Chapter 3
Distribution of Vegetation Types

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Abstract This chapter presents an overview of the vegetation types of the Yucatán Peninsula. Mean annual precipitation, terrain and soil characteristics explain the large-scale distribution of forest types in the Yucatán Peninsula. Tropical (high) forest is found in areas with >800 mm of mean annual precipitation, while dry (low) tropical forest is distributed in areas with <800 mm of mean annual precipitation. Tropical forest has canopy heights of more than 30 m and mostly presents three well-defined vegetative strata. The distribution of tropical forest is mainly in the central, eastern and southern parts of the Yucatán Peninsula. Dry tropical forest has canopy heights up to 20 m, and is widely distributed in the Yucatán Peninsula in different successional stages. Other woody vegetation types include mangroves, *petenes* and pine savannas. Open vegetation types include coastal dunes, marsh, and savanna vegetation. Disturbed tropical and dry tropical forest of all successional stages covers more than 7.4 million ha at present, and requires detailed management plans to maintain future ecosystems benefits.

Keywords Tropical forest • Distribution • Precipitation • Succession • Mangroves • Coastal dunes • Marsh vegetation

3.1 Introduction

Although the Yucatán Peninsula is characterized as an extensive limestone plateau with no significant altitudinal variation, a relatively large number of vegetation types can be identified. Vegetation types are mainly distributed along a north-to-south

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gradient of precipitation and according to different soil types, as well as precipitation variability in an east to west direction (Miranda 1958; Wright 1967). Tropical forest vegetation can be classified into two major groups with stand-specific associations, namely high and low forest. Other forest types, like mangrove forest, are found along coastal areas of the peninsula. Aquatic and subaquatic vegetation is present in open seasonally flooded areas locally known as *sabana*s, swamps, lakes and other water bodies.

The climate and hence the vegetation of the Yucatán Peninsula is determined by a series of factors: the lack of major orographic variation, the Tropic of Cancer, the influence of the Bermuda High, the presence of jet streams, tropical cyclones during the rainy season, cold fronts during the winter months, and the presence of a warm ocean current in the Yucatán Channel (Orellana et al. 2003). The driest region is located in the northwestern Yucatán Peninsula, in the Sisal-Progreso region, where mean annual precipitation is around 500 mm. The isohyet of 1000 mm runs east to west from northern Campeche, Yucatán to northern Quintana Roo. Toward the southern part of the Gulf of Mexico, precipitation increases rapidly up to 2000 mm; to the south of Quintana Roo, isohyets of around 1400 mm are found. Most of the precipitation falls between May and November, while the period between December and April is considered dry. Cold fronts between December and February are locally known as *nortes*, and provide occasional winter precipitation.

Tropical forest is found as the potential natural vegetation in areas with $>$ 800 mm of annual precipitation, mainly in the central, eastern and southern Yucatán Peninsula, in the states of Campeche and Quintana Roo. High forest as a major vegetation type presents floristic and structural variations and covers around 70 % of the peninsula before significant human-induced landscape transformation, which began in the twentieth century (Rogan et al. 2011; Schmook et al. 2011).

Tropical dry forest is generally found in areas with generally less than 800 mm average precipitation, on a variety of soil types, including Gleysols to Vertisols, and as a potential natural vegetation type, covers large parts of Quintana Roo, Campeche and Yucatán. A unique vegetation type is low flooded forest, covering low-lying areas in Quintana Roo and Campeche. Species of this vegetation type withstand several months of flooding, as well as dry conditions. *Petenes*, also a unique vegetation type, are forest islands with fresh water inlets surrounded by marsh vegetation.

Recent human impact has caused profound changes in vegetation (Rico-Gray and García-Franco 1991) due to over-exploitation of timber species and changes in land use (Rueda 2010; Snook and Negreros 2004). Many plant species have specific ethnobotanical uses and values, ranging from medicinal to religious purposes (Barrera 1962; La Torre-Cuadros and Islebe 2003; Andersen et al. 2005). The Yucatán Peninsula is recognized to have an exceptional degree and detail of traditional ecological knowledge and utilization of local plants.

3.2 Forest Types and Distribution

The first systematic descriptions of the vegetation of the Yucatán Peninsula are provided by Miranda (1958), Miranda and Hernández-X (1964) and Barrera (1962). Earlier work by Lundell (1934, 1937) compiled botanical and ecological aspects of the vegetation of northern Guatemala and the Yucatán Peninsula. The work of Lundell was impressive, as he also included ethnobotanical and economic factors in his reports, mainly from observations and data collection in Campeche, Yucatán and the Petén province of northern Guatemala. Lundell's botanical collections can be seen in Chicago's Field Museum of Natural History (http://collections.mnh.si.edu/search/botany/). Lundell (1937) divided the vegetation in two categories, upland and lowland, which correspond to specific soil characteristics. The upland type included broad-leaved forest, also known as "high forest" or (seasonally) evergreen tropical forest, the soils of which featured a distinct organic layer. Lowland vegetation types were characterized by Lundell as forest with clayey soils originating in erosion from the uplands. This vegetation type is locally known as *akalché*.

In the classic work "Vegetación de México", Rzedowski (1978) described species composition and physiognomy of the major vegetation types of the Yucatán Peninsula. Other regional vegetation studies are from Sánchez-Sánchez and Islebe (2002), analyzing plant communities along precipitation gradients, and Barber and colleagues (1999), presenting phytosociological units. Ibarra-Manríquez and co-authors (1995) analyzed the phytogeographical relationships of the trees of the Yucatán Peninsula and concluded that the strongest ecological and botanical affinities exist with other Mesoamerican locations, while affinities with the Caribbean region are much weaker.

Distribution of vegetation types are presented in two maps (Figs. 3.1 and 3.2) based on inventories carried out in 2009, 2010 and 2011 (Inegi 2013). Vegetation types are separated on the two maps into forest (zonal) vegetation, and vegetation related to water bodies (azonal). Area covered and geographical distribution is given in Table 3.1. Disturbed dry tropical forest is the largest category with more than 3.9 million ha, followed by disturbed tropical forest with over 3.5 million ha. Following the data of Inegi, tropical and dry tropical forests together occupy less than 240,000 ha. However, it should be noted that disturbed tropical and dry tropical forests include all successional stages, from 5 to 30 or more years of age.

Vegetation related to water bodies with fluctuating water tables covers more than 2,474,244 ha in the Yucatán Peninsula. Most of these areas are covered by *Typha*- and Cyperaceae-dominated swamps and disturbed low flooded forest. Mangrove forests cover more than 400,000 ha along the coasts of the peninsula. However increased deforestation rates of nearly 1 % per year (Hirales-Cota et al. 2010; Sánchez-Sánchez et al. 2009), specifically along the Caribbean coast, are threatening this ecosystem.

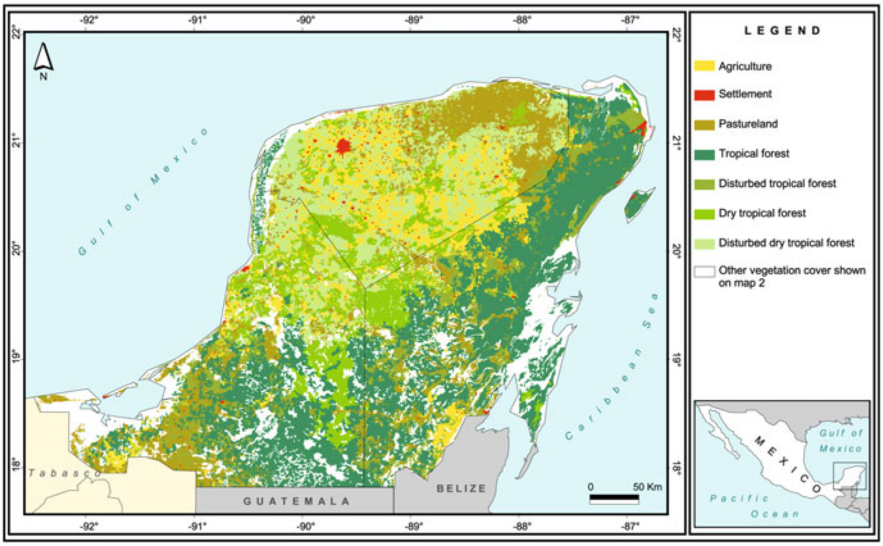

Fig. 3.1 Distribution of main vegetation types

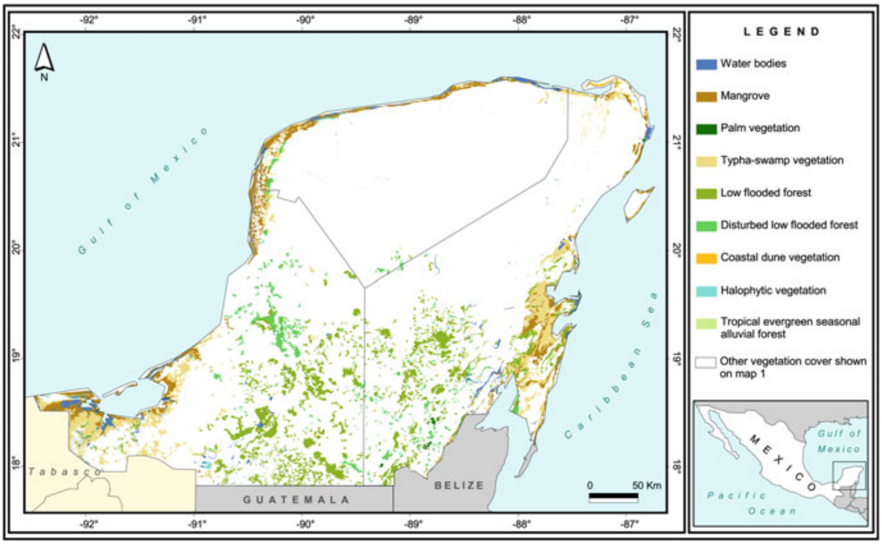

Fig. 3.2 Distribution of vegetation related to water bodies

3.2.1 Tropical Forest

Tropical forest or high forest (Selva alta and *selva mediana subperennifolia* in the Spanish literature) is widely distributed in the Yucatán Peninsula

Table 3.1 Main vegetation types, land use and areas covered 2011

Main vegetation type and land use	Cover (ha)[a]	Distribution
Agriculture	724,880	PY
Human settlement	149,358	PY
Pastureland	1,561,832	N, C
Tropical forest	1,356,095	E, C, S
Disturbed tropical forest	3,638,819	E, C, S
Dry tropical forest	92,221	W, C, N, S
Disturbed dry tropical forest	3,907,388	W, C, N, S
Water bodies	286,045	
Mangrove	400,124	E, N, W
Palm vegetation	6831	E
Typha-swamp vegetation	516,159	E, N, W
Low flooded forest	513,673	E, N, W
Disturbed low flooded forest	656,360	E, N, W
Coastal dune vegetation	8525	E, N, W
Halophytic vegetation	14,392	E, W
Tropical evergreen seasonal alluvial forest	57,176	E
Disturbed mangrove	15,673	E, N, W
Disturbed tropical evergreen seasonal alluvial forest	5339	E
Undefined vegetation types	500,000	PY

PY Yucatán Peninsula, *N* North, *C* Central Yucatán Peninsula, *E* East, *S* South, *W* West
[a]Cover of all data is based on Inegi (2013)

(Sánchez-Sánchez 2000). This vegetation type is characterized by 25–50 % of the trees composing the high forest losing their leaves during the dry season. Mean annual precipitation values are above 1200 mm. Mean annual temperature in these forests is above 20 °C, while mean minimum annual temperatures are 11 °C. Trees have canopy heights of more 30 m and three well-defined strata can generally be observed (Martínez and Galindo-Leal 2002).

The dominant tree is *Manilkara zapota* (Sapotaceae), with a wide distribution in southern Mexico, extending into northern Belize and Guatemala. Tropical forest is common in southern-central Campeche and most parts of Quintana Roo. Characteristic and commercially valuable canopy species include *Swietenia macrophylla* (Meliaceae), *Swartzia cubensis* (Leguminosae), *Pimenta dioica* (Myrtaceae), *Aspidosperma megalocarpon* (Apocynaceae), *Caesalpinia gaumeri* (Leguminosae), among many others (Snook and Negreros-Castillo 2004). An upper shrub layer consists mainly of the species *Ficus spp*. (Moraceae), *Bursera simaruba* (Burseraceae), *Sickingia salvadorensis* (Rubiaceae), *Chlorophora tinctoria* (Moraceae), *Enterolobium cyclocarpum* (Leguminosae), *Sapindus saponaria* (Sapindaceae) and *Acrocomia mexicana* (Arecaceae). High forest consists of different plant communities, in which *Manilkara zapota-Coccothrinax readii* is the dominant (Sánchez-Sánchez and Islebe 2002).

Another widely distributed plant community of the high forest is *Vitex gaumeri-Caesalpinia gaumeri*. This community has as characteristic species *Acacia gaumeri*

(Leguminosae), *Byrsonima bucidaefolia* (Malphigiaceae), *Alseis yucatanensis* (Rubiaceae), *Spondias mombin* (Anacardiaceae), *Diospyros verae-crucis* (Ebenaceae) and *Caesalpinia gaumeri* (Leguminosae). An additional characteristic feature of this plant community are the stone slabs, which can cover up to 45 % of the soil surface (Sánchez-Sánchez and Islebe 2002). In southern Quintana Roo, where the wettest conditions are found, the characteristic community is *Trichilia glabra-Brosimum alicastrum-Attalea cohune*. This community is a dense forest with the following characteristic subdominant species: *Chrysophyllum mexicanum* (Sapotaceae), *Piper sempervirens* (Piperaceae), *Chlorophora tinctorea* (Moraceae), and *Swartzia cubensis* (Leguminosea).

The *Hampea trilobata-Metopium brownei-Bursera simaruba* community is widely distributed in the central Yucatán Peninsula and includes many characteristic taxa of secondary forests (Sánchez-Sánchez and Islebe 2002) like *Nectandra coriacea* (Lauraceae), *Sabal yapa* (Arecaceae), *Bauhinia divaricata* (Leguminosea), *Lysiloma latisiliquum* (Leguminosae) and *Bauhinia jenningsii* (Leguminosae).

Soils of the high forest are generally shallow, but rich in organic material and of Lithosol-Rendzina or even Luvisol and Vertisol types (Flores 1977, FAO 1988; Wright 1967), depending on the region. In the southern Yucatán Peninsula, soils are mostly Vertisols, while in the central Yucatán Peninsula soils are of the Lithosol-Rendzina type.

Climbers are common in these forests, and characteristic species are *Paullina sp*. (Sapindaceae) and *Cardiospermum corindum* (Sapindaceae). At local terrain depressions in high forests, pure stands of *Attalea cohune* (Arecaceae) can be found (Quero 1992). These local vegetative communities consist of one distinctive upper layer 20 m in height, and an understory herbaceous layer, typically with 90 % cover. At similar conditions of deficient drainage, pure stands of *Sabal mauritiiformis* (Arecaceae) can be found in southern Quintana Roo. These palm communities have total heights of nearly 25 m. High forest has nearly disappeared in the Yucatán Peninsula due to excessive timber extraction, cattle farming and development of rice plantations in southern Quintana Roo over the last 50 years (Sánchez-Sánchez et al. 2007; Turner et al. 2001). Old growth forest plots have estimated values of 103.5 ± 4.4 Mg ha^{-1} AGB (above ground biomass) (Urquiza-Haas et al. 2007). However, higher values of 190 Mg ha^{-1} AGB are additionally reported from the same authors (Urquiza-Haas et al. 2007). Basal area estimates of tropical forest are highly variable: values between 11.9 and 45.0 m^2 ha^{-1} are reported (Urquiza-Haas et al. 2007; Dickinson et al. 2000; Ceccon et al. 2002; González-Iturbe et al. 2002; Lawrence and Foster 2002; La Torre-Cuadros and Islebe 2003; White and Hood 2004). Most likely, differences are due to the sampled vegetation type and numerical methods applied.

Selva mediana subcaducifolia (*semi-deciduous medium dry forest*) can be found in the states of Yucatán, Campeche and in some parts of northern Quintana Roo, although much of its original vegetation has been removed, mostly for logging, cattle and agriculture (Zamora-Crescencio et al. 2008). Canopy heights are usually from 20 up to 35 m. Fifty to 75 % of all trees lose their leaves during the dry season.

Soils are shallow with rocky outcrops with a very thin organic upper layer, mostly less than 7 cm (Sánchez-Sánchez and Islebe 2002). These soils are classified as Lithosols and Luvisols (Zamora-Crescencio et al. 2008). Characteristic species include *Brosimum alicastrum* (Moraceae), *Vitex gaumeri* (Verbenaceae), *Byrsonima* (Malphigiaceae), *Lysiloma latisiliquum*, among others (Dzib-Castillo et al. 2014; Zamora-Crescencio 2003). Epiphytes can be found in these forests.

3.2.2 Dry Forest

Low seasonally deciduous forest, or *selva baja caducifolia* in Spanish, has canopy heights of less than 15 m, and occurs in areas with annual precipitation varying between 600 and 800 mm or rarely more, located in the states of Yucatán, Campeche and Quintana Roo. Nearly 100 % of tree species drop their leaves during the dry season. Characteristic species are *Lysiloma bahamensis* (Leguminosae), *Baeucarnea pliabilis* (Nolinaceae), *Gymnopodium floribundum* (Polygonaceae), *Cassia alata* (Leguminosae), *Acacia milleriana* (Leguminosae), *Mimosa bahamensis* (Leguminosae), *Diospyros anisandra* (Ebenaceae), *Pseudophoenix sargentii* (Arecaceae) and *Piscidia piscipula* (Leguminosae) (Valdez-Hernández et al. 2014). Those species can also grow directly on eroded limestone. On a community level *Sebastiania adenophora-Plumeria obtusa var.cericifolia-Agave angustifolia* was identified as dominant in the eastern Yucatán Peninsula (Sánchez-Sánchez and Islebe 2002).

Seasonal flooded low forest (*Selva baja inundable*) occurs in areas that are geographically similar to those of high forest (Miranda and Hernández 1964), but is related to *sabana* areas. These forests are found in central and southern Quintana Roo, as well as northern Campeche and Yucatán. Soils with poor drainage are characteristic of these dry forests, and soils can withstand high water levels during long periods. The areas of low drainage are locally known as *akalchés*, which are periodically flooded during the rainy season. Several tree species can be found, the most conspicuous being *Byrsonima crassifolia* (Malphigiaceae), *Chrysobalanus icaco* (Sapotaceae), *Curatella americana* (Dilleniaceae), *Crescentia cujete* (Bignoniaceae) and *Hyperbaena winzerlingii* (Menispermaceae) (Cortés-Castelán and Islebe 2002; Díaz-Gallegos et al. 2002). Canopy heights rarely surpass 10 m. Some of those low forests can form pure stands, as in the case of *Haematoxylon campechianum* (Fabaceae) (common name *tasistal*), *Bucidas buceras* (Combretaceae) (common name *pukte*) and *Metopium brownei* (Anacardiaceae) (Miranda and Hernández 1964). There is no distinctive herbaceous layer present, mainly due to the prevalence of seasonal flooding. If undergrowth is present, species belonging to the Poaceae and Cyperaceae families can be found, like *Eleocharis*. Epiphytes of Orchidaceae and Piperaceae are quite common, such as *Encyclia alata, Peperomia* spp., and climbers belonging to *Dahlbergia* (Leguminosae). Deforestation rates for low forest have been estimated around 1.2 % per year in Calakmul for the last 30 years (Schmook et al. 2011).

In the northwestern part of the peninsula seasonally dry tropical forest (low deciduous forest) with columnar cacti can be found (Miranda and Hernández 1964). It is restricted to areas of 600–800 mm of annual precipitation, with no precipitation occurring during a 7- to 8-month period. The presence of rocky areas is conspicuous, and the soils are described as Lithosols (Thien et al. 1982). Characteristic endemic species of this vegetation type are: *Mammillaria gaumeri*, *Beaucarnea pliabilis*, *Guaiacum sanctum*, *Pilosocereus gaumeri*, *Nopalea gaumeri*, *Nopalea inaperta* and *Pterocereus gaumeri*.

3.2.3 Mangrove Vegetation

Mangroves can be found along the entire coast of the Yucatán Peninsula. Four mangrove species are distributed within different types of vegetative association: *Rhizophoramangle* (Rhizophoraceae), *Conocarpus erectus* (Combretaceae), *Avicennia germinans* (Acanthaceae), and *Laguncularia racemosa* (Combretaceae). *R. mangle* forests form nearly pure stands along the coast, while *A. germinans* and *L. racemosa* are found in mixed stands depending on the degree of soil salinity (Sánchez-Sánchez et al. 1991). The same authors distinguish four different mangrove communities. *C. erectus* is distributed on higher grounds with Gleysols, and can withstand variation in water table depths. Canopy heights of mangrove forests do not surpass 6–12 m, and consist of one predominant tree layer. The edges of mangrove areas are mostly dominated by *Acrostichum danaeifolium* (Pteridophyta), *Bravaisia tubiflora* (Acanthaceae), *Cladium jamaicensis* and other Cyperaceae (Islebe and Sánchez 2002; Torrescano-Valle and Islebe 2012). In southern Quintana Roo, dwarf *Rhizophora mangle* stands can be found with heights of only up to 1 m (Valdéz-Hernandez and Islebe 2011). Soils of mangrove communities are mostly sandy with clayey material, but can develop deep organic horizons.

3.2.4 Peten Vegetation

Peten vegetation is unique to the Yucatán Peninsula. It takes the form of closed woody vegetation islands consisting of a mosaic of mangroves and tropical forest species surrounded by salt marshes and mangroves (Durán 1987). Mangrove species can occasionally be found mixed with common tropical forest tree species. The most prominent and largest petenes are those of the biosphere reserve Los Petenes in Campeche, but these formations are also present on a smaller scale in the eastern part of Quintana Roo (Sian Ka'an Biosphere). Canopy heights may reach 12 m. Soils are rich in organic material, deep and slightly saline. Characteristic species are *Conocarpus erectus* (Combretaceae), *Metopium brownei* (Anacardiaceae), *Thrinax radiata* (Arecaceae), *Bucida buceras* (Combretaceae), *H. campechianum* (Leguminosae), among others.

3.3 Open Vegetation Types

Open vegetation types, including sabana, marsh and coastal dune vegetation are well defined and widely distributed in the Yucatán Peninsula. The coastal dune type is found along the shoreline of the Yucatán Peninsula (Espejel 1984, 1986, 1987; Moreno-Casasola and Espejel 1986; Flores and Espejel 1986; Torres et al 2010), and coastal plant communities are distributed along distinctive ecological gradients, such as salinity (Islebe, unpublished). Espejel (1987) identified 237 species for coastal dunes, and cosmopolitan families like Poaceae, Asteraceae and Leguminosae are the most common. Low non-woody plants (<30 cm high) like *Ambrosia hispida* (Asteraceae), *Canavalia rosea* (Leguminosae), *Distichlis spicata* (Poaceae), *Ipomoea pes-caprae* (Convolvulaceae), *Suriana maritima* (Surianaceae) and *Ernodea littoralis* (Rubiaceae), among other species, are found close to the sea. A transition occurs to higher elevation plant communities with woody taxa like *Coccoloba uviferae* (Polygonaceae), *Pouteria campechana* (Sapotaceae), *Cordia sebestena* (Boraginaceae) and *Chrysobalanus icaco* (Chrysobalanaceae). Woody taxa reach up to 6 m high, and sometimes a low shrub layer is present (Sánchez-Sánchez et al. 1991). Plant species from coastal dunes show typical morphological adaptations such as thicker leaves and glandules (like *S. maritima* and *E. littoralis*). Altitudinal differences between the highest and lowest parts of the dune along the coasts of Quintana Roo averages 5 m. Near-shore vegetation includes creeping species like *I. pres-caprae,* while dunes with woody taxa show the development of early shallow soil formation with thin organic layers. Coastal dunes are one of the most threatened vegetation types of the Yucatán Peninsula, with less than 8500 ha remaining, as coastal dunes are used to build hotels and tourism infrastructure (Lapointe 2011). Coastal dune vegetation is mostly delimited by the presence of *Thrinax radiata* palm vegetation, or by swamp like vegetation with abundant Cyperaceae and a transition to tropical forest types. Marsh vegetation is influenced by a high level of carbonate dissolved in water and soil, and is relatively species-poor relative to its biogeographical position. *Typha dominguensis, Cyperus jamaicensis, Scirpus* and C*arex* spp. are the main taxa found in marsh environments and are locally named *tulares* or *popales*. Marsh vegetation is mainly distributed along the eastern and western margins of the peninsula, though marshes cover large areas of the northern Yum Balam reserve. Their floristic composition is determined by nutrient availability, phosphate limitation, and the influence of salinity. *T. dominguensis* dominates in nutrient-rich conditions (Rejmankova et al. 1996).

In southern Quintana Roo and reaching further into Belize and parts of Guatemala, relic *Pinus caribaea* forest can be found (Macario-Mendoza et al. 1998). It is an open savanna-like vegetation type on sandy soils, with taxa from the Poaceae dominating the herbaceous layer. Following Chavelas (1981) it is the only pine species occurring at sea level in Mesoamerica, with an original distribution running from the Yucatán Peninsula through Belize to Nicaragua, along coastal areas.

3.4 Human and Natural Impact

Human impact on the vegetation of the region has occurred over the last four millennia (Rico-Gray and García-Franco 1991; Islebe et al. 1996). The earliest corn cultivation in the Yucatán Peninsula and its subsequent impact on vegetation is recorded from 2000 BC on (Aragón-Moreno et al. 2012; Carrillo-Bastos et al. 2010; Torrescano-Valle and Islebe 2015), although it could date back as much as 5000 years, as evidence from Northern Belize suggests. The use of agroforestry is part of ancient Mayan cultural knowledge and is well established among present-day farmers (Barrera 1962). The sustainable use of natural resources has been documented in many ethnobotanical studies (Barrera 1962; Andersen et al. 2005). Forest sustainability is incorporated into agroforestry practices like shifting cultivation, depending on the crops and areas cultivated, as well as cultivation intensity (Schmook et al. 2011; Valdez-Hernández et al. 2014). Fire is an important factor, and has been used since early Maya culture to clear land (Islebe et al. 1996). For the last 4000 years, and until the present day it is, intentionally or unintentionally, used to modify the landscape at different scales (López-Portillo et al. 1990). According to soil and paleoecological data from central Peten in northern Guatemala, full recovery of tropical forest vegetation from fire can take up to 80 years (Müller et al. 2010). However, using physiognomic criteria and plant species composition data, secondary vegetation cannot be distinguished from primary vegetation after 30 years (Miranda 1958; Sánchez-Sánchez and Islebe 2002). Traditional Mayan nomenclature makes no linguistic distinction between secondary vegetation of more than 30 years and primary forest (Barrera et al. 1976), but the first seral stages are well defined in traditional ecological knowledge (Sánchez-Sánchez et al. 2007). Conversely, Lawrence and Foster (2002) report that biomass from 25 year old secondary forests was only 40 % that of mature forests.

Hurricanes as natural hazards are a major determinant of forest structure in the Yucatán Peninsula (Tanner et al. 1991; Sánchez-Sánchez and Islebe 1999; Ramírez-Barajas et al. 2012; Rogan et al. 2011; Vandecar et al. 2011). The coastal and immediate interior vegetation of Quintana Roo is especially vulnerable to hurricanes as natural disturbances, since coral reefs and mangroves are severely affected and reduced in geographical extent. Hurricane damage to vegetation includes tree snapping (complete or partial, by branches), uprooting, defoliation, tree mortality, strong flooding and eventually, weeks after the event, intensive fires, due to the high quantities of accumulated woody and foliar debris on the ground (López-Portillo et al. 1990; Rodríguez-Trejo et al. 2011). During the last century, more than 100 hurricanes have hit the coast of Quintana Roo and the Yucatán Peninsula, damaging mangroves and other forest types (Islebe et al. 2009). The hurricanes causing the most severe damage were Gilbert in 1989 (Sánchez-Sánchez and Islebe 1999), Isidor in 2003, Emily in 2005 and Hurricane Dean (Islebe et al. 2009; Ramírez-Barajas et al. 2012), which damaged more than 2 million ha of forests in 2007 (CONAFOR, Ramírez-Barajas et al. 2012). For a high forest in northern Quintana Roo, Sánchez-Sánchez and Islebe (1999) estimated 4.5 t/ha of fallen biomass during Hurricane Gilbert. For more details, please see Chaps. 6 and 7.

3.5 Floristic Diversity

Floristic lists of the Yucatán Peninsula include the works of Standley (1930), Cabrera and Sousa (1983) for Quintana Roo, Sosa and colleagues (1985), Duran and co-authors (1998), Martínez and Galindo-Leal (2002), Gutierrez-Baez (2003) for Campeche, and Carnevali and co-authors (2010). The latter authors recognize some 3000 taxa. Some checklists on a local or regional scale are available, e.g., for the El Eden reserve in northern Quintana Roo, see Schultz (2005) and for Cozumel, Téllez and Cabrera (1987). Endemic species of the Yucatán Peninsula are listed in Durán and colleagues (1998), which follows Ibarra-Manríquez and co-authors (1995) in summing up 54 species, most of them with Caribbean phytogeographical affinities.

More than 500 tree species have been identified for the Yucatán Peninsula (based on the CIQRO-Herbarium data base, 2015). The most species-rich woody families are Leguminosae, Euphorbiaceae and Rubiaceae. Including all plant life forms, Fabaceae, Poaceae, Asteraceae and Orchidaceae (Carnevali et al. 2010) are the most represented families. The genera with most species are *Ipomoea, Croton, Euphorbia* and *Cyperus,* following Carnevali and colleagues (2010).

3.6 Outlook for Future Vegetation Studies

Given the threat to all vegetation types, several actions should be taken to preserve large connected forest tracts, specifically in the core conservation areas of Calakmul, central Quintana Roo, Campeche and the Sian Ka'an Biosphere reserve. Conservation efforts are being made to guarantee genetic connectivity and habitat range for biodiversity, such as the biological corridor of Sian Ka'an-Calakmul. The effectiveness of these efforts must be analyzed in future years, as the areas containing this corridor are also used for the construction of roads and rural infrastructure. Floristic and structural parameters should be monitored; forests should be locally recognized as ecosystem service providers to boost local income; and plant demographic studies should be undertaken to establish scientifically based rules for long term sustainable timber extraction (Valdez-Hernández et al. 2014). Scientific knowledge of natural succession should be included in management plans to avoid excessive unnecessary exploitation of major timber species with specific basal area parameters. The last 30 years of history has shown that the *ejido* (communally owned land) system has worked well (Porter-Bolland et al. 2013), though not perfectly, to guarantee the conservation of major forest tracts on a large regional scale in the central and southern Yucatán Peninsula. Although most of the remaining forests are secondary, at different successional stages, they cover more than 3.5 million ha, and still harbor a high and valuable degree of biodiversity (Ramírez-Barajas et al. 2012) and supply rural communities with income and use-value (Rico-Gray and García-Franco 1991). The following research should be encouraged in the future: understanding the succession of the different vegetation types; improvement and application of restoration ecology; accurate and precise assessment of the carbon stocks of distinct forest types; and the eco-physiology of characteristic tree species of Yucatán forests. In the case of mangrove forests, some species are currently protected by national laws. Continuous development of the tourism industry along coastal areas makes effective conservation almost impossible, however, as ecosystem functioning is altered with the construction of roads, drainage and other infrastructure.

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