Chapter 8
Conservation and Use

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Abstract The Yucatán Peninsula has a great biological, ecological and cultural diversity, marked historically by the Mayan civilization and biologically by its high endemism, and affinity with nearby regions. It is botanically well known with an estimated total richness of over 2300 vascular plant species, but there is uncertainty about the number of rare species (195 rare woody species are estimated to occur in its forests). Further research on the population dynamics, distribution and ecology of rare and endemic species of the peninsula is needed. Its biodiversity also provides various ecosystem services, such as provisioning, including about 680 species of medicinal plants, 145 edible species and 130 timber-species; and regulation of air and water quality (terrestrial ecosystems of the peninsula protect and help regulate one of the largest karstic aquifers worldwide), and climate. The Yucatán Peninsula has the second-largest forested area in Latin America after the Amazon basin, and harbors the largest natural reservoir of carbon in Mexico (3554 Pg). However, this biodiversity and the environmental services it provides are threatened by human activities linked to development policies focused on short-term economic benefits, leading to forest fires and land use change for agriculture, tourism, roads or urban development. Thus, by 2010, the primary vegetation occupied only 22 % of the region. Fortunately, protected areas cover 21.6 % of the total land area and, along with other initiatives (Mesoamerican Biological Corridor-Mexico), and sustainable productive activities (beekeeping, alternative tourism), have conserved large tracts of forests, along with the biodiversity and environmental services they provide.

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8.1 Introduction

From a geographical and geomorphological perspective, the Yucatán Peninsula includes the Mexican states of Campeche, Quintana Roo and Yucatán, as well as northern Belize and Guatemala (Ferrusquía-Villafranca 1993). It is a region of high biodiversity, but also high ecological and cultural diversity, marked historically by the social and cultural development of Maya culture (Durán and Méndez 2010; Ramírez-Carrillo 2010). The Mexican part of the peninsula is considered one of the country's biotic provinces (Barrera 1962; Rzedowski 1978; Morrone 2002); considering its geographic position, its flora and fauna exhibit a strong relationship with neighboring areas like Central America, the Caribbean Basin and southeast Mexico. It also presents a considerable number of endemic species (Estrada-Loera 1991; Durán et al. 1998; Ibarra-Manríquez et al. 2002).

The region presents tropical vegetation formed by several types of forest, which historically occupied large tracts, like the evergreen, semi-evergreen and subdeciduous forest, as well as deciduous forests (Miranda 1958; Flores and Espejel 1994; Olmsted et al. 1999). In fact, the area occupied by forests in the Yucatán Peninsula forms the one of the largest forest tracts in Latin America, second only to the Amazon basin. In addition to forests, a variety of different vegetation types are present on the peninsula, such as coastal dune vegetation and mangroves in the coastal areas, low flooded forests, palm vegetation, flooded grasslands and hydrophytic communities found inside the forest matrix (see Chap. 3; Espejel 1982; Trejo-Torres et al. 1993; Olmsted et al. 1999; Zaldivar et al. 2010).

In tandem with its high biodiversity, the peninsula has a long history of natural resource use by its indigenous inhabitants, the lowland Maya, who recognized the alimentary, medicinal, forestry, and ritual value of its native flora and fauna (see Chap. 3; Espejel 1982; Trejo-Torres et al. 1993; Olmsted et al. 1999; Zaldivar et al. 2010). However, in recent decades ecosystems have been severely affected by a suite of different human activities. The development of agricultural and husbandry practices has transformed and destroyed large extensions of forests and caused the drying of wetlands (Hernández-Barrios 2002; Andrade 2010). The region plays host to one of the largest centers of tourism in the country, which combined with chaotic urban development and an increasingly extensive road network, has caused changes to numerous terrestrial ecosystems. Due to its geographical position, this region in Mexico also experiences extreme weather events, like hurricanes, which regularly impact the peninsula, causing natural disturbances, the negative effects of which are compounded by consequent flooding and forest fires (Jáuregui et al. 1980). To deal with these processes of degradation and the concomitant pressures on the biodiversity of the Yucatán Peninsula, multiple

conservation initiatives were launched, including the establishment of natural protected areas, the conservation of species in situ and ex situ in botanical gardens, and the development of sustainable productive activities which use natural resources while helping to conserve communities and ecosystems.

8.2 Plant Diversity

The vegetation of the Yucatán Peninsula is strongly associated with the edaphic conditions of the region and its karstic substrate. It is composed of a mosaic of plant communities, in which high and low forests dominate, frequently interspersed with flooded communities and water bodies (lakes and sinkholes). In the region different types of plant associations abound, from forests, mangroves, and coastal shrub vegetation, to *petenes* (forest islands surrounded by salt water marshes, that receive discharges from the acquifer), *sabanas* (savannahs), and different associations of aquatic plants (see Chap. 3; Durán 1987; Campos and Durán 1991; Flores and Espejel 1994; Olmsted et al. 1999).

In the most southern part of the region, some areas of evergreen high forest can be found, alternating with medium statured forest. Evergreen high forests are more structurally complex communities, and more diverse in their floristic composition. Medium statured forest, semi-evergreen and subdeciduous forest cover a greater proportion of the region, blanketing most of Campeche and Quintana Roo and the south of the State of Yucatán. Although diverse in their composition and structure, medium statured forests are less diverse than high forests, especially in regards to epiphytes. Low deciduous and subdeciduous forest also covers a large portion of the northwestern part of the peninsula, large parts of the state of Yucatán, a small portion of Campeche and some areas along the coast of Quintana Roo. Low forests are communities with a high diversity of trees. Due to their rocky, shallow soils, their understories are floristically and structurally simpler than other forests.

A characteristic vegetation type of the area is its low flooded forests, which develop in low-lying, poorly drained depressions that accumulate precipitation for several months. This period of flooding alternates with a long period of drought causing water stress to the vegetation. These communities are formed by the few species of trees and shrubs capable of resisting stressful hydrological conditions (Olmsted and Durán 1986). Epiphytes are present, while understory species are nearly absent.

As described earlier, the forest matrix has additional vegetation types that occupy smaller areas like *petenes*, palm vegetation, flooded grasslands, and aquatic vegetation, among others (Olmsted et al. 1999). Along the coast, dune communities are present and mangroves grow in flooded areas, bordering a wide area of wetlands with different species of hydrophytes in salt, brackish and fresh water (Espejel 1982; Trejo-Torres et al. 1993; Zaldivar et al. 2010). This diversity of communities gives the peninsula a high environmental heterogeneity and floristic diversity.

8.2.1 Plant Richness

The floristic composition of the Yucatán Peninsula is one of the best-explored in Mexico. Botanical studies go back to the nineteenth century with the explorations of Arthur C. Schott, Charles Frederick Millspaugh and George F. Gaumer. In the first half of the twentieth century, works by Paul Standley and Cyrus Lundell continued the botanical exploration (Standley 1936). From 1980 onwards, this research was strengthened by the floristic studies by Mexican institutions like the National Institute for the Study of Biotic Resources (Instituto Nacional de Investigación sobre Recursos Bióticos, INIREB), the Biological Institute of the Autonomous University of México (Instituto de Biología de la UNAM, IBUNAM), the Quintana Roo Center for Research (Centro de Investigaciones de Quintana Roo, CIQRO), and the Yucatán Center for Scientific Research (Centro de Investigación Científica de Yucatán, CICY). Later, other institutions, like the universities of Yucatán, Campeche, and Quintana Roo and El Colegio de la Frontera Sur (ECOSUR) have continued to advance the state of botanical research.

Several botanical publications describe the floristic richness of the region (Millspaugh 1895, 1896; Standley 1930; Lundell 1934; Sousa and Cabrera 1983; Sosa et al. 1985; Durán et al. 2000; Arellano et al. 2003; Gutiérrez-Báez 2003; Carnevali et al. 2010a), as well as its phytogeographical relationships (Estrada-Loera 1991; Durán et al. 1998; Ibarra-Manríquez et al. 2002; Espadas-Manrique et al. 2003). The most recent inventory shows that the flora encompasses more than 2300 species, with 956 genera and 161 botanical families (Carnevali et al. 2010a).

8.2.2 Endangered Species

Among the plant species that deserve special attention and should be considered priority for conservation, are three groups of species: first, those that are endemic to the Yucatán Peninsula. Second, species that are considered rare, either because they are not common in communities where they grow, or because they have a reduced spatial distribution, or highly specialized habitat requirements. Third, species that are considered threatened because their populations have been reduced by human activities, especially those that lead to degradation and loss of ecosystems.

At present only 40 native species of the Yucatán Peninsula are legally protected (SEMARNAT 2010). Just seven of these are endemic to the peninsula, despite the documented existence of 198 endemic species (Carnevali et al. 2010b). Some of the protected species have a wide distribution, as is the case of the four species of mangroves and some aquatic herbs. Their protection status is based on their importance to high value ecosystems, which are under threat in the entire country. Other species that are widely distributed, like cedar (*Cedrela odorata*), guayacán (*Guaiacum sanctum*) and kulinché (*Astronium graveolens*), are severely threatened due to timber extraction.

An unknown number of species, as many as several hundred, could be catalogued as rare, but to date no clear evaluation of their status is available (Durán and Trejo 2010). Tetetla et al. (2012) estimate that 195 woody species are rare in the Yucatán Peninsula, considering only species present in forest communities, but leaving out species of coastal, mangrove and dune communities, as well as all herbaceous species. Therefore the actual number of rare species could be much higher.

8.2.3 *Useful Flora*

Maya communities which have inhabited the Yucatán Peninsula for several centuries have a long tradition of natural resource use, based on their cosmovision and a deep knowledge of their environment. Ethnobotanical studies have documented the diversity of species of plants and animals which indigenous communities use to fulfill their physical, cultural and spiritual needs, as well as local uses of biodiversity (Durán and Méndez 2010; Villalobos-Zapata 2010; Pozo et al. 2011).

Databases of useful species developed by CICY (Durán et al. 2012) show that more than 130 timber species are used in the region, including species used for the construction of rural homes and the manufacture of furniture and tools. The same researchers recorded 145 food species, 88 of them native and 57 introduced. In addition, the authors reported 680 plant species used for medicinal purposes, mainly for gastrointestinal diseases, skin and respiratory problems (Méndez and Durán 1997). Ninety-seven species were recorded as ornamentals, mainly trees, with some palms and shrubs, and 36 melliferous species were noted, 28 of which were native to the peninsula. For use in handicrafts, 27 species (25 native) were documented, while 24 native species were reportedly used for firewood. Twelve fodder species were identified, and five species were recorded as dyestuffs. It is noteworthy that, of the useful species documented, 64 are used in an industrial manner, for their wood, fiber, fruits, seeds, or pigments and substances (Durán et al. 2012).

8.2.4 *Environmental Services of Plant Biodiversity*

The documented uses in the previous section form part of the environmental services provided by biodiversity, or ecosystem services, that is, all the benefits human society receive from ecosystems (MA 2005). Particularly, the plant uses enlisted in the previous section can be considered as goods, or provision services, which are the most directly for our benefit, as they are part of the sustenance of human life. However, humans obtain from ecosystems many more benefits that are less tangible and easy to recognize, which can be classified into three other types of services (Table 8.1; CONABIO 2006; MA 2005). Regulatory services encompass complex processes by which ecosystems regulate or modulate the conditions of the

Table 8.1 Environmental services of Yucatan ecosystems

Provision	Regulatory	Cultural	Support
Food	Biodiversity	Recreational (tourism)	Biodiversity
Medicines	Pollination	Environmental education	Soil protection
Genetic heritage	Air quality	Science and research	Permanence of human communities
Scenic landscape	Soil erosion	Uses and traditions (spiritual values)	Connectivity
Water quantity	Biogeochemical cycles	Appropriation of territories	Primary productivity
Organic soil layer	Hydrological cycles	Feeling of well being	Biogeochemical cycles
Forest products (timber & non timber)	Climate		
	Vector regulation		
	Impact of natural disasters		

environment, including regulation of climate, soil erosion, flooding and droughts, air and water quality and disease vectors, among others. Cultural services depend strongly on collective perceptions and the sociocultural context, and include recreational benefits (e.g. tourism), educational, aesthetic and spiritual or religious benefits, as well as societies' knowledge, perceptions and classifications of their natural environment (Balvanera et al. 2009; De Groot et al. 2005). Finally, support services are all those basic ecological processes which guarantee the adequate functioning of ecosystems and the flux of other services, and include primary productivity, the soil genesis, biogeochemical cycles of nutrients and protection of biodiversity, among others (Table 8.1).

Biodiversity modulates the supply of nearly all ecosystem services, like primary productivity (which in turn supplies food and other goods), soil development and maintenance, and nutrient cycling (affecting nutrient availability, soil fertility and agricultural production). Biodiversity also alters the hydrological cycle (and therefore the quantity, quality and seasonality of water), and plays a role in climate regulation and regulation of pollinators, pests and disease vectors, affecting human health and the primary sector (Balvanera et al. 2009; Díaz et al. 2005; Hooper et al. 2005).

Over 7 million ha of the Yucatán Peninsula's forests are still well-conserved (vegetation of more than 40 years of age, Table 8.2), including continuous patches of more than half a million ha (Garcia-Contreras 2014). This mosaic of forests fulfills an important role in the functioning of one of the world's largest karstic aquifers (Bauer-Gottwein et al. 2011). It also hosts the largest natural carbon stock in the country (de Jong et al. 2007), but is under strong pressure from deforestation and degradation by human activities (García-Contreras 2014; see Sect. 8.3).

Table 8.2 Area and density of above-ground carbon stocks in the Yucatán Peninsula

	Area		Stored carbon	
Cover type	Thousands of ha	%	Mt	%
Agro.-Urban	4223.6	31.3	691.5	19.5
Forest < 40 years	2100.5	15.6	477.9	13.4
Forest > 40 years	7181.5	53.2	2384.7	67.1
Total	13,505.7		3554.0	

Source: Land use change 1974–2014, Pronatura Península de Yucatán. 2014 and map of carbon density in Woody biomass of forests in Mexico, Alianza MREDD+ 2013

Therefore, in this region, the Early Action Area for REDD+ (Reduction of Emissions from Deforestation and forest Degradation and enhancement of forest carbon stock) Puuc-Chenes was established, covering an area of 1,381,924 ha (Alianza México REDD+ 2015). Besides, the peninsula contains three intensive carbon monitoring sites as part of the strengthening REDD+ and south-south cooperation project of the National Forest Commission-United Nations Development Program (Proyecto Fortalecimiento REDD+ y Cooperación Sur-Sur 2015). These sites contribute to the parametrization of models of carbon dynamics at different scales, and developing a system of measuring, reporting and verification (MRV) of anthropogenic emissions of greenhouse gases due to deforestation and forest degradation, and carbon absorption due to regeneration and forest management.

The largest reservoirs of carbon in the peninsula are located in high forests and medium statured forests in the south, as this area hosts the largest trees (in diameter and height), many with high commercial value (generally species with high wood-density and therefore high carbon content), compared to other vegetation types on the peninsula (Pennington and Sarukhán 2005). In each vegetation type, the largest reservoirs are found in older successional stages of abandoned agricultural areas, where vegetation is most developed and more biomass has accumulated (Vargas et al. 2008; Hernández-Stefanoni et al. 2011; Dai et al. 2014). At the same time, these areas have high agricultural potential, and are therefore susceptible to land-use changes (Dupuy et al. 2012).

According to data from Alianza México REDD+ (2013), the total above-ground carbon reservoir of the Yucatán Peninsula is 3554 Pg (10^{15} g). As shown in Table 8.2, forests older than 40 years occupy 53 % of the peninsula and contain 67 % of its above-ground carbon stocks. The largest reservoir of above-ground carbon is in the state of Campeche (43.6 % of all), followed by Quintana Roo (35.2 %) and last, Yucatán (21.2 %). The differences in carbon reservoirs among the three states are due to differences in territorial extent and distribution of vegetation types in each state, as high forest and medium forest are mainly located in Campeche and Quintana Roo, as well as to differences in deforestation rates in each state (see Sect. 8.3).

Despite the relevance of the environmental services provided by the Yucatán Peninsula's biodiversity, their quantity, quality and spatial and temporal distribution are strongly affected by human development, which has been achieved without adequate planning or consideration of regional sustainability.

8.3 Threats and Present Condition of the Vegetation

Almost 80 % of the vegetation of the Yucatán Peninsula has been deforested or degraded, a trend driven by several factors, including land use change transforming large tracts of forest to agricultural land or to urban and tourism development. Additionally, forest fires, development of road infrastructure and services, the high extraction rates of species of economic relevance, and use of products for domestic use have also contributed to deforestation and land degradation (García-Contreras 2014).

Historically, but particularly during the last four decades, a host of social and economic events have driven the conversion of natural ecosystems into productive systems, without a due process of planning or establishment of limits to the growth of each activity (Ramírez-Carrillo 2010). For example, driven by federal settlement incentives, the population of the peninsula has increased enormously the last 40 years, from just over one million in 1970 to over four million in 2010 (Table 8.3), with the consequent growth of cities and increased social and productive pressures on land.

During those years, population growth has concentrated in a few cities in the region. In Yucatán more than 42 % of the population is concentrated in Merida, while the city of Campeche hosts 31 % of the population of Campeche State. In Quintana Roo nearly half of the population lives in the municipalities of Benito Juárez, Solidaridad and Othon P. Blanco, due to the tourism development of Cancun, the Riviera Maya and, to a lesser extent, Chetumal.

The main threats to the vegetation of the Yucatán Peninsula and its biodiversity and environmental services are deforestation and land degradation (Fig. 8.1). Loss of forest cover, caused mainly by land-use change for agriculture and urban development, and by fires, has a particularly high impact. Activities driving these land-use changes are road-building, urbanization, commercial agriculture, extensive livestock raising, quarrying, and to a lesser degree the traditional milpa and intensive animal husbandry. Forest fires, which also diminish forest cover, are mainly caused by agricultural practices, followed by hunting, open garbage dumps, and tourism. The primary driver of forest degradation is extraction of timber and non-timber products, followed by contamination by rural waste, and open garbage dumps (Fig. 8.1, García-Contreras 2014).

Table 8.3 Population increase in the three states of the Yucatán Peninsula from 1970 to 2010

Year	Yucatán	Campeche	Quintana Roo	Total
1970	758,355	251,556	88,150	1,098,061
1980	1,063,733	420,553	225,985	1,710,271
1990	1,362,940	535,185	493,277	2,391,402
2000	1,658,210	690,689	874,963	3,223,862
2010	1,955,577	822,441	1,325,578	4,103,596

Source: INEGI

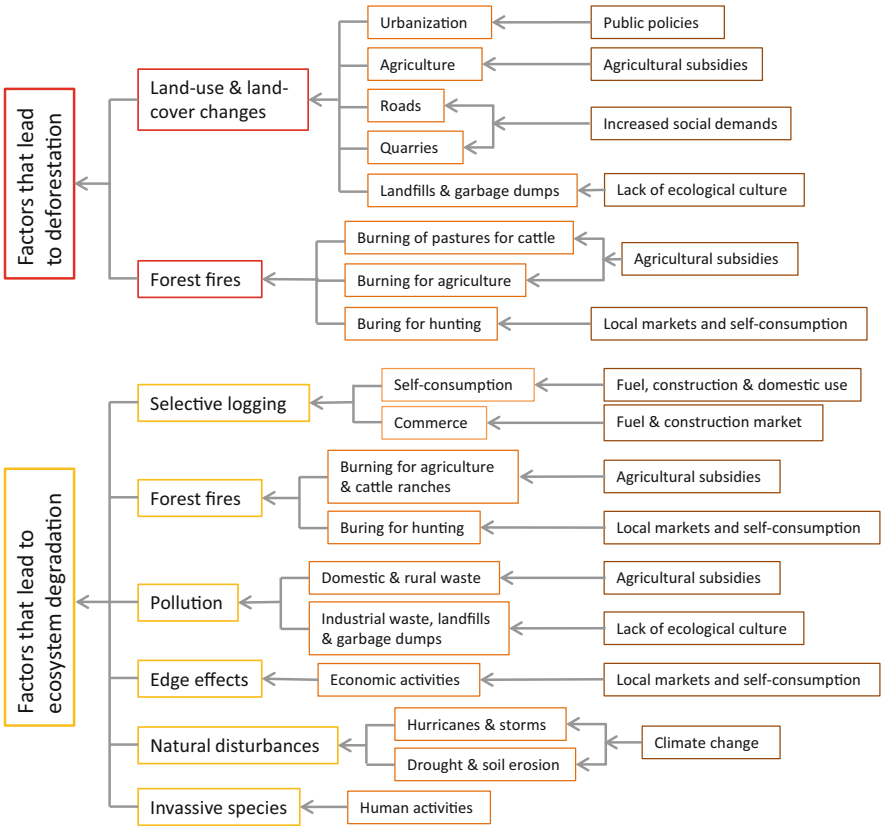

Fig. 8.1 Primary threats to ecosystems of the Yucatán Peninsula and their causes. *Source*: García-Contreras (2014)

8.3.1 Land Use Change

Land use conversion causes loss of forest cover and hence damages biodiversity and environmental services. For example, with deforestation, a large proportion of an area's stored carbon is released to the atmosphere as CO_2 and other greenhouse gases, thereby not only reducing the mitigation potential of tropical forests, but also further contributing to climate change (Pan et al. 2011).

The Yucatán Peninsula has an extension of 13,781,229 ha, of which 90.43 % was historically covered by low, medium and high forests (dry and humid), while the remaining areas (9.57 %) were wetlands. In the year 2010, only 22 % was still covered by primary vegetation, 59.4 % by secondary vegetation (herbaceous, shrub and arboreal) and 18.1 % by urban and agricultural areas (Table 8.4). The most affected vegetation types were deciduous and subdeciduous medium forests: only 1.8 % of their original cover remains. Low subdeciduous and evergreen forests have also been hit hard, retaining just 7.5 % of their original cover, while medium and

Table 8.4 Historical (potential) cover and recorded cover in 2010 in the Yucatán Peninsula (area in thousands of ha)

Vegetation type	Potential vegetation	Veg. 2010	Change (%)
Agriculture	0	2284.4	16.6
Urban	0	148.2	1.1
Water bodies	111.0	71.5	−35.6
Without vegetation	0	57.4	0.4
Mangroves	492.2	443.9	−9.8
Secondary mangrove vegetation	0	16.2	3.3
Palm vegetation	9.1	6.4	−29.2
Hydrophylic vegetation	705.5	604.0	−14.4
Coastal dunes	20.4	10.9	−46.6
Low deciduous and subdeciduous forest	1316.9	450.0	−65.8
Secondary vegetation of low deciduous and subdeciduous forest	0	938.8	71.3
Low semi evergreen and evergreen forest	1134.7	84.9	−92.5
Secondary vegetation of low semi evergreen and evergreen vegetation	0	16.5	1.5
Medium stature deciduous and subdeciduous forest	4031.7	72.3	−98.2
Secondary vegetation of medium deciduous and subdeciduous forest	0	3593.9	89.1
Medium and high semi-evergreen and evergreen forest	5959.7	1360.4	−77.2
Secondary vegetation of medium and high semi evergreen and evergreen forest	0	3621.6	60.8

Source: Pronatura Península de Yucatán, 2015

high semi-evergreen and evergreen forests still cover 22.8 % of their original extent. The least affected ecosystems are mangroves with 90.2 % of their original cover (Table 8.4).

The oldest record of forest cover is from 1974, with subsequent datasets available for 1994, 2000, 2007 and 2014. These data permit analysis of changes in cover over the last 40 years. Table 8.5 shows how forest cover changed in the region, as the area occupied by humans increased.

Forest cover decreased from 89.2 % in 1974 to 79.3 % in 2014, a net loss of about 10 %. However, in the different periods analyzed, variations in forest cover can be observed, due to deforestation, abandonment and natural regeneration. The period 1994–2000 is the time frame that exhibits the highest net deforestation (11.1 %), relative to the previous period (1974–1994). These reductions are due to areas converted for agriculture. The period 2000–2007 is the only one showing a net recovery of forest cover, an increase of nearly 7.5 % relative to the previous period. In the last period evaluated, a slight net loss of forest cover (1.8 %) is observed (Table 8.5, Fig. 8.2).

The spatial distribution of these land use changes was not uniform (Fig. 8.2). Historically, the state of Yucatán has experienced the highest deforestation rates,

Table 8.5 Changes in land cover of the Yucatán Peninsula (area in thousands of ha)

	1974	1994	2000	2007	2014
Vegetation	12,294.1	12,091.5	10,288.7	11,295.0	10,976.1
Human-occupied	1487.1	1689.7	3492.5	2486.3	2805.1

Source: Pronatura Península de Yucatán, 2015

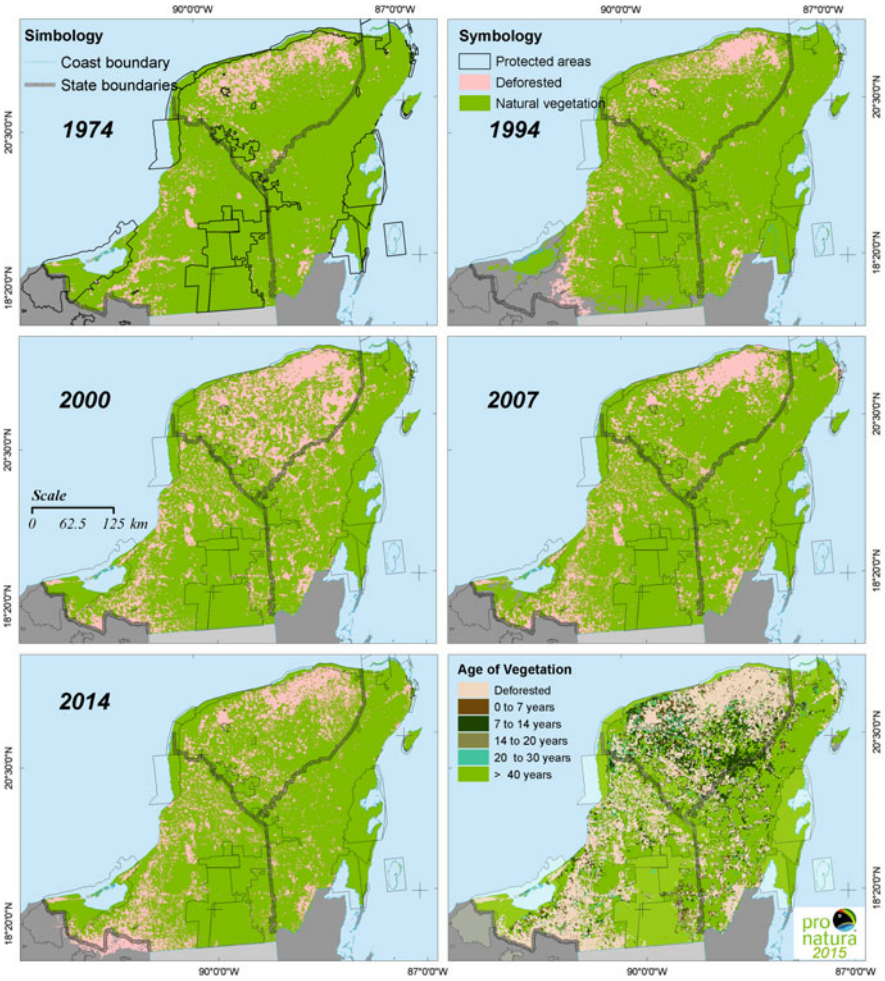

Fig. 8.2 Land use change of the last 40 years, *marking areas* with and without natural vegetation. Based on the first five maps (1974, 1994, 2000, 2007 and 2014) areas were identified which remained used for agriculture and urban areas, areas with vegetation and areas with continuous changes (deforestation-afforestation). The age for the last category was estimated. *Source*: Pronatura Yucatán Península, 2015

especially in the northeast. In the state of Campeche a huge loss of forest cover is also observed, mainly in the region of Escarcega and Candelaria (southern Campeche), due to extensive livestock production. Quintana Roo is the state with lowest deforestation rates, although in 2014 some large deforested areas (mainly grasslands for cattle) can be identified, for example in the La Union area, and along the Highway Jose Maria Morelos-Chetumal.

Based on the land cover data in the years 1974, 1994, 2000, 2007 and 2014, a map was developed to identify areas of agricultural and urban land use, vegetated areas, and areas of constant change (deforestation-afforestation). For the last category, stand age was calculated. As can be observed (Fig. 8.2), most of the peninsula is covered by secondary vegetation of less than 40 years of age or areas occupied by human activities, while vegetation older than 40 years tends to be located in southern Campeche and eastern Quintana Roo, mainly associated with federal natural protected areas.

For the last four decades the expansion of cattle husbandry constituted the main driver of land use change in the region, a pattern consistent with other areas in Latin America. According to Hernández-Barrios (2002), the area with cattle husbandry in the 70's was only 2.7 % of the peninsula, while in 1995 this activity covered 12 % of the region's land area. Villegas et al. (2001) report that, in 1999 livestock grazing subsumed 28.3 % of the peninsula: 1,500,000 ha in Campeche, 1,200,000 ha in Quintana Roo, and 1,200,000 ha in Yucatán.

Land use change driven by extensive cattle husbandry is a clear example of applying an inappropriate model of ecological exploitation. Ecosystems of high potential productivity were converted for an economic activity generating poor yields, occupying large areas, and supporting a mainly low-wage workforce. In many instances, this activity also extends into forests where cattle graze freely, without proper regulation, causing forest degradation.

On the other hand, the main productive activity of the indigenous population of the peninsula has been the milpa or shifting cultivation (Hernández-X 1959; Terán and Rasmunssen 1994; Hernández-X et al. 1995; Terán et al. 1998), an activity carried out extensively, modifying forest structure and composition. The subsequent population increase in rural areas created a need for expansion of agricultural lands, and placed increased pressure on land, considerably shortening the fallow period, a fundamental aspect of this type of agriculture (Terán and Rasmunssen 1994; Hernández-X et al. 1995). In the state of Yucatán, 150,000 ha of seasonal corn are sown annually, 80,000 ha of which correspond to recently cleared lands. Based on data from SAGARPA, during 2005, the area for agricultural practices was 201,000 ha in Yucatán, 38,000 ha in Quintana Roo and 42,000 ha in Campeche.

8.3.2 Forest Fires

The Yucatán Peninsula leads Mexico in forest fire damage. For example, 42 % of mature forest areas that burned in Mexico from 2003 to 2014 were located in the

Table 8.6 Forest area (in thousands of ha) damaged by fires from 2003 to 2014

State	Damaged area (thousands of ha)	% of total fire-affected area
Campeche	40.1	14.6
Quintana Roo	51.7	18.9
Yucatán	23.5	8.6
Rest of Mexico	158.5	57.9

Source: Centro Nacional de Control de Incendios Forestales (CENCIF) de la Comisión Nacional Forestal (2015)

peninsula, mainly in Quintana Roo and Campeche (Table 8.6; CONAFOR 2015). Forest fires reduce the mitigation capacity of ecosystems and directly trigger the release of greenhouse gases, risking human health, reducing vegetation cover, biodiversity and environmental services.

Use of fire in agriculture is prevalent throughout the region. Most fires stem from agricultural practices. The second cause of fires is roads, mainly via land-clearing for their construction, or started by motorists with discarded cigarettes or glass bottles (Secretaría de Medio Ambiente y Recursos Naturales 2015). The damage to vegetation produced by hurricanes like Isidor in 2002, Emily and Wilma in 2005, and Dean in 2009 cause a considerable increase of fuel material, both standing and fallen dead biomass, which increases the frequency, strength and extent of area affected by fires in the following dry seasons.

Apart from the incidence and track of the hurricanes that affect the peninsula, the probability of forest fires is distributed heterogeneously, depending on fuel load and human impact. Based on heat points, which reflect sources of ignition and areas with higher fuel loads and more human impact, a map of fire risk was developed (Fig. 8.3). It can be observed that agricultural areas of southern Campeche, central Yucatán and northern Quintana Roo are high risk and should give high priority to fire prevention mechanisms, including regulation of use of fire as a tool for agricultural practices and implementation of a fire warning system during the dry season.

Considering the main threats to the vegetation of the Yucatán Peninsula and its biodiversity, we developed a map of human impact (Fig. 8.4). Most of the area of the Yucatán Peninsula is subject to medium to high human impact, associated with activities that lead to ecosystem destruction, fragmentation and degradation. Those activities are generally linked to government-promoted development policies, which favor exploitation focused on short-term economic benefits, without management to protect natural resources (Leff 1990). Those policies have characterized the exploitation of the natural resources of the peninsula, causing damage to forests and displacing autochthonous productive systems. Fortunately, as can be observed in Figs. 8.2, 8.3, and 8.4, the establishment of protected areas has helped to counter the effects of these development policies to some degree.

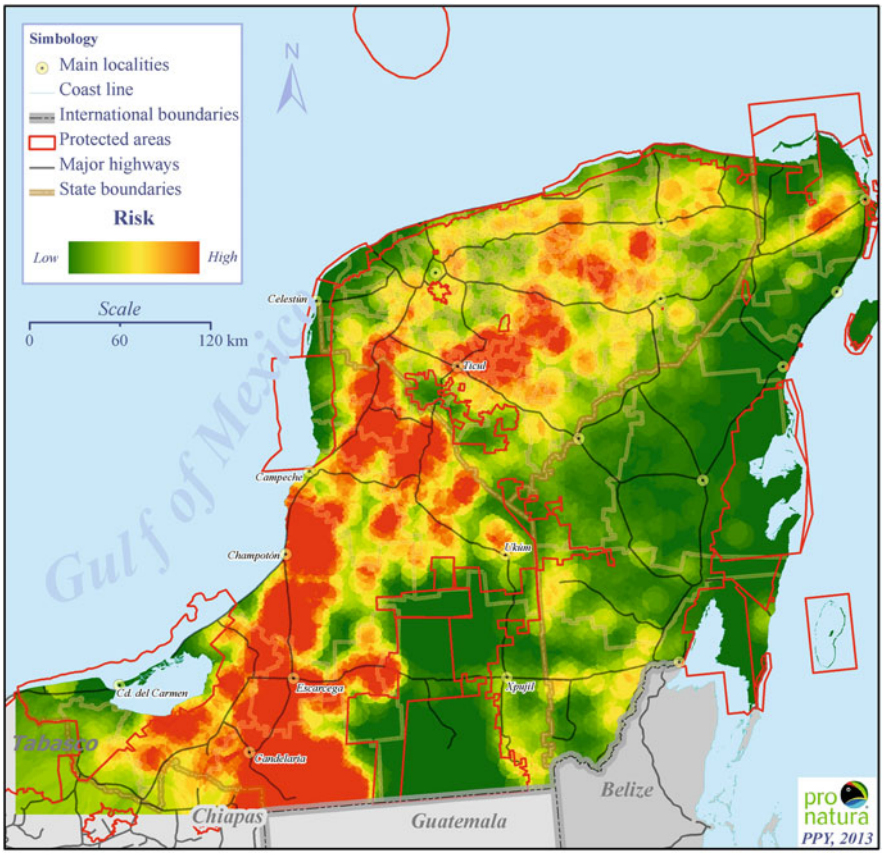

Fig. 8.3 Fire risk of the Yucatán Peninsula, based on heat points and areas of mayor human impact and biomass fuel loads. *Source*: Pronatura Península de Yucatán, 2013

8.4 Strategies for Conservation and Use of Plant Diversity

8.4.1 Conservation

In Mexico, Protected Natural Areas (ANP, by their Spanish acronym) represent the government's main instrument for conservation of biological diversity. Besides working to protect and conserve landscapes, ecosystems and species, ANPs have served as a focal point for the development of activities promoting sustainable use of biodiversity and involving participation of local communities (Benítez Torres and Villalobos-Zapata 2010; Ruiz Barranco and Arellano 2010; Prezas 2011; Secretaría de Ecología y Medio Ambiente 2014; Secretaría de Medio Ambiente y Aprovechamiento Sustentable del Gobierno de Campeche 2014; CONANP 2015; Secretaría de Desarrollo Urbano y Medio Ambiente 2015).

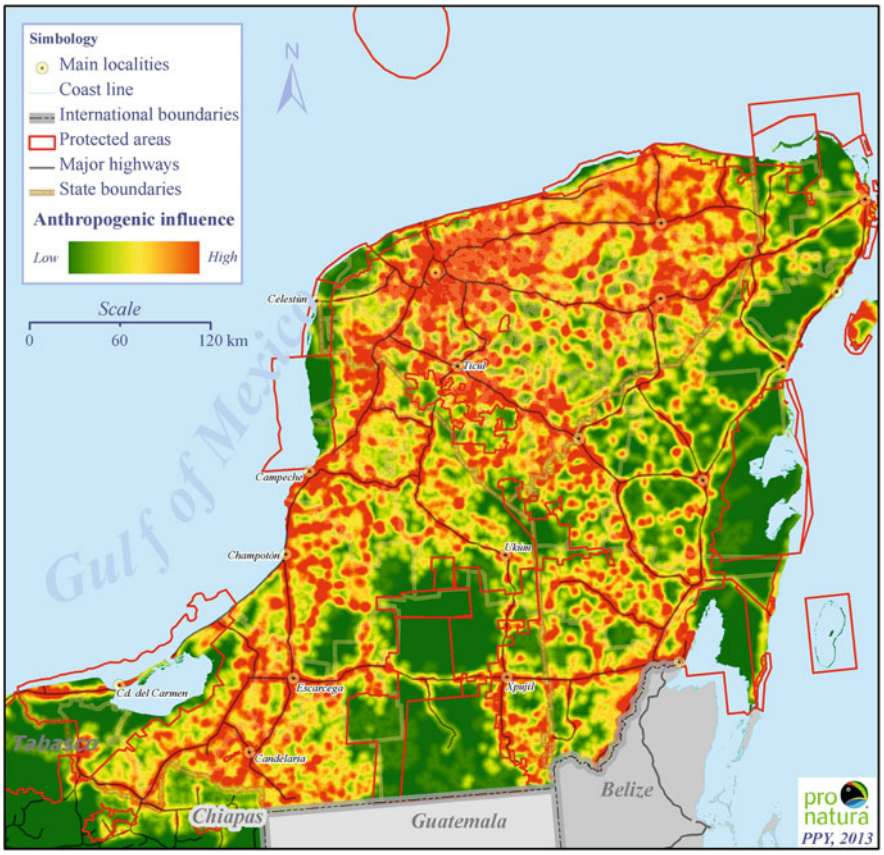

Fig. 8.4 Human impact on ecosystems of the Yucatán Peninsula. *Source*: Pronatura Península de Yucatán, 2012

The Yucatán Peninsula has 39 protected areas covering a total land area of 2,977,752 ha, which represents 21.6 % of the entire peninsula (Table 8.7). The analysis of land use changes on the peninsula in the last four decades (Table 8.5, Fig. 8.2), the risk of forest fires (Fig. 8.3) and anthropogenic influence (Fig. 8.4), indicates that protected natural areas in the region have contributed significantly to the conservation of large tracts of forests and other tropical ecosystems, along with their biodiversity and the environmental services they provide, such as sequestration of atmospheric CO_2.

Although all types of vegetation in the region are represented in these protected areas, studies to determine if the area currently protected in the Yucatán Peninsula is sufficient to sustain ecological processes or maintain viable populations of native species indicate that current networks of protected areas do not adequately cover all the eco-regions or priority sites within the area devoted to conservation

Table 8.7 Area conserved by Protected Areas (the data do not include marine reserves)

Administration	Type of area	Campeche	Quintana Roo	Yucatán	Area (ha)
Area and cover per category of protected area					
Federal	Biosphere Reserver	Calakmul			723,185
		Los Petenes			282,858
		Ría Celestún		Ría Celestún	81,482
				Ría Lagartos	60,348
			Sian Ka'an		528,148
	Areas of protection for flora and fauna	Laguna de Términos			706,148
			Otoch Ma'ax Yetel Kooh	Otoch Ma'ax Yetel Kooh	5367
			Uaymil		89,118
			Yum Balam		154,052
			Bala'an Ka'ax		128,390
			Nichupte Mangroves		4257
			North portion and Eastern coast of Cozumel		37,829
			Contoy Island		5126
			Tulum		664
			Xcalak reef		17,949
				Dzibilchaltun	539
State	State Reserves	Conservation area Balam-Kin			110,990
		Conservation area Balam-Kú			409,200
			Kabah Urban Park		41
			Manatí Lagoon refuge for Flora and Fauna		203
			State refuge for Flora and Fauna Lagoon System Chacmochuch		1915
			Refuge for Flora and Fauna Colombia Lagoon		1114
			State Reserve Lagoon System Chichankanab		11,610

(continued)

Table 8.7 (continued)

Administration	Type of area	Campeche	Quintana Roo	Yucatán	Area (ha)
Area and cover per category of protected area					
			Bacalar Lagoon Park		5367
			State Reserve Cozumel Forests and marshes		19,846
				El Palmar State Reserve	50,177
				Dzilam State Reserve	69,039
				State Park Yalahau Lagoon	5683
				San Juan Bautista Tabi and Sacnicté Anex Natural Proteceted Area	1356
				Kabah State Park	947
				Mangroves and Marches of the Northern Coast of Yucatan State Reserve	54,777
				Ring of Cenotes Geohydrological Reserve	219,208
				Puuc Biocultural State Reserve	135,849
Town	Town Reserves	"Salto Grande" Urban Park			1570
		Laguna Ik			28,820
			Ombligo verde		4064
				Cuxtal Reserve	10,757
	Total	8	18	13	2,977,752

Source: National Commission of Protected Natural Areas (CONANP), 2015

(CONABIO-CONAP-TNC-PRONATURA-FCF, UAN L 2007; CONABIO-PNUD 2009; Durán and Pacheco 2010; Koleff and Urquiza-Haas 2011). In addition to increasing the number and extent of areas under protection, the authors recommend strengthening the network of federal, state and municipal protected areas, by using a full range of conservation tools, including management units for the conservation

of wildlife (UMA), programs for sustainable forest management and forest certification, and voluntary conservation areas (VCA), as well as the program of payment for environmental services (PES). In addition, the Mesoamerican Biological Corridor-Mexico seeks to maintain connectivity in some areas, particularly in the areas of influence of protected areas in the region, allowing free movement of wildlife, as well as encouraging conservation of flora.

The Yucatán Peninsula also has other strategies for in situ and ex situ conservation, namely the establishment of botanical gardens such as that of Yucatán Center of Scientific Research (CICY) which houses about 700 species (Centro de Investigación Científica de Yucatán 2014), the botanical garden of the College of the Southern Border (ECOSUR) at Puerto Morelos, which is the country's largest, with 65 ha of tropical evergreen forest, preserving several collections and 170 species (El Colegio de la Frontera Sur 2015), and the Autonomous University of Carmen which protects 25 ha of mangrove and also houses several collections (Universidad Autónoma del Carmen 2014). In addition, the Mayab Medicinal Gardens Network houses about 250 species of medicinal plants; and the CICY germplasm bank contains over 1200 collections of 242 species and several collections of live plants (Hernández 2015).

8.4.2 Use and Sustainable Use

The use of forest resources in the region has not always been sustainable, and has gone through different stages. In the middle of the last century, a 25-year forestry-project was launched for timber production in northeast Yucatán. Unfortunately this experience resulted in the devastation of forest resources, as it focused on the extraction of the highest quality individual trees from the forest, leaving poor quality trees behind at the end of the process (Galletti 1994; Merino 2004). Later, during the 1980s, the so called "Plan Piloto" (pilot plan) was promoted in the states of Quintana Roo and Campeche, which tried to encourage the participation of communities and ejidos in management and forestry (Argüelles 1999; Merino 2004; Santos et al. 2005). A major achievement of Plan Piloto was that *campesinos* were given and assumed responsibility for the care of forest, which in turn has allowed large forested areas to persist without major changes in land use. Although in recent years there has been an increased in the volume of tropical timber species utilized in the Yucatán Peninsula, this increase is considered very limited in scope, since total timber production in the region represents less than 2 % of national production. Furthermore, the territorial extent of forest areas under active management is still very limited, especially in the State of Yucatán.

At present, other productive activities in the region have also contributed to biodiversity conservation through sustainable use of natural resources. Examples include the beekeeping programs, sustainable agriculture, and alternative tourism and conservation initiatives supported, through the Small Grants Program of the Fund for Global Environment in the Yucatán Peninsula, among others (Small

Grants Program 2008). This program has supported numerous beekeeping projects which together kept an area of approximately 472,000 ha of forest under productive management, while forestry projects cover an area of approximately 100,000 ha of forests under management (Durán et al. 2013).

However, to achieve conservation and sustainable use of biodiversity, improvements in effectiveness and efficiency of public policies are needed. Similarly, the region lacks tools designed for management of natural resources that contribute to an equilibrium among social, economic and environmental benefits of ecosystems in the peninsula, and improved knowledge about biodiversity and environmental goods and services provided to society.

8.5 Conclusions and Prospects

The Yucatán Peninsula is a region of great biological, ecological and cultural diversity, and historically has been marked by the development of the Mayan people and biologically by its affinity with the neighboring regions of Central America, the Caribbean Basin and Southeast Mexico, as well as by having high endemism. This region contains several types of forests that constitute the second-largest forested area in Latin America after the Amazon basin, and other coastal and hydrophilic vegetation, resulting in high environmental heterogeneity and floristic diversity.

The Yucatán Peninsula is one of the best-explored regions of Mexico with an estimated total number of vascular plant species surpassing 2300 species. However, there is still uncertainty concerning the precise number of rare species (there are an estimated 195 rare woody species in the forests of the peninsula alone), so given their vulnerability to extinction, botanical studies focusing on this species group are urgently needed. In addition, a review and update of legal protection of the most vulnerable species is needed. Currently, only 40 species are legally protected and of these only seven are endemic, though conservative estimates suggest the occurrence of 198 endemic species in the region. So, clearly further research on population dynamics, distribution and ecological requirements of rare and endemic plant species of the peninsula is required.

In addition to the intrinsic value of the plant diversity of the Yucatán Peninsula, it is important to highlight its utility value, since vegetation is the basis of a wide variety of environmental and ecosystem services such as provisioning, including about 680 medicinal species, 145 edible species and 130 timber-species; cultural, including tourism; and regulation of air and water quality (terrestrial ecosystems of the peninsula protect and help regulate one of the largest karstic aquifers worldwide), floods, droughts, and climate. Concerning climate, the peninsula is home of the largest natural reservoir of carbon in Mexico, estimated at 3554 Pg (10^{15} g) of above-ground carbon, which is concentrated in semi-deciduous forests towards the south of the peninsula and in the vegetation of late successional stages.

However, the biodiversity of the Yucatán Peninsula and the environmental services that it provides have been threatened by various human activities linked to development policies that have focused on short-term economic benefits, without proper planning. The main threats to biodiversity in the region are land use change that has transformed large tracts of forests into agricultural land and tourist developments, roads, or urban areas; and the occurrence of forest fires. As a result of these processes, by 2010, primary vegetation occupied only 22 % of the territory of the peninsula, while agricultural, urban areas and roads occupied 18.1 % and secondary vegetation (mostly under 40 years old) occupied 59.4 %. The Yucatán Peninsula has also been heavily impacted by forest fires, accounting for 42 % of the national extent of damage to mature forests in Mexico during the period 2003–2014.

Fortunately, the state has also developed conservation initiatives to address the processes of deterioration and pressures on biodiversity of the peninsula, mainly through the establishment of protected areas covering 21.6 % of the land area of the region. The analysis of changes in land use over the past four decades, anthropogenic influence and risk of forest fires, indicate that conserved areas have contributed significantly to the conservation of large tracts of forests and other tropical ecosystems. Conserved areas also contribute to biodiversity and the environmental services it provides, such as sequestration of atmospheric CO_2. In this sense, the importance of the region for climate change mitigation through REDD+ has recently been recognized, particularly through the establishment of a REDD+ Early Action Area of 1,381,924 ha, and three sites of intensive forest carbon monitoring. The Yucatán Peninsula is therefore a pioneer in the implementation of this international strategy, which aims to preserve and increase the ability of ecosystems to capture and store atmospheric CO_2. It also proposes to contribute to training and governance for rural residents and to create alternative sources of income to promote more sustainable development and lower emissions of greenhouse gases.

It is also important to note other conservation efforts, such as the Mesoamerican Biological Corridor-Mexico. This corridor seeks to maintain connectivity in the areas of influence of protected areas in the region, allowing free movement of wildlife and promoting the conservation of flora and fauna. It further supports the management of wildlife conservation units (UMA), voluntary conservation areas and program of payment for environmental services (PES). All these initiatives endeavor to ensure the permanence and function of ecosystems, and contribute to maintaining viable native populations throughout their ranges. In addition to this, the development of sustainable productive activities such as beekeeping, sustainable agriculture and alternative tourism, supported by initiatives such as the Small Grants Program of the Fund for Global Environment, have allowed for sustainable use of natural resources in the peninsula. However, improvements are still needed in the implementation and enforcement of effective public policies and in developing tools for conservation and use of natural resources of the Yucatán Peninsula. Ideally, these policies will serve to harmonize social, economic and environmental benefits from ecosystems, as well as to improve the knowledge and sustainable use of biodiversity from the region.

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