Chapter 8
Expanding the North American Perspective—Mexico

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Impacts of Climatic Variability on Mexican Agriculture

Based on national assessments, Mexico is expected to see temperature increases of 0.9 to 2.5 ºC by the year 2020, and it is very probable that, by the year 2050, the climate will be warmer by 2.0 to 4.0 ºC, especially in the central and northern parts of the country (MENR 2007). Rainfall is expected to decrease as much as 15 percent in the central part of the country, but the number of severe storms and the intensity of severe droughts are expected to increase nationwide (MENR 2007).

Mexican agriculture will be particularly vulnerable to these predicted changes in climate. Changes in precipitation may have the greatest impact, because most of the country's agricultural land (about 85 percent) is classified as arid or semiarid (Houghton et al. 2001). Increases in temperatures and soil moisture deficits will likely decrease land area suitable for rain-fed crops such as maize. Severe droughts will compound the situation in a country where, on average, more than 90 percent of agricultural losses are already attributed to drought events (Appendini and Liverman 1994). More intense tropical storms in the southern and coastal parts of the country are likely to cause extensive damage to crop and livestock production. It is also anticipated that changing weather and climate will increase the scale and frequency of forest fires, which may contribute to a shift from tropical forests to savannas (MENR 2007). Reducing agricultural vulnerability to climatic variability is of critical importance in the agricultural sector in Mexico, especially given the role the sector plays in support of food security and livelihoods of rural populations.

Agroforestry systems are gaining greater attention within Mexico as one strategy for mitigating and adapting to predicted climate change. Work by Locatelli et al. (2011) identified agroforestry as a tool for adaptation, enabling poor rural families, communities, and watersheds to be less vulnerable to extreme and erratic weather events by generating diverse environmental and socioeconomic benefits. This contribution by agroforestry systems was also recognized in Mexico's National Climate Change Strategy, which serves as a guide for Mexico's actions during the next 40 years (SEMARNAT 2013). This Federal strategy targets the reduction of greenhouse gas emissions, and specifically includes initiatives related to agroforestry.

In this chapter, we first provide an overview of the history of agroforestry in Mexico, focusing on the most prominent agroforestry systems and their associated tree and crop species, management practices, geographic range, and environmental and climatic conditions. When available, we also provide information about the agroforestry systems' potential for enhancing climate change mitigation (through carbon sequestration and storage) and adaptation to climate change (through improving food security and resilience). Next, we discuss the existing Government policies aimed at promoting different agroforestry practices and how these relate to important long-term goals related to climate change mitigation or adaptation. Finally, we describe some major constraints to the adoption of agroforestry systems and also the needs and emerging opportunities for agroforestry in Mexico.

Overview of Agroforestry in Mexico

Mexico has an area of 1.97 million square kilometers (761,200 square miles) and is one of the 14 most biodiverse countries in the world (Mittermeier et al. 1998). Together with its large, diverse mosaic of climatic zones, terrestrial ecosystems, and plant and animal species, Mexico has immense cultural diversity that has contributed a wide range of different domesticated crops (e.g., corn, bean, cocoa, vanilla, pineapple, avocado, amaranth, chia) and also land-use systems that include agroforestry (Toledo et al. 2001, 2003). Agroforestry practices were known to have been implemented during pre-Hispanic times, based on evidence of production systems that combined crops and multipurpose trees (Barrera et al. 1977). According to Moreno-Calles et al. (2014), the most well-documented examples include the *chinampas* (e.g., floating gardens with trees and crops) that the Aztecs used in central Mexico and the homegardens (e.g., complex combinations of crops, livestock, and multipurpose trees established adjacent to the home) that the Mayans used in the Yucatan. Agroforestry systems are especially typical of the extensive tropical habitats, where they are characterized by complex, spatially and temporally stratified combinations of trees, crops, and animals. Combined with other production strategies, such as roza-tumba-quema (slash-and-burn), these systems were implemented extensively in pre-Hispanic times.

During the long history of agroforestry in Mexico, the most important objective has been the production of subsistence food crops and other immediate necessities, such as fiber, medicine, and fuel wood, and only more recently have other products of commercial value been included to a great extent (Moreno-Calles et al. 2014). Although most agroforestry systems have not contributed significantly to country-level agricultural production and commercialization based on volume or land cover, they have been vital to sustaining rural farmers and to retaining the cultural and biological diversity of Mexico.

Some of these agroforestry systems have been modified or expanded more recently in response to the introduction of foreign crops like coffee, the internationalization of markets, technological advances, and changing policy and economic environments, especially for valuable products such as coffee, cocoa, and vanilla.

Despite their long historical importance, agroforestry systems in Mexico first gained broad recognition and relevance in 1991, when a collaborative agreement was signed by the International Center for Research in Agroforestry and the Institute of Forest, Agriculture, and Animal Husbandry Research in Mexico. This collaboration lasted about 10 years and resulted in several long-term research programs and the creation of educational and graduate programs focusing on agroforestry at major universities in Mexico.

The seven most common agroforestry systems in Mexico in recent times are (1) homegardens, (2) improved fallows, (3) living fences, (4) shade trees for agricultural plantations (e.g., coffee, cacao, fruit trees), (5) alley cropping (both with crops and fodder/pasture), (6) windbreaks, and (7) silvopastoral systems (Bautista 2009, Budowski 1987, CONAFOR 2014, Dominguez Alvarez and Sanchez Velez 1989, Garcia 2010, Gutierrez Ramirez 2006, Musalem-Santiago 2002, Santoyo 2004, Wilken 1976).

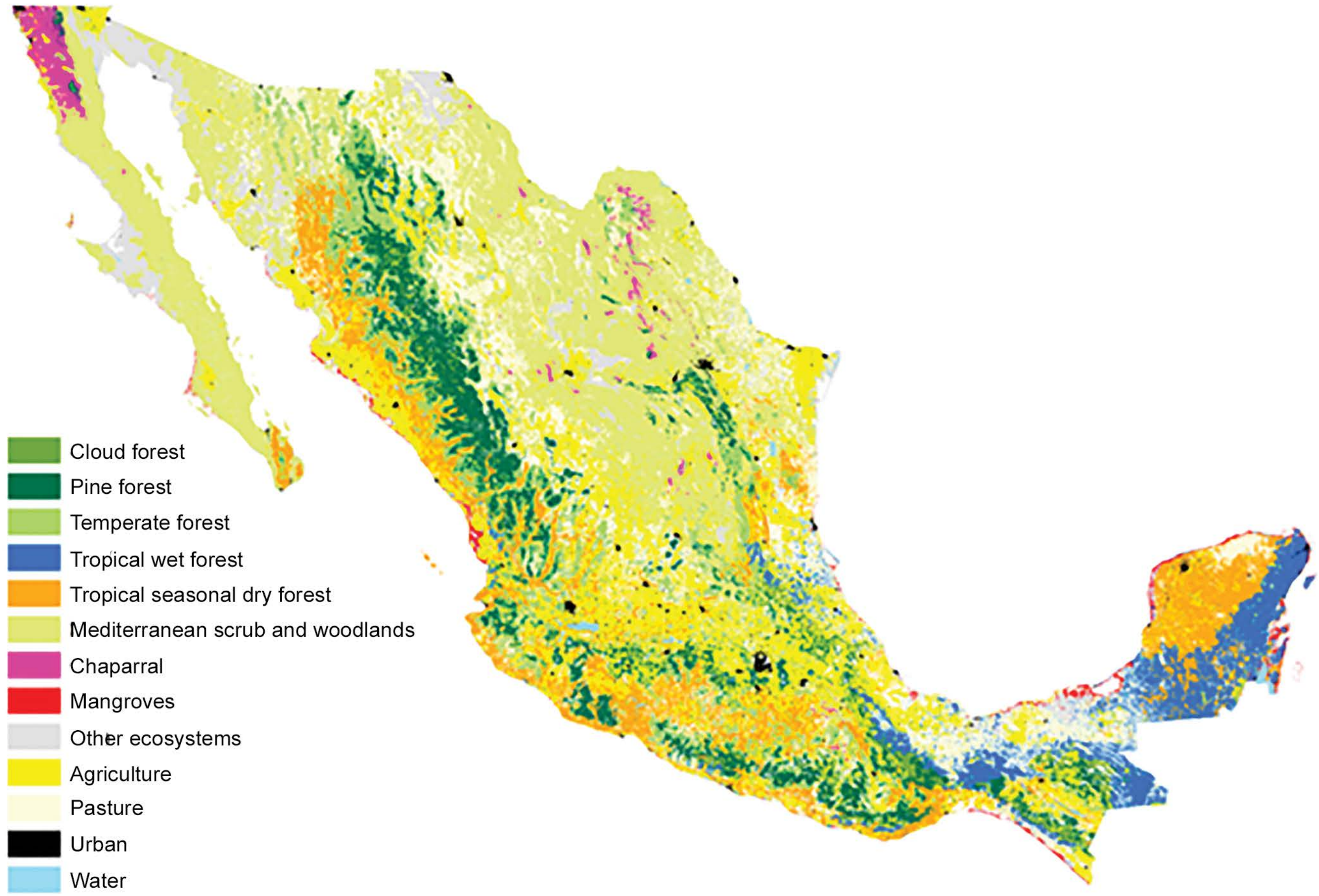
It is notable that agroforestry systems in Mexico have been intimately linked with indigenous natural resource management practices, including the rapid adoption and integration of new crops (e.g., coffee) into existing indigenous agroforestry practices having high levels of biodiversity (Beaucage 1997). Based on biocultural diversity, Moreno Calles et al. (2013) identified three main types of agroforestry systems in Mexico: (1) those associated with spaces near houses, (2) those associated with plots, and (3) those associated with forests and mountains; each has different levels of management intensity. These agroforestry systems commonly found in Mexico contribute to 15 different primary uses, most importantly, food (especially fruits), forages and medicines, ornamentals, construction materials, energy, alcoholic beverages, fibers, resins, and latex.

Also relevant for considering the role of agroforestry in land use and climate change mitigation is the land tenure system, which is unique to Mexico and differs from most other countries in Central and South America. A major land tenure reform favorable to common property management arose from the Mexican Revolution (1910–1920) (Bray et al. 2005), enabling the communal lands or *ejidos* to be established. For these reforms, the State effectively gave collective land entitlements to thousands of rural communities, resulting in more than 60 percent of Mexico's forested land currently being under communal ownership (Bray et al. 2003, FAO 2010). The internal organization of an *ejido* allows for collective activities in communal lands and family-level management in individual parcels. In total, some 60 percent of the country's forest resources are within communal lands where traditional agroforestry practices have been documented in at least 25 distinct indigenous groups scattered throughout the country, but mainly in the center and south (Boege 2009, Moreno-Calles et al. 2014). Notably, agroforestry systems in Mexico are primarily maintained at the individual-family scale. The new Agrarian Law of 1992 involved several changes in land tenure in Mexico and its Federal support. The most significant change was the possibility to obtain freehold rights of the parcels, including their privatization (Agrarian Law, Articles 81 and 82).

Regional Adoption Trends and Constraints

Mexico consists of eight dominant ecosystem types, in addition to areas dominated by pasture or agricultural crops (fig. 8.1).

Figure 8.1. Distribution of major ecosystems in Mexico. (Modified from INEGI 2012).



In this chapter, we focus on a subset of these ecosystems when describing the dominant trends and constraints in adopting agroforestry systems: tropical wet forests, tropical montane cloud forests, and tropical seasonal dry forest.

Tropical Wet Forests

Tropical wet forests are located close to the equator, where the climate is predominantly wet, with an average of more than 2000 millimeters (mm [79 inches]) of rainfall per year and uniformly high temperatures, between 20 and 35 °C. In Mexico, tropical wet forests occur primarily in the States of Chiapas, Tabasco, Oaxaca, and Veracruz and are characterized by a high diversity of plant and animal species, and by large trees—from 50 to 70 meters (m [165 to 230 feet]) tall—often supported by strong buttresses at the base of the trunk that help to stabilize them in the shallow forest soils and with abundant vines and lianas attached to their trunks. Another distinctive characteristic of tropical wet forests is the high degree of vertical stratification, often composed of several layers of vegetation, each one quite diverse in plants and animals (Rzedowski 1978).

Cacao. The cacao tree *(Theobroma cacao)*, which grows under the canopy of tropical wet forests, has been cultivated by several cultures in Mexico and Central America for the past three millennia. Considered one of the oldest agroforestry systems in the world, the earliest evidence (1900 B.C.E.) of cacao cultivation traces to the pre-Olmec cultures known as the Mokaya. Mesoamerican people, including the Mayans and Aztecs, used the seeds of cacao fruit to make a beverage known as *xocol lt*, a Nahuatl word that means *bitter water* (McNeil et al. 2009, Young 1994). Table 8.1 provides an example of the extent and production of cacao agroforestry plantations in the State of Chiapas. Cacao trees can be productive for up to 50 years, and the older the cacao trees in the plantation are, the

Table 8.1. Surface area planted and harvested with cacao in the municipalities in the State of Chiapas in 2010, by municipality.

Municipality	Surface area planted (ha)	Surface area harvested (ha)	Production (tons)
Pichucalco	8,020	7,918	3,374
Palenque	932	902	391
Tapachula	10,159	10,159	4,415
Tuxtla Gutierrez	620	620	210
Total	**19,731**	**19,599**	**8,390**

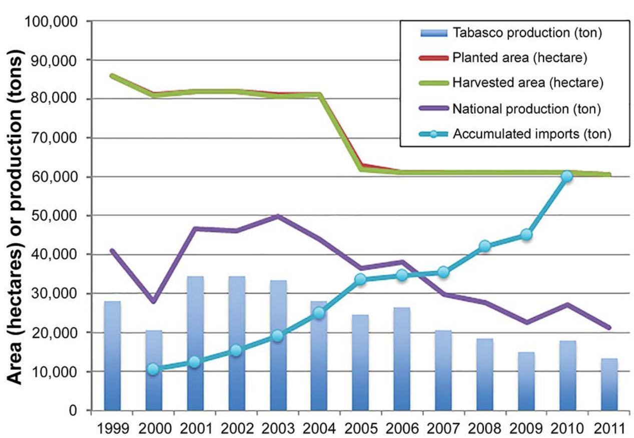
ha = hectares.

Sources: SIAP (2010); c.f. Zequeira-Larios (2014).

higher the biodiversity. A 30-year-old plantation can hold up to 500 individual plants per hectare, representing 23 families, 30 genera, and 32 species, and a 50-year-old plantation can hold 1,238 individuals representing 24 families, 40 genera, and 44 species. Cacao plantations are not only very important as biodiversity conservation areas but also as sources of timber products, fruits, and many tree species in general, and, above all, because of their ancestral origin as a cultural symbol in the tropical regions of Mexico (Ramirez-Meneses et al. 2014). A common practice today in response to declining cacao prices is the planting of valuable timber species such as *Cedrela odorata* within cacao plantations as a means of boosting revenues. Cacao trees are currently threatened by *Moniliophthora roreri*, which causes frosty pod rot, a highly destructive disease found in 11 countries in South and Central America.

Agroforestry systems based on cacao production at the national level in Mexico are declining (fig. 8.2), and often then systems are replaced by more intensive agricultural crops or livestock production. However, there is interest in stimulating cacao production in Tabasco, because it was Mexico's first global exporter of cacao.

Figure 8.2. Comparative historical data on the national production of cacao in Mexico, 2000 to 2010. (SIAP 2010; c.f. Zequeira-Larios 2014).



Homegardens. The homegarden is an integral part of smallholders' production strategies in Mexico. Although they can be found throughout all of the Mexico, homegardens are particularly common in the tropical wet forest zone. Homegardens tend to harbor high levels of biodiversity, which are maintained and enriched by farmers' practices, particularly plant and seed exchange (DeClerck and Negreros-Castillo 2000). Most homegardens are multipurpose, providing goods for home consumption, sales, environmental services, and experimentation and learning (Aguilar-Stoen et al. 2009). From a climate change perspective, homegardens provide an important strategy for increasing the resilience of small farms to a changing environment by supporting a diversity of plant (and often animal) species adapted to diverse conditions. Because homegardens often have a high proportion of woody biomass relative to agricultural systems dominated by annual crops, they also generally have higher potential for carbon sequestration.

Vanilla. Vanilla (*Vanilla planifolia*) is a nontimber forest product that has been managed in Mexico since pre-Hispanic times, especially among the Totonaca indigenous group in the region of Totonacapan (the States of Puebla and Veracruz) (Barrera-Rodriguez et al. 2009). Four agroforestry production systems have been recognized within Totonacan management strategies, each having different management intensities and diversity and composition of tree species: (1) secondary forests (traditional), (2) shade tree systems with *Erythrina* and *Gliricidia sepium* (technified), (3) shade tree systems with orange trees (*Citrus x aurantium* L.) (semitechnified), and (4) living fences (with 50 percent shade) (Barrera-Rodriguez et al. 2009, Hernandez-Hernandez 2011, Sanchez et al. 2001). Vanilla is cultivated within each of these four agroforestry production systems in the States of Chiapas, Oaxaca, Puebla, and Veracruz and, to a lesser extent, in Hidalgo, Michoacán, Quintana Roo, and San Luis Potosi (Damiron 2004, Hernandez-Hernandez 2011, Lopez et al. 2009). Consequently, vanilla-based shade-tree agroforestry systems typically support a high degree of species and structural diversity, which contributes to maintaining species diversity and biogeochemical cycling and providing multiple ecosystem services (Arroyo-Rodriguez et al. 2008, Hernandez-Hernandez 2011, Lopez et al. 2009, Soto-Arenas 2006). Today, vanilla is primarily produced as part of subsistence-based agroforestry systems, using a range of techniques, from traditional to more intensive-technical. The latter is characterized by greater use of chemicals to control pests, disease, and weeds and also by the use of tree species as trainers, particularly from the Leguminosae family (*Gliricidia* spp. and *Erythrina* spp.). The traditional system is characterized by the use of secondary forest species that regenerate naturally, or, in slightly more intensive systems, use of citrus trees that have been planted. Overall, vanilla production has been declining—from 445 tons in 1993 to 189 tons in 2002—largely because of the increased instability in the market price of green vanilla in recent years combined with lack of economic incentives in recent years (Barrera-Rodriguez et al. 2011); consequently, producers have been developing alternative production activities (Toussaint-Samat 2002).

Silvopasture and agrosilvopasture. Extensive cattle production throughout Mexico and many tropical regions in Latin America has led to the conversion of natural tropical forest to pasture. The integration of trees within pastures, referred to as silvopasture systems, has, in some cases, evolved naturally as farmers protect trees that are valued particularly for their shade, food, or other products. In other cases, this integration has been promoted specifically as a means for improving environmental quality and sustainability. Silvopastoral systems improve cattle raising because of high-quality forage provided by the trees, shade provided by timber trees, and the reduced costs of using live fences. Silvopastoral systems also increase the diversity of ecosystem services provided by cattle-raising systems, such as carbon sequestration, mitigation of methane emissions, and fixation of atmospheric nitrogen. In some Mexican States, such as Chiapas, knowledge and use of fodder trees and shrubs play an important role in the design of more environmentally sound cattle-raising systems and also provide significant income to farmers. Within the region of the Selva Lacandona, Chiapas, local people cultivate a total of 28 fodder species, representing 16 botanical families. In addition to being used for forage, most of the species are also used for shade, food, fuel wood, live fences, medicine, and construction (Jimenez-Ferrer et al. 2008).

Tropical Montane Cloud Forests

Also known as fog forest and, in Spanish, as *bosque mesófilo de montaña*, tropical montane cloud forests are broadly characterized as ecosystems that experience frequent and persistent fog, or low-lying clouds. Because of its geographical location, this forest type is considered to be a transitional vegetation between the temperate forest and the tropical deciduous dry forest along elevational gradients. It is comprised of deciduous and evergreen trees and is covered with brilliantly colored orchids, bromeliads, mosses, and lichens. Although cloud forests occupy less than 1 percent of the country's land area, they are home to 10 to 12 percent of plant and animal species, many of which are endemics. More than 50 percent of this type of forest has been transformed to other land uses in Mexico during the past few decades, and the cloud forest is considered the most endangered type of tropical forest worldwide. Agroforestry production is an important alternative in regions of cloud forest that can help insure the socioeconomic wellbeing of landowners while simultaneously helping to protect these endangered forests by creating habitat for forest species, increasing connectivity, and minimizing edge effects along forest remnants. The main agroforestry production systems that are employed in regions of cloud forest in Mexico and that are capable of balancing conservation and development concerns include coffee, chamaedorea palm, pita, and pepper spice. These systems are discussed in more detail below.

Shade coffee. In areas with tropical seasonal dry forest and cloud forests, one of the most important agroforestry systems has been shaded coffee plantations. Mexico historically has been an important producer of higher quality shade coffee and currently occupies ninth place in production worldwide (Financiera Nacional de Desarrollo 2014). *Coffea arabica* dominates production in the country (97 percent of cultivated area) and grows best between 600 and 1200 m (2,000 to 4,000 ft) above sea level. Coffee is currently the most important export crop in Mexico, after grains, and is cultivated on 690,000 ha (1,700,000 acres [ac]) spread across 12 States (SAGARPA 2012). Production by some 500,000, mostly small (90 percent less than 1 ha [2.5 ac]) and indigenous (66 percent of municipalities), coffee growers provides a source of income for 3 million Mexicans.

The traditional and commercial shade polycultures that dominate (90 percent of cultivated area) coffee production in Mexico (Escamilla et al. 1994; Moguel and Toledo 1999) include a mix of native and introduced tree species that are typically nitrogen fixers and/or are useful commercially. These species include *Citrus* spp., banana (*Musa* spp.), rubber (*Castilla elastica*), pepper (*Pimenta dioica*), cedar (*Cedrela odorata*), jinicuil or chalahuite (*Inga* spp.), and colorin (*Erythrina* spp.). Coffee agroforestry systems are often enriched with chamaedorea palms, pepper trees, and pita, but in extreme cases such as the Tosepan cooperative Titataniske in the State of Puebla, such enrichment can reach 69 plant species per parcel or 250 to 300 plant species in total (Toledo and Moguel 2012). Because of the high biological diversity (an average of 29 tree species per farm) (Lopez-Gomez et al. 2008) and concomitant structural diversity, these agroforestry systems help conserve an important proportion of the fauna and flora of tropical montane cloud forests (Manson et al. 2008; Moguel and Toledo 1999; Philpott et al. 2008). These benefits, and associated ecosystem services (Jose 2009), have helped make Mexico a pioneer in the production of organic coffee (10 percent of production area), a recognized leader in other types of certification such as fair trade, and a target of payments from national and local programs focused the conservation and restoration of key ecosystem services.

Coffee production in Mexico has suffered since the early 1990s, with the collapse of international coffee agreements that regulated coffee production and stabilized prices and with the elimination of INMECAFE, which provided technical training and financing to growers and also collected, processed, and commercialized the coffee of the nation's coffee growers. Recurring international cycles of overproduction and low prices have hit Mexican growers hard (Manson et al. 2008). Coffee production in Mexico is also suffering because of pests and diseases such as broca, nematodes, and La Roya. Both the quantity and quality of coffee production may decline further because of the warmer, drier weather conditions expected under current scenarios of global climate change, unless growers implement measures to mitigate or adapt to these changes (Gay et al. 2006; Laderach et al. 2011). Two consequences of these trends have been a shift to resistant, more productive, varieties that require more agrochemicals and less shade cover, and increased rates of conversion of shade coffee plantations to other land-use systems, especially sugarcane or pasture, which typically lead to greater environmental degradation and reduce climate change mitigation potential.

Chamaedorea palm. The chamaedorea palm is one of the principal nontimber forest products primarily found in cloud forest ecosystems in Mexico and comprises 37 percent of the international market. Mexico is considered a center of diversification. Of the 130 species of *Chamaedorea* known on the American continent, about 50 are found in Mexico, of which 14 are native species. Planted populations of these palms do not produce seed because of a lack of pollinators, and therefore seed must be collected from natural populations found in forest ecosystems, an important factor in the conservation of forests where the plant is found. Chamedorea palm leaves (particularly from *Chamaedorea elegans*) have been exported as an ornamental internationally, especially to the United States, for more than a century, but the rate of exportation increased greatly starting in the 1940s. Palm populations overall have remained stable, although overexploitation, habitat destruction, and land-use change threaten populations in some parts of Mexico. Diverse initiatives by the National Forestry Commission (CONAFOR) of Mexico (CONAFOR 2014) and various nongovernmental organizations (NGOs) have promoted the cultivation of palm in forested areas and also as part of agroforestry systems, such as shade coffee, especially in the States of Chiapas, Oaxaca, and Veracruz. Both the chameadorea palm and pita (see details in the following section) grow well in as part of more intensively managed agroforestry systems (e.g., shade coffee), and they are especially important in providing a safety net for poor farmers to rely on when production of other subsistence or cash crops is lower than anticipated (Marshall et al. 2006).

Pita. Pita (*Aechmea magdalenae)* is a highly resistant fiber obtained from a terrestrial bromeliad, originally used in pre-Hispanic times primarily for fishing nets; more recently, it has been popularized through its use in artisan *charreria* with decorative borders in pita, especially in Chiapas and Oaxaca. With increasing demand, rural communities began to domesticate the pita plant by collecting cuttings to plant within their gardens, coffee and fruit plantations, and nearby forest plots. Productivity is estimated at 15 to 25 kg/ha (13 to 22 lb/ac), representing a value of $4,500 to 10,000 Mexican pesos/ha ($100 to $220 U.S. dollars/ac), which is greater than the value of coffee or cattle. Thus, the pita provides an important means of economic diversification and alternative income source when prices of other products are low, and it contributes to conservation of remaining forest patches within agricultural landscapes. Annual production of pita in Mexico varies between 30 to 40 tons.

Pepper tree. The pepper tree (*Pimenta dioica*), also known as the pepper spice, grows throughout Central America, the Caribbean, northern South America, and Mexico. Trees typically reach a height of 6 to 10 m (20 to 30 ft) and grow as isolated trees with open pastures, where they are valued for their shade. They are also integrated as part of home gardens and with other crops (e.g., orange, banana, cacao, coconut), where they help control weeds. The pepper spice was originally used in pre-Hispanic times and continues to be a valuable condiment internationally, with demand for dry pepper and essential oils increasing progressively. It is an important crop grown within coffee plantations in the States of Campeche, Chiapas, Oaxaca, Puebla, Tabasco, and Veracruz. Production in Mexico between 1990 and 2000 increased from 868 to 4,980 tons, with most of this product exported internationally. Mexico is the second major producer and exporter of pepper worldwide, after Jamaica.

Tropical Seasonal Dry Forest

Tropical seasonal dry forests are characterized by pronounced seasonality in rainfall. The many deciduous species in these forests are adapted to the seasonal absence of rainfall, and plant species abundance is nurtured by the warm temperatures. Tropical seasonal dry forests have a high diversity and endemism (Trejo and Dirzo 2000). In the neotropics, these forests reach their northernmost distribution in Mexico (across the States of Baja California, Sonora, Sinaloa, Tamaulipas, all the way down to Chiapas) (Cairns et al. 1995, Ceballos and Garcia 1995, Lopez-Barrera et al. 2014).

A large portion of tropical dry forest was lost in the 1970s, when the Mexican Government supported the clearing of these forests along the Pacific coast of the State of Jalisco to be used for agriculture, cattle ranching, tourism, and housing uses (Romero-Duque et al. 2007). By 1980, human use had eliminated 44 percent of the original area of tropical dry forests in Mexico. Some of the human uses included converting the forests into grasslands for cattle grazing, employing slash-and-burn agriculture, and harvesting wood for fuel (Galicia et al. 2008). It is also important to note, however, that some of these pasture-based land-use practices may be considered agroforestry silvopastures for cases in which trees comprise integral components of the pastures, and slash-and-burn agricultural systems may be considered agroforestry if sufficient fallow periods and/or preservation of isolated trees within crop fields allow for the maintenance of permanent woody vegetation cover during longer periods.

Some tropical regions in Mexico, particularly those with dry forest, are used as silvopastoral systems, in which cattle forage on small trees and, during the dry season, on leaves and fruits that have fallen on the ground. The forage quality, in general, is higher in pastures. For example, in the Sierra de Manantlan, 19 species (herbs, shrubs, and trees) are used as forage, although in this silvopastoral system, the *Gramineae* species produced higher biomass per square meter, and *Verbesina greenmanii, Leucaena esculenta,* and *Acacia riparia* showed higher nutrient content. On the other hand, two layers—trees and herbs—in the tropical dry forest might produce more biomass than grassland alone (Montano et al. 2003), while potentially providing other diverse products, such as pitayas, honey, and spices, such as oregano and candelilla.

Potential Carbon Sequestration From Use of Agroforestry in Mexico

Many different agroforestry systems occur in Mexico; however, only a few systems involve large-scale production of products that are supported under Government incentives or programs (e.g., shade coffee, cacao). In terms of total area covered and potential for contributing to climate change mitigation and food security, these other more traditional agroforestry systems are extremely important. Table 8.2 presents a summary of studies that have quantified contributions of different major agroforestry systems to carbon storage in Mexico, including comparisons with available global estimates and studies conducted in other Central American countries. Table 8.3 presents an overview of the distribution of major commercial agroforestry systems (e.g., shade coffee, cacao, and vanilla) by State in Mexico.

Table 8.2. Carbon storage in different agroforestry systems.

System	Location	Other characteristics	Carbon T/ha
Agrosilviculture[a]	Global synthesis	Humid tropical lowlands	39–102
Silvopasture[a]	Global synthesis	Dry tropical lowlands	39–195
Silvopasture[a]	Global synthesis	Humid tropical highlands	133–154
Corn fields with trees[b]	Chiapas, Mexico	3.7 years old	127.9
Taungya (6.8 years)[b]	Chiapas, Mexico	6.8 years old	109.4
Natural fallow (acahual)[b]	Chiapas, Mexico	23.7 years old	117.6
Improved fallow (acahual)[b]	Chiapas, Mexico	7.3 years old	150.1
Homegarden[c]	Veracruz, Mexico	Citrus + coffee	40.5–73.2
Homegarden[c]	Veracruz, Mexico	Citrus + banana	32.6–59.0
Homegarden[c]	Veracruz, Mexico	Citrus + coffee + banana	43.4–77.3
Homegarden[c]	Veracruz, Mexico	Citrus + coverage	37.9–44.8
Homegarden[c]	Veracruz, Mexico	Citrus + pelibuey sheep	63.4–94.7
Pasture[c]	Veracruz, Mexico		1.4–2.1
Shade coffee, conventional[d]	Costa Rica		69.0
Shade coffee, organic[d]	Costa Rica		98.0
Improved fallow[e]	Chiapas, Mexico	Low tropical agroclimatic zone	140.8
Taungya[e]	Chiapas, Mexico	Low tropical agroclimate zone	140.8
Pastures with scattered trees[e]	Chiapas, Mexico	Low tropical agroclimate zone	129.3
Pastures with live fences[e]	Chiapas, Mexico	Low tropical agroclimate zone	118.6
Pastures without trees[e]	Chiapas, Mexico	Low tropical agroclimate zone	71.5
Taungya[e]	Chiapas, Mexico	High tropical agroclimatic zone	173.9
Improved fallow[e]	Chiapas, Mexico	High tropical agroclimatic zone	148.3
Traditional fallow[e]	Chiapas, Mexico	High tropical agroclimatic zone	157.5
Inga-shade organic coffee[e]	Chiapas, Mexico	High tropical agroclimatic zone	194.0
Polyculture-shade organic coffee[e]	Chiapas, Mexico	High tropical agroclimatic zone	151.9
Polyculture-shade nonorganic coffee[e]	Chiapas, Mexico	High tropical agroclimatic zone	173.2
Traditional maize[e]	Chiapas, Mexico	High tropical agroclimatic zone	109.7

T/ha = teragrams per hectare.

[a] Winjum et al. (1992); Brown et al. (1993); values standardized to a 50-year rotation and represent total carbon storage in vegetation and soils.

[b] Roncal-Carcia[Garcia? As in Lit. Cit. entry? Which spelling is correct?] et al. (2008), modified by Casanova-Lugo et al. (2011); total carbon storage in vegetation and soils.

[c] Callo-Concha et al. (2004), modified by Casanova-Lugo et al. (2011). Carbon storage in aboveground vegetation and litter.

[d] Hager (2012); total aboveground and belowground carbon.

[e] Soto-Pinto et al. (2010); total aboveground and belowground carbon.

Table 8.3. Current distribution and production of dominant agroforestry systems (shade coffee, cacao, and vanilla) in Mexico by State.

State	Coffee area (ha)	Coffee value (1,000s of pesos)	Cacao area (ha)	Cacao value (1,000s of pesos)	Vanilla area (ha)	Vanilla value (1,000s of pesos)
Chiapas	259,315	2,508,647	20,299	306,840	0	0
Veracruz	147,384	1,791,264	0	0	740	26,798
Oaxaca	142,766	481,808	0	0	145	4,195
Puebla	72,175	645,347	0	0	71	1,960
Guerrero	47,190	284,106	237	1,084	0	0
Hidalgo	25,821	147,266	0	0	0	0
Nayarit	17,678	129,113	0	0	0	0
San Luis Potosi	17,154	19,769	0	0	97	999
Jalisco	3,835	30,176	0	0	0	0
Colima	2,378	13,051	0	0	0	0
Tabasco	1,040	4,670	40,783	708,477	0	0
Mexico	479	2,085	0	0	0	0
Queretaro	270	2,066	0	0	0	0
Total	**737,485**	**6,059,368**	**61,319**	**1,016,401**	**1,053**	**33,952**
Millions of dollars		459		77		3

ha = hectares.

Source: SAGARPA (2013).

Overview of Existing Policies

In 1997, the National Forestry Commission of Mexico (CONAFOR) established the Commercial Plantations Development Program (PRODEPLAN). This program included support for establishing agroforestry systems as part of its primary goal of expanding commercial forestry plantations in Mexico. Between 2000 and 2010, 83,172 ha (205,522 ac) of agroforestry plantations were established with CONAFOR's funding support; however, the classification of these systems was based purely on the plantation density (e.g., 600 trees/ha [1,482 trees/ac]) without specifying the types of agricultural or livestock components that are managed in combination with forestry production. Thus, available information on areal extent of implementation should be interpreted cautiously (CONAFOR 2014).

The target goal of expanding forest plantations was not fully realized in this program, which was largely attributed to landowner unwillingness to invest the resources when financial returns occur on such long time scales. This lack of success led to agroforestry systems being included within PRODEPLAN in 2011, focusing on those systems having a woody component with merchantable timber as an alternative to stimulate the establishment of forestry plantations. The modification made to the operational rules for PRODEPLAN, for the first time, identified the specific agricultural, livestock, and forestry components included in the agroforestry system and the required field verification that the system was implemented according to the original proposal.

Between 2011 and 2012, 3,852 ha (9,518 ac) of agroforestry systems were supported under this program, and, in 2012, another 182 ha (450 ac) were established. Relative to the total number of hectares planted and resources distributed under this program, however, the proportion dedicated to agroforestry systems remains small. Figure 8.3 shows the distribution of agroforestry systems by State during the period from 1997 to 2012 that were implemented through CONAFOR. The program for the Production and Commercialization of Non-Timber Forest Products also provides support to certain agroforestry systems. Table 8.4 presents the agroforestry systems that have been supported as part of this new category of Agroforestry Plantations within PRODEPLAN, by bioclimatic region.

The proposal "Agroforestry-Timber Systems Most Appropriate for Mexico" calls for future CONAFOR support to target the following four systems: (1) taungya, (2) alley cropping,

Figure 8.3. Distribution of agroforestry systems, by State, established with support from CONAFOR's PRODEPLAN program between 1997 and 2012. (CONAFOR 2014).

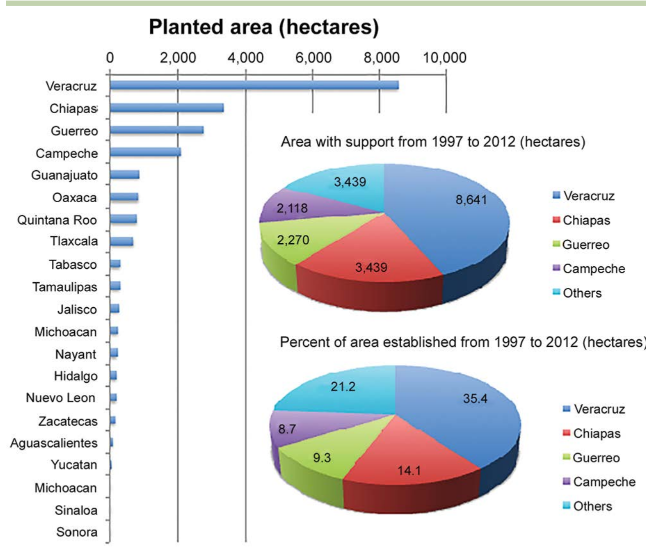


Table 8.4. Agroforestry-timber systems established in tropical regions in Mexico since 2011 under Comisión Nacional Forestal's Plantation Agroforestry category, by climatic zone. (1 of 2)

State	Surface area (ha)	Agroforestry system (tree species)	Associated plant species
Tropical zone			
Guerrero	25 25 60 50 50 50 100 124 50 169	*1. Cedrela odorata, Swietenia macrophylla, Cordia eleagnoides* *2. Cedrela odorata* *3. Cedrela odorata, S. macrophylla* *4. Cedrela odorata, S. macrophylla* *5. Cedrela odorata, S. macrophylla* *6. Cedrela odorata, S. macrophylla* *7. Cedrela odorata, S. macrophylla* *8. Cedrela odorata, S. macrophylla* *9. Cedrela odorata, S. macrophylla* *10. Cedrela odorata, S. macrophylla*	1. Coconut 2. Agricultural crops 3. Corn, beans 4. Corn 5. Corn, beans, pasture 6. Corn, beans, pasture 7. Corn, beans, pasture 8. Corn, beans, pasture 9. Corn, beans, pasture 10. Corn, beans, pasture
Hidalgo	100	*Cedrela odorata*	Coffee
Quintana Roo	71 5	*1. Cedrela odorata, S. macrophylla* *2. Cedrela odorata, S. macrophylla*	Corn
Chiapas	20 6	*1. Cedrela odorata, Tectona grandis* *2. Tectona grandis, Tabebuia donnell-smithii, Tabebuia rosea*	Cacao Mango
Oaxaca	42	*S. macrophylla, Tabebuia donnell-smithii, Cedrela odorata*	Coffee
Tamaulipas	162 118	*1. Eucalyptus camaldulensis* *2. Gmelina arborea, Tectona grandis, Eucalyptus camaldulensis*	Sorghum Pasture
Puebla	50	*S. macrophylla*	Forages
Tabasco	27 83	*1. Cedrela odorata* 2. *Eucalyptus* spp.	*1. Elaeis guineensis* *2. Brachiaria brizantha*
Veracruz	25	*Gmelina arborea*	*Leucaena* spp.
Michoacan	50	*Gmelina arborea, Tectona grandis, Eucalyptus camaldulensis*	*Leucaena* spp.
Nayarit	25 35 25	*1. Tabebuia donnell-smithii, Tabebuia rosea* 2. *Eucalyptus* spp. *3. Tabebuia donnell-smithii, Gmelina arborea, Cedrela odorata*	1. Pasture 2. *Leucaena* spp.], *Brosimum alicastrum, Guasima* spp., 3. *Leucaena* spp.
Temperate and semiarid zones			
Guanajuato	50 200	*1. Pinus greggii* *2. Pinus greggii*	1. Corn, beans 2. Corn, beans
Tlaxcala	30 79	*1. Pinus pseudostrobus, Pinus montezumae* *2. Pinus pseudostrobus, Pinus montezumae*	1. Rye, corn, basic grains 2. Wheat, corn
Puebla	22	*Pinus pseudostrobus*	Coffee
San Luis Potosi	100	*Prosopis spp.*	*Opuntia* spp.
Nuevo Leon	56 53 36 67 75	*1. Prosopis glandulosa* *2. Prosopis glandulosa* *3. Prosopis glandulosa* *1. Prosopis glandulosa* *2. Prosopis glandulosa*	1. Pradera 2. Sorghum (forage), vegetable crops 1. Forage 2. Forage 3. Forage
Sonora	44	*Prosopis* spp.	Native grasses
Queretaro	20 25	*1. Pinus greggii* *2. Pinus greggii, Prosopis laevigata*	1. Rye 2. Alfalfa

ha = hectares.

Source: CONAFOR-UNACH (2013).

(3) mixtures of perennial crops and trees, and (4) tree plantations with pasture and livestock (see details in table 8.5). Additional criteria for consideration include that the system should be established under areas having good agroecological conditions and with fast-growing trees with timber potential to ensure both maximum ecological and financial success for interested producers and to reduce costs to the program (CONAFOR 2014).

As part of its proposal for Agroforestry-Timber Systems Most Appropriate for Mexico, CONAFOR conducted a study to identify and prioritize potential areas for establishing agroforestry systems throughout the entire country (CONAFOR 2014). Areas with the following characteristics were excluded from the analysis: areas higher than 3000 m (9,842 ft) above sea level, areas susceptible to flooding, natural protected areas, areas with severely saline or sodic soils, areas with slopes of

Table 8.5. Principal characteristics of the proposed agroforestry-timber systems for Mexico.

Agroforestry system	Principal characteristics
Taungya	Temporal combination of trees with agricultural crops; trees are planted with uniform spacing; crops are grown while there is sufficient light; crops with greater shade tolerance may be substituted as the plantation develops.
Alley cropping	Permanent mixture of crops or pasture in alleys; the timber trees can be established in lines of different sizes; the pasture can be for cutting or grazing.
Mixtures of perennial crops and trees	Permanent combination of agricultural crops and timber trees that may (or may not) provide shade for the crops; examples of tree species include rubber, coffee, cacao and coconut.
Tree plantations with pasture and livestock	Permanent combination of timber trees with dispersed shade within pasture maintained for livestock.

Source: CONAFOR-UNACH (2013).

more than 25 percent (more than 20 percent for tropical lands), arid zones with less than 300 mm mean annual precipitation (MAP), tropical zones with less than 800 mm MAP, temperate zones with less than 600 mm MAP, polygons of less than 100 ha in size, areas with thin soils or soils with rocky outcroppings (lithosols), and severely degraded lands. Application of these criteria resulted in a total surface area of 13.9 million ha (34.3 million ac), distributed across 30 States, which were considered priority areas for agroforestry implementation as part of this study. The analysis (using a geographic information system) resulted in a total "potential" surface area for agroforestry of 4 million ha (10 million ac), with nearly 86 percent concentrated in eight States (table 8.6).

Data from the States of Veracruz and Tabasco show that at least one of the most common 15 genera of agroforestry species were planted outside of established priority zones (fig. 8.4). Agroforestry systems were likewise established in areas where water scarcity was considered as a fundamental limitation and potential cause of failure of agroforestry systems (CONAFOR 2014). CONAFOR's recommendation is that future agroforestry programs target the priority areas (CONAFOR 2014).

Distribution of agroforestry species and priority areas based on elevational zones; e.g., Zone A (0 to 700 m above sea level), Zone B (700 to 1500 m above sea level), Zone C (1500 to 2200 m above sea level), and Zone D (more than 2200 m above sea level) has been identified (CONAFOR 2014). Of the total area with high potential for agroforestry (i.e., 3.96 million ha [10 million ac]), the majority (82 percent) is located in Zone A, with 14 percent of the remaining area in Zone B and 4.5 percent in Zones C and D. The most frequently used agroforestry woody species and associated crops for each elevational zone were coffee and cacao and corn, beans, oats, and pasture, respectively (table 8.7)

Table 8.6. Distribution of potential surface area for agroforestry systems in Mexico, by State.

State	Surface area (ha)	Percent of surface area
Veracruz	1,403,500	35.3
Chiapas	414,871	10.4
Oaxaca	369,146	9.3
Tabasco	340,242	8.5
Guerrero	339.844	8.5
San Luis Potosi	214,664	5.4
Puebla	170,207	4.3
Nayarit	161,919	4.1
Quintana Roo	100,916	2.5
Michoacan	80,984	2.0
Campeche	65,981	1.7
Tamaulipas	57,533	1.4
Hidalgo	57,228	1.4
Yucatan	54,360	1.4
Jalisco	52,235	1.3
Mexico	46,991	1.2
Durango	17,3355	0.4
Chihuahua	13,610	0.3
Colima	10,353	0.3
Sinaloa	5,065	0.1
Morelos	3,315	0.1
Sonora	600	0.01
Nuevo Leon	83	0.002
Total	**3,980,002**	**100**

Source: CONAFOR 2014.

Figure 8.4. Comparison of identified agroforestry priority areas (orange) for the States of Tabasco and Veracruz with the areas where at least one of the most common 15 genera in agroforestry systems were planted (green). (CONAFOR 2014).

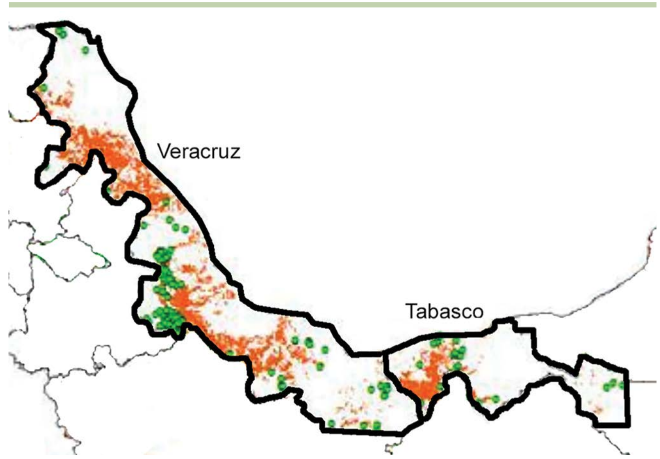


Table 8.7. Potential surface area for major agroforestry crops, by altitudinal zone.

Crop	Surface area (hectares)				
	Zone A (0–700 m)	Zone B (700–1500 m)	Zone C (1500–2200 m)	Zone D (> 2200 m)	Total
Coffee	2,182,307	377,711	85,296	—	2,645,314
Chocolate	545,893	150,272	38,377	—	734,542
Corn	3,156,853	549,751	155,597	21,831	3,884,032
Beans	2,972,847	469,592	115,596	19,812	3,577,847
Oats	183,381	61,677	46,270	8,584	299,912
Pasture	3,193,381	546,487	142,819	20,795	3,903,482

Note: Zone elevations (in meters) in parentheses.

Source: CONAFOR 2014.

Payments for Ecosystem Services Programs

Agroforestry production in Mexico has also been strengthened by the rapid growth of programs making payments for ecosystem services (PES). These programs were originally envisioned as a means for conserving and restoring the country's endangered forest and water resources, linked through the multiple services provided by these ecosystems (Manson 2004, Mora 2015, Munoz-Pina et al. 2011). There is also a growing interest for using PES programs to address the socioeconomic and cultural problems, which may be limiting their effectiveness in achieving environment goals (Alix-Garcia et al. 2012, Munoz-Pina et al. 2011). Mexico's national PES program was established in 2003 through the redistribution of 2.5 percent of water-concession payments nationwide from the National Water Commission to CONAFOR. These funds were used to establish 5-year contracts with landowners in key watersheds throughout the country for providing hydrological services. Starting in 2004, payments were authorized for additional services, including carbon sequestration, biodiversity conservation in forest plots, and improvement of shade cover in agroforestry systems (mostly shade coffee and cacao farms). Payments for carbon sequestration were eliminated in 2006. The national PES program is now one of the largest in the world, having made more than $650 million in payments covering 4.16 million ha during the period from 2003 to 2013 (table 8.8).

Table 8.8. Beneficiaries, area, and amount paid by year in Mexico's national program making payments for ecosystem services.

Year	Number of beneficiaries	Area (thousands of ha)	Amount paid (millions of pesos)
2003	272	127	192
2004	578	215	388
2005	302	196	310
2006	315	146	232
2007	1,447	610	1,061
2008	1,114	462	982
2009	693	502	1,096
2010	688	509	1,116
2011	558	465	980
2012	747	567	1,222
2013	637	471	1,006

ha = hectares.

Source: CONAFOR (N.d.).

The proportion of payments to lands in the category of PES including agroforestry systems has been growing and comprises 26 percent of all areas that have been included in the national program to date (table 8.8). To receive such payments, farmers with agroforestry production need to show that their shade cover is diversified and composed of native tree species and that cattle and other grazing animals are not part of the production system. Most payments have been made to shade coffee farms, followed by cacao, vanilla, and the chamaedorea palm.

Reducing Emissions From Deforestation and Forest Degradation

According to CONAFOR's "Terms of Reference for the Operation of REDD+" (CONAFOR [N.d.]), one objective of REDD+ in Mexico is "to promote the establishment of agroforestry and silvopastoral systems, as well as other innovative production schemes, that simultaneously enhance food security of local people and the restoration of degraded areas." Within this program, *agroforestry* is defined as "a management system focusing on agricultural production that integrates forestry activities through productive reforestation and the management of degraded areas, with the goal of obtaining diverse benefits such as food security, production diversification, ecosystem connectivity, biodiversity conservation, among other ecosystem products and services."

Several special programs known as "early actions REDD+" have been launched recently in Mexico. In 2013, such programs were established in Campeche, Chiapas (Lacandon Forest), Oaxaca, Quintana Roo, and Yucatan. These programs support the establishment of agroforestry systems (crops plus trees) and silvopastoral systems (mostly live fences). In 2014, a new special program was launched in the coastal region of Michoacan to support the establishment and management of both agroforestry and silvopastoral systems. The only special programs that include the production of tree seedlings are the ones for Campeche, Chiapas, and Oaxaca. These special programs are administrated through the Department of Community Forestry of CONAFOR. The special programs were established as a strategy to mitigate climate change, join biological corridors, provide socioenvironmental benefits, and slow down or stop deforestation. So far, these special programs are applied only in the aforementioned States.

Constraints to Adoption and Implementation of Agroforestry Systems in Mexico

To a large extent, adoption of different agroforestry system depends on the cultural practices of the particular indigenous groups present in each region and on the climatic constraints of the different agroforestry crops (e.g., vanilla in Veracruz, avocado in Michoacán, cacao in Tabasco). Several major threats to the future continuation or expansion of agroforestry systems in Mexico include: (1) the reduction in species and agroforestry practices represented; (2) the loss of knowledge and/or abandonment of traditional agroforestry practices, a process related to the out-migration of young men and women, along with the aging and death of the farming populations; (3) agricultural intensification that results in a reduction or loss of the fallow period, the vegetative cover, and traditional crops, along with an increase in the use of machinery, agrochemicals, and annual crops; and (4) the rental or sale of private lands for development of intensive crops or residential homes (Moreno Calles 2013).

Another factor that potentially limits the expansion of agroforestry systems to new areas is the oftentimes inadequate alignment between support and resources available from the different institutions, especially because cattle ranching and agricultural activities that are promoted by many Government programs often result in the destruction of forest resources (Moreno Calles et al. 2013). Land tenure issues may also limit agroforestry expansion. For example, cattle ranching laws in Mexico manipulate the definition of s*tocking densities* to circumvent the definition of *small property* in the redistribution of lands after the Mexican Revolution, resulting in the establishment of relatively large properties that are dedicated to cattle ranching and that do not generally favor the establishment of agroforestry or other production systems (Gonzalez-Montagut 1999).

To understand what factors influence decisions and motivations to adopt agroforestry practices, a survey of previous and current program participants was conducted (CONAFOR 2014). The following list includes some of the major findings from this study.

- The selection of a particular species to incorporate within agroforestry systems depended on familiarity, growth rates, market value, ease of propagation and management, multiple use options, interactions with crops, availability, recommendations from programs, and the environmental impacts. Although exotic species were previously favored, an increasing interest in working only with native species has recently emerged. In general, producers preferred a mixture of different species.
- In general, agroforestry projects were more useful to landowners when they were provided with information about the behavior and resource requirements for a variety of species and agroforestry designs, rather than when they were offered a single standard system. This approach enables landowners to choose which combination of species and systems best meets their available resources and needs.
- Even though agroforestry systems may be inherently profitable, the success of adoption was greatly enhanced when landowners received technical assistance that provided information about the management of tree species and agroforestry configurations, which often were unfamiliar. In particular, the involvement of local people as technicians and extensionists has proven to be a successful and low-cost method for promoting agroforestry systems and also for developing local capacities and human resources for disseminating agroforestry in the future.
- The primary four reasons for participation in CONAFOR's agroforestry program were (1) to provide a source of employment (i.e., because the program paid landowners directly to participate) (24 percent); (2) to increase the production of trees in certain areas (19 percent); to improve the environmental conditions on the land (38 percent); and to improve the economic value of the land (19 percent). Two-thirds of the participants perceived a potential for obtaining an income from the harvest of the trees as a major benefit of the agroforestry system.
- Major problems identified by the CONAFOR participants included the lack of sufficient economic resources for investing in infrastructure, labor, etc. (43 percent); biophysical limitations, such as pests and disease, lack of rain, excessive temperatures, or steep slopes (31 percent); social problems, such as vandalism, damage to plants from people (19 percent); and institutional problems related primarily to complex and slow bureaucratic requirements (7 percent).
- The subsidies provided by CONAFOR were instrumental in determining adoption of the agroforestry practices; 89 percent indicated they would not have established the practices without the subsidies. In addition, many were unwilling to implement management practices (e.g., thinning, road maintenance) because of their high cost and/or labor requirements.

A broader analysis of 21 agroforestry projects in Central America and the Caribbean by Current et al. (1995) identified several underlying themes that emerged as important factors influencing the adoption of agroforestry practices, including:

- The management intensity that is economically attractive for farmers depends on the degree of scarcity of forest resources, the level of demand, the opportunity cost of alternative uses, the availability of labor and capital, and the production costs relative to the cost of available substitutes for the products and services provided by trees. For example, this study found that, in Panama, traditional extensive land-use systems (e.g., migratory agriculture or slash-burn-fallow) were profitable in areas where land was widely available, whereas in areas with limited land area, such as El Salvador or the highlands of Guatemala, more intensive management systems such as agroforestry were more common.

- The adoption of agroforestry systems by small famers is usually most successful when it occurs gradually (i.e., during a 5-to-10 year period), taking into account the food security and risk reduction needs, especially because these producers often have limited resources and management options. The focus should be on starting with a few farmers and on agroforestry systems that offer continuous benefits during long periods. Overall, acceptance and adoption of agroforestry practices were higher among larger landowners, largely because they were able to better adapt their available resources compared with small landowners.

Needs and Emerging Opportunities for Agroforestry in Mexico

The "Second Revision of the FAO Strategic Forestry Program 2025," conducted in 2013 in collaboration with the Autonomous University of Chapingo, Mexico, states that one of Mexico's strengths is the potential of its ecosystems to sequester carbon, which can promote conservation of resources and alternative incomes for inhabitants of forested areas (CONAFOR-FAO 2014). Despite important efforts, such as the recent PES programs, however, the generation of markets and access to international credit funds are still in their initial phases. The area incorporated within the PES programs for carbon, biodiversity, and agroforestry in 2007 was 64,835 ha (160,211 ac). The panel of experts felt that the current PES system does not constitute a true market, and they recommended that Mexico develop the PES programs so that the projects can become eligible for the global carbon credit markets. Regarding hydrologic services, the panel observed that payments are not linked with the quality or quantity of services provided, therefore becoming just a subsidy for not using the forest resources. In response to these suggestions, CONAFOR is in the process of revising its PES programs to facilitate greater contributions by public resources, international donations, and users of ecosystem services to maintain PES programs.

In terms of sustainable management, agroforestry systems are unique. Agroforestry systems can serve as an important source of income to poor rural communities and can provide a host of other important ecosystem services, such as carbon sequestration, habitat and biological corridors for wildlife, and scenic beauty (Beer et al. 2003, Jose 2009, Martinelli 2012, Moguel and Toledo 1999). Despite these many benefits, production via the principal agroforestry systems in Mexico is declining because of a host of problems, including disease, climate change, low profits, and abandonment (Bacon et al. 2008; Diaz-Jose et al. 2013; Gay et al. 2006; Tucker et al. 2009). Such trends make these agroforestry systems vulnerable to conversion to other, more intensified land uses with a concomitant loss of ecosystem services. This trend is particularly apparent in States such as Veracruz, where high population densities and a tradition as a major producer of farm produce and cattle for the country have left only a small remaining fraction of undisturbed natural vegetation (less than10 percent). Some 7,000 ha (17,297 ac) of shade coffee were converted to other land uses in central Veracruz during the past decade alone (2000 to 2010) (Cabrera Garcia 2015). In this context, agroforestry systems such as shade coffee play an even more important role by providing about 35 percent of the tree cover in mountainous regions of the State.

Major agroforestry systems in Mexico (table 8.3) are currently considered as crops and fall under the sole responsibility of the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA), thus facilitating shifts from shade coffee plantations to other crops (e.g., sugar cane) as a simple transition from one crop to another. On the other hand, the classification of cacao and shade coffee farms as crops also limits their inclusion in CONAFOR's forestry programs, which are designed to help promote sustainable forestry or plantations and that provide landowners with financing of up to $8,000 pesos/ha or around 20 times that for which they can currently receive in PES payments if they are within eligible areas. This situation has created a vacuum whereby neither SAGARPA (responsible for agricultural activities) nor CONAFOR (responsible for forestry activities) has a specific mandate within their mission or terms of reference to promote large-scale agroforestry practices.

To counteract these tendencies, a coalition of academics, NGOs, and regional decisionmakers is proposing a modification of national laws that would recognize and conserve the multiple cultural, socioeconomic, and ecosystem service benefits provided by agroforestry systems (Mora 2015). The proposed legal reforms would make land under agroforestry production a hybrid land use eligible to participate in all relevant SAGARPA and CONAFOR programs and thus provide additional financial incentives for this type of production system. Further, classifying agroforestry as a type of forestry system would provide additional legal protections, so that converting cacao or shade coffee into more intensified and simplified production systems as a means of short-term profit would become more difficult. Such changes would make their protection more likely in regional planning exercises. The program recently established under REDD+, called "Forests and Climate Change," proposes to create a common technical agency that would operate across both SAGARPA and CONAFOR, with the goal of facilitating agricultural activities within forested landscapes (including agroforestry practices) with an overall focus on integrated landscape management. If successful, this program has the potential for significantly increasing climate change mitigation and adaptation contributions by agroforestry systems in Mexico.

Key Findings

- Many agroforestry systems practiced in Mexico today are derived from traditional land-use systems developed by indigenous people over long periods of time and thus are well adapted to the local climate and biophysical conditions.
- Agroforestry practices in Mexico provide opportunities for sequestering and storing larger amounts of carbon compared with other agricultural systems, such as pastures and crops.
- Existing policies in Mexico often do not adequately consider agroforestry practices as part of the country's programs that address the challenges of sustainable land-use practices and climate change, largely because these systems are outside the mission of the main Government agencies responsible for either agricultural-related or forestry-related programs.
- In recent years, greater attention has been placed on specifically identifying agroforestry systems as meeting the criteria of Government programs to promote sustainable land use, especially for those programs related to ecosystem services and climate change mitigation.
- Future success in promoting the adoption and maintenance of agroforestry practices will require more focused policy initiatives that link specific agroforestry practices with anticipated benefits and funding opportunities.
- Agroforestry contributes to food security by integrating a diversity of edible species, especially fruit tees cultivated together with perennial food crops, and by providing fuel for cooking.

Key Information Needs

- Quantification and economic valuation of the ecosystem services provided by different agroforestry systems, especially as related to water resources, carbon storage and sequestration, biodiversity, and resilience to climate change and volatile national and global markets.
- Social, economic, and policy drivers that influence land-use change involving the establishment or conversion of agroforestry practices.

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