landforms that allow the accumulation of water (Jackson, 2006). Swamps in Veracruz are found both on floodplains and in depressions of coastal dune systems, and each type of forest maintains a particular soil type and hydroperiod as a result of differences in the main sources of water (Mitsch and Gosselink, 2000; Kolka and Thompson, 2006). Floodplains are identified by flood pulses and the inflow of surface water (Middleton, 2002); the hydroperiod of forested wetlands in depressions depends on fluctuations of the water table (Yetter, 2004).

Hydroperiod is a crucial component in the functioning of wetlands (Junk et al., 1989; Mitsch and Gosselink, 2000; Richardson et al., 2001; Jackson, 2006). In coastal areas of the Gulf of Mexico, freshwater forested wetlands have increased water levels during the rainy season, and the species that inhabit them have adapted their phenologies by adjusting the waterborne dispersion of their seeds to periods of flooding; both *P. aquatica* and *A. glabra*, two of the dominant trees of these flooded forests, have adopted this strategy (Infante and Moreno-Casasola, 2005). Biogeochemical processes in the soil are also dominated by the annual cycle of flooding-drying that occurs in tropical wetlands, as has been found in Brazil's forested wetlands (Piedade et al., 2010) and in Guyana's (van Andel, 2003). Water inflow enriches wetlands with nutrients (Lodge et al., 1994; Mitsch and Gosselink, 2000; Middleton, 2002) but also causes a decrease in oxygen and runoff of both beneficial and toxic compounds to plants (Kadlec and Wallace, 2009). Wetland plants have adapted to withstand periods of flooding through anatomical and physiological adaptations that allow them to endure the presence of toxins and low oxygen conditions in the soil (Cronk and Fennessy, 2001). When the dry period returns, the functioning of wetland soils responds to the return of oxygenated conditions that allow for the microbial activity necessary for the decomposition of organic matter and the mineralization of compounds that are toxic to plants (Collins and Kuehl, 2001; Boon, 2006; Reddy and DeLaune, 2008).

The objectives of the study were to (i) characterize the floristic composition, structure and diversity of wetland forests located in floodplains and dune depressions in the southern Gulf Coast of Mexico and (ii) characterize the soil properties and flooding level of these wetlands during the rainy season and dry season. We developed the following hypotheses with regard to the vegetation and soil properties of the tropical freshwater forested wetlands under study:

i. The structure and composition of vegetation differs between wetlands in floodplains and in flooded depressions in coastal dunes. Diversity will be higher in forested wetlands on floodplains. Forested wetlands that remain flooded for longer periods of time, i.e. in depressions, will have lower diversity values.
ii. The soil texture of the floodplain forests will be dominated by fluvial materials and that of the dune depressions by sand.
iii. In floodplain forests, we expect higher concentrations of exchangeable cations because these forests are exposed to nutrient input by inflow from the land and the overflow of rivers. In the forests located in dune depressions, the main change in water level is through the elevation of groundwater, and thus nutrient input from runoff is less important, thus exchangeable cations will have lower values.
iv. The forested wetlands that remain flooded for a longer time show higher values of carbon and nitrogen storage in the soil.