Chapter

Introductory Chapter: Biodiversity of Mexico

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1. Introduction

1.1 Flora, fauna and vegetation

Mesoamerica (starting from the southern states of Mexico) differs from Central America, which is a geopolitical name. The expression "Middle America" is in use as well, which involves all areas south from the border of the US including the Islands of the Caribbean [1]. In this chapter the biodiversity of Mexico is presented and the literature on its protection is analyzed.

Mexico being the largest country in the region is very rich in species in itself (**Tables 1–4**). Lot of species occur even in the dry northern areas. In the Chihuahuan Desert 826 plant species are noted by Villarreal-Quintanilla et al. [7], out of which 560 are endemic, 165 are quasi-endemic and és 176 are microendemic. 116 taxa can be originated from a non-arid habitat. The most species-rich are Cactaceae with 141, Asteraceae with 106, Boraginaceae with 34 and Brassicaceae with 31 species. On the California Peninsula 723 endemic species are noted by Riemann and Exequiel [8], claiming that the great number of endemic species is due to the heterogenity of the environment. The flora and fauna are very interesting because the area of Mexico involves the border of *Neotropis* and *Nearctis* (Mexican Transition Zone), which is not exactly a border but rather a wide transition zone, its accurate definition is yet to be created. The determinaion is based on the distribution of the endemic genera characteristic to one or the other area. The several results obtained regarding this vary hugely. The determination of the location and width of the transition zone is different among authors without a consensus, which requires further floristic examinations [9]. Vegetatio varies depending on the topography that has a great role in the fromation of the great number of endemic species as well [10].

Group	Number of species worldwide	Number of species in Mexico	Worldwide/Mexico %	Number of endemic species	Endemic species %
Vascular plants	248 428	18000–30000	7–12	10000–15000	33–50
Amphibians	4222	284	7	169	60
Reptiles	6458	717	11	368	51
Birds	9040	1050	12	125	12
Mammals	4629	450	10	140	31

Table 1.
Biodiversity of Mexico according to Mittermeier et al. [2].

Vegetation	% area	Number of species	Endemisms %
Cloud forest	0.7	3000	30
Rainforest	4.4	5000	5
Pine and oak	12.9	7000	70
Xerophyl and steppe	34.8	6000	60
Wetlands	1.43	1000	15
Tropical deciduous	7.9	6000	40
Agricultural and ruderal	ND	2000	20

Table 2.
Flora of Mexico according to vegetation types based on Flores-Villela and Gerez [3].

Biom/ecoregions	Area (km^2)	Estimated number of species	Remaining intact vegetation %
Tropical and Subtropical Moist Broadleaf Forests			
Chiapas moist forests	5759	3000–4500	67
Chimalpas montane forests	2076	2000–3000	49
Pantanos de Centla	17152	1500–3000	11
Petén-Veracruz moist forests	148604	5000–8000	31
Sierra de los Tuxtlas	3890	2400–3500	11
Sierra Madre de Chiapas moist forests	11218	3500–4700	34
Veracruz moist forests	68949	4500–7000	20
Veracruz montane forests	4942	2200–3500	55
Yucatán moist forests	69485	1300–1900	64
Tropical and Subtropical Dry Broadleaf Forests			
Bajío dry forests	37282	2900–5000	0,64
Balsas dry forests	62249	2500–5100	2
Central American dry forests	67777	2800–400	12
Chiapas Depression dry forests	13974	1500–3500	7
Jalisco dry forests	26051	1000–2500	26
Revillagigedo Islands dry forests	210	ND	ND
Sierra de la Laguna dry forests	3975	500–1000	0,008
Sinaloan dry forests	77364	1700–2500	13
Sonoran-Sinaloan transition subtropical dry forest	50326	ND	ND
Southern Pacific dry forests	42283	2500–5100	15
Veracruz dry forests	6616	900–2000	5
Tropical and Subtropical Coniferous Forests			
Central American pine-oak forests	110948	4000–6000	42
Sierra de la Laguna pine-oak forests	1061	700–1200	4

Biom/ecoregions	Area (km^2)	Estimated number of species	Remaining intact vegetation %
Sierra Juárez and San Pedro Mártir pine-oak forests	4000	ND	ND
Sierra Madre de Oaxaca pine-oak forests	14299	2500–3700	55
Sierra Madre del Sur pine-oak forests	60976	3600–5000	43
Sierra Madre Occidental pine-oak forests	222700	ND	ND
Sierra Madre Oriental pine-oak forests	65600	ND	ND
Trans-Mexican volcanic belt pine-oak forests	91800	4000–6000	26
Tropical and Subtropical Grasslands, Savannas, and Shrublands			
Western Gulf coastal grasslands	77425	2150–2250	3
Deserts and Xeric Shrublands			
Baja California desert	45940	1500–2200	8
Central Mexican matorral	59195	2500–4500	0,011
Chihuahuan desert	501896	3300–3600	50
Gulf of California xeric shrub	22573	900–1900	29
Meseta Central matorral	124975	3000–4500	4
San Lucan xeric scrub	3685	ND	12
Sonoran desert	260000	2600–3000	37
Tamaulipan matorral	16300	1500–2500	9
Tamaulipan mezquital	141500	1700–2500	23
Tehuacan Valley matorral	9842		0
Flooded Grasslands and Savannas			
Central Mexican wetlands	259	100–600	ND
Montane Grasslands and Shrublands			
Zacatonal	306	150–500	ND
Mangroves			
Alvarado mangroves	4534	20–400	1,12
Marismas Nacionales-San Blas mangroves	2034	20–400	
Mayan Corridor mangroves	4079	20–400	
Mexican South Pacific Coast mangroves	1168	20–400	
Petenes mangroves	1971	20–400	
Ría Lagartos mangroves	3457	20–400	
Tehuantepec-El Manchon mangroves	2685	20–400	
Usumacinta mangroves	3118	20–400	
Mediterranean Forests, Woodlands, and Scrub			
California chaparral and woodlands	121000	1550–1750	1

Table 3.
Bioms and ecoregions of Mexico according to Kier et al. [4] and Dinerstein et al. [5].

State	Birds	Mammals
Veracruz	664	101
Chiapas	628	90
Oaxaca	687	116
Jalisco	481	107
Guerrero	476	72
Puebla	367	76
San Luis Potosí	469	93
Michoacán	460	79
Chihuahua	329	95
Edo. México	281	55
Tamaulipas	444	90
Sonora	456	100
Durango	308	81
Nayarit	407	72
Nuevo León	252	63
Hidalgo	236	59
Morelos	274	46
Sinaloa	460	69
Coahuila	275	80
Tabasco	370	47
Baja California	292	95
Quintana Roo	340	51
Distrito Federal	222	44
Yucatán	343	58
Baja California Sur	258	77
Colima	318	51
Zacatecas	154	75
Guanajuato	256	45
Campeche	281	50
Querétaro	181	36
Aguascalientes	89	33
Tlaxcala	89	21

Table 4.
Bird and mammalian fauna of Mexico according to CONABIO [6] (National Commission for knowledge and use of biodiversity) by states. In coastal states marine mammals are included.

The climate formed by the emerging mountains (Sierra Madre Oriental, Sierra Madre Occidental, Trans-Mexico Volcanic Belt) also affects evolutionary processes resulting in the development of new species [11, 12]. The richness of species and the species composition of the community depends on the heterogenity and diversity of the environment [10]. As Moonlight et al. [13] presents on the example of *Begonia* genus regarding the DNA sequence data of the plastis diversification is fast and new species develop in the hetrogeneous environment. According to their results there were two indipendent colonization events from Africa towards the Neotropis. Two different clads were reconstructed, which diversified around the middle of miocene in South America and radiation occurred once towards Central America and Mexico.

Today tropical deciduous forest is typical on the western side but it is fragmented due to human activity and only 3% is protected. Agriculutal areas are concentrated in areas where the climate is seasonal that is why the reduction is faster than in the case of rainforests [14]. 10% and 19.7% of tropical forest and shrubland, respecively are protected. On the east side 28% of the rainforests are protected (Estado [15]). Examinations of flora and fauna are still not complete, our knowledge on the wildlife of the area is deficient [16, 17]. New species are still identified in Mexico such as *Tryonia* (Caenogastropoda: Cochliopidae) species discovered by Hershler et al. [18] in the creeks of the Chihuahuan Desert (Durango State). Some of these probably have become extinct since they were failed to be found again. The cause of their extinction is the destruction and disappearance of their habitat. According to forcasts the average annual temperature will rise by 3,7–3,8°C to 2090 in Mexico, the amount of precipitation will reduce by 18,2% and AAI (Annual Aridity Index) will rise by 26% [19]. These will result in a 25% decrease in the value of ENS (effective number of species), if the forcasts prove to be accurate [20]. Characteristic plants of Mexico the cacti (Cactaceae) can also become rare by then due to land transforming activity of man, 31% of the species are already endangered. Climate change may cause other species to become endangered. Cacti are drought tolerant but because of climate change species may become endangered due to the reduction or extinction of pollinators and animals dispersing seeds. In the case of cacti often ants carry the seeds (Myrmecochory) only to limited distances. Many species have a small area of distribution (75–100 km^2) as well, making them particularly vulnerable [21]. A remarkable example of the destruction of human activity to habitat is the wall that is being built on the border of the US and Mexico, which parts that have already been set up initiated the reduction of size, quality and connections of habitat in the otherwise diverse area [22]. Migration of many amphibian, reptile and mammal species are hindered by the barrier and human activity. This becomes relevant when certain species look for new habitat due to climate change. Obstructing their movement endanger species or certain popoulations. The genetic diversity of species reduce with the extinction of populations endangering the entire species [23].

2. Environmental protection and biodiversity conservation

Since the nineties Mexico have been involved in the work of international environmental organizations with increasing activity and now have signed 44 international agreements. It is an active stakeholder of organizations such as the CBD (Convention on Biological Diversity) and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), CEC (Commission for Environmental Cooperation), Trilateral Committee, The Ramsar Convention on Wetlands, EMSA (Mesoamerican Biological Corridor and the Mesoamerican Strategy of Environmental Sustainability). The NDP (National Development Plan) can be considered as a legal framework within the country providing basic regulations for the federal government by giving guidance for the work of the government with the development of clear strategies, setting regional aims and measures to be implemented, coordinating institutional and regional programs involving several areas [24].

The program, in which Mexico also participates, aiming to preserve biodiversity is the Payments for Ecosystem Services (PES) that is an economic framework to plan and introduce payment schemes that provide market remuneration for ecosystem services [25]. This tool seems to be eligible for the protection of rainforests in the developing countries. 2.6 million hectares are involved in the program in

Mexico, which in terms of money means 450 million USD and this is one of the biggest among such programs in the world [26]. With these territories approximately 25% of the biodiversity that needs protection is now included in the program [27]. According to Honey-Rosés et al. [28] 3–16% more forest were managed to be preserved along with those habitats that these forests include. Deforestation in those areas that are involved in the program is carried out at a slower rate, than in those that are not invovled. This can be beneficial to the population and to the owners of the forests as well since it can lead to other income sources, such as with the development of ecotourism. In the protected areas it is also important to invovle local residents and educate them on the importance of wildlife protection since mostly they only experience difficulties in accessing their resources [29, 30].

In order to preserve at least some part of biodiversity a system of protected areas is required. Determination of the most valuable protected areas can be carried out by ecological modeling. Torres-Miranda et al. [31] used red oaks and their distribution area to estimate (section *Lobatae*; 75 species) those area that worth the most concerning protection.These species representing ecosystems prove to be useful indicators for conservation professionals.These species occur in various habitats often as dominant species and have an important part in preserving diversity. Based on a computer simulation (Complementarity analyses) 12 current areas under protection should be enlarged and 26 new should be established with a total of 512 500 ha area to ensure adequate protection for habitats. Certain species, especially arthropods bond to certain plant communities. With the protection of fast reducing oak forests species bonded to them can also be preserved [32].

An experiment in the Tehuacán Valley showed that biodiversity is preserved with greater succes in areas under forest management than in areas that are not involved. Although, preserving rare species is limited even in this system. In average 59% of plant species and 94% of the genetic variety of dominant species (*Polaskia chichipe*, *Escontria chiotilla*, *Myrtillocactus schenckii*) was managed to be preserved in the examined area. In areas that are not involved the remaining natural flora decrease fast due to the increasing intensity of agriculture [33]. The number of species that can be preserved depends on whether the areas in question are private or community properties, also on the availability of natural resources, ecosystem services to people, as well as on the culture of certain communities. Ornamental or herbal species and those that are used for human or animal nutrition tend to be preserved even if the area gets involved in agriculture. Lanes dividing plots and islands within the agricultural area promote later regeneration [34]. Traditional methods of agriculture have less harmful effects on biodiversity than the current intensive mechanized agriculture. In the state of Oaxaca indigenous people have been carrying out agricultural production for centuries, which lead to a mosaic landscape with patches of forest and agricultural land. Nowadays due to urbanization more and more people give up farming and move to cities. On lands left behind a secondary forest forms, which surprisingly lead to the decrease of biodiversity.

3. Agricultural aspects

Traditional agriculture plays a part in sustaining biodiversity, since the landscape renews regularly. Traditional farming also has to be considered in the decision making process related to protected area [35]. Larios et al. [36] also claim that traditional farming has a great role in the preservation of biodiversity. According to a survey carried out in the area of the Tehuacán Valley 281vascular plants were identified even in the gardens out of which 34% were endemic. Though abundance of cultivated plants was the largest. The highest value (199) was found in gardens lying near the cloud forests in the mountains. The lowest valule (141) was found in those that are located near deciduous forests. This can be explained by the tendency that owners cultivate plants in their own land to compensate the rarity of useful species in the nearby forests.

An agricultural effort to protect the diversity of the species is the production of shade-grown coffee [37]. With the production of shade-grown coffee most of biodiversity can be preserved since a proportion of the original vegetation survives. Coffee produced with this method has a high price, which can encourage more and more people to choose this cultivation method. Cultivation area is increasing unfortunately to the detriment of the primary forest, thus in its current form this is not the appropriate method to preserve biodiversity [38]. For the protection of marine ecosystems aquaculture is spreading in Mexico as well regarding both fishes and marine invertebrates. The development of the technology means income for the economy and wildlife can also be protected since the importance of illegal fishing decreases. Aquacultural production can mean a legal income source for the local people, while overfishing and the decrease of biodiversity can be avoided [39].

Phytoremediation plays and important part in the region as well in the nutralisation of industrial pollutants, therefore the research of those organizations are important, which can be used for this purpose [40]. An abandoned mine in the state of Hidalgo was recultivated and the area was reforested. 56 species representing 29 families were managed to be planted. Samples of AMF (Arbuscular Mycorrhizal Fungi) from tree roots *Glomus* (Glomeraceae: Glomerales) and *Acaulospora* (Acaulosporaceae: Diversisporales) species were the most common. These have a great role in phytoremediation due to incereasing the trees tolerance against heavy metals in the extreme environment, as well as decreasing the distribution of toxic subsatnces in the environment [41]. Harmful effects of industrial pollutants can be reduced by phytoremediation, therefore it serves the protection of wildlife. Regarding the big biodiversity of the area it is likely that new species will be found to be suitable for this purpose. There is another example of a microbial scale biodiversity research with direct economic benefits. Diversity of bacteria and fungi living around cultivated *Agave tequilana* roots in the soil, rizosphere and phyllosphere, in the endosphere of the root and the leaf was compared by Coleman-Derr et al. [42] with similar microbes of wild *Agave salmiana* and *Agave deserti* populations. *Agave tequilana* can be cultivated in areas where no other crop can survive and can be used for bioethanol production. Symbiotic microorganisms influence plant health and accomodation to stress due to this the rate of growth as well [43]. Manipulation of microbiom may increase the rate of growth and therefore, the amount of ethanol that can be produced [44]. The composition of the microorganism community based on the analysis of the traceable DNA changes depending on the compartment, which was obtained by the amplification of ITS2 and16S regions. Geographical distributation also affected composition. In the case of cultivated plants alpha diversity was low, which can be explained with agricultural practices.The community is dominated by the genera of Enterobacteriaceae family (*Pantoea*, *Leclercia*, *Trabusiella*), therefore soft rot disease became often, which cost millions. Genetic diversity of plants is also low due to vegetative reproduction. That is why the bacteria *Pantoea agglomerans* could develop avoiding strategies during the evolution against the plants defense mechanisms [42]. Apart from agave, oil pressed from the seed of *Jatropha* (Euphorbiaceae) species, especially from the seed of *J. curcas*, is also appropriate for the production of biodiesel [45]. 50 of the 186 species occur in Mexico as well, most of which are endemic. They are distributed from the rainforests to the deserts everywhere. Their distribution is limited by the frost in the mountains. Other species may be eligible for agricultural use, which require further research [46].

Area, estimated number of species and percentage of remaining intact vegetation. The boundaries of ecoregions are not the same as national borders.

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