# 10 Biological Invasions by Plants in Continental Central America

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**Abstract**

Central American biota has been shaped by natural biological exchanges resulting from complex geological and climatic events during its formation. However, it has also been significantly affected by the arrival and spread of humans, which introduced domesticated species as well as others that incidentally came with them. Several non-native plant species have been established as a result of anthropogenic transport and the climatic and geographic properties of the region. Among naturalized species, several plants have become problematic in different ecosystems and are now recognized as invasive species. In this chapter, we present a list of non-native species of plants for each Central American country. The plants were classified as cultivated or naturalized. From these, we have compiled some examples of plants considered invasive species. Our compilation lists 1628 non-native plant taxa (species and varieties) introduced in Central America, of which only 3.9% (64 species) are common to all countries and 50.1% (816 species) are naturalized in at least one country. We present 26 invasive plant species that are problematic in at least one or several countries. We have considered five types of natural ecosystems and two types of managed ecosystems across Central America and examined how non-native species have impacted them. Although there are invasive species in all the ecosystems analyzed, most

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of the consequences remain unknown. We conclude that many invaders have the potential to displace native plant species, significantly impact the functionality of both natural and managed ecosystems, and also have an economic impact. Policies to prevent invasions and management practices of invasive species are required among Central American countries.

**Keywords**

Central America · Belize, Costa Rica · El Salvador · Guatemala · Honduras · Nicaragua · Panama · Invasive plants

## 10.1 Introduction

Biological invasions are not a novel phenomenon in Central America. Charles Elton's seminal book on biological invasions refers broadly to the Great American Biotic Exchange as one of the most important biogeographic events of the last 60 million years. It took place after the emergence of the land bridge and the closure of the Central American canal between Middle and Late Miocene, ~13–3 million years ago (Marshall 1988; Montes et al. 2015). For the first time since the breakup of Pangaea during the Early Cretaceous Period (150–140 Ma), the biota of North and South America met once again after evolving in isolation for millions of years. This event represents one of the best-known examples of biological invasions under natural conditions. Nonetheless, this event had far-reaching consequences on the current composition of terrestrial and marine biotas (Elton 1958), not only in Central America but also in North and South America (Marshall et al. 1982; Bagley and Johnson 2014; Leigh et al. 2014). The natural faunal exchange allowed the movement and range expansion of terrestrial elements between North and South America and the isolation and diversification of marine organisms and caused physical and chemical changes in the properties of the Atlantic and Pacific Oceans (Jackson and D'Croz 1997). As a result, most of the marsupial species of South America were driven to extinction, whereas placental mammals from North America became dominant and now comprise 50% of the present-day South American fauna. At the time of the canal closure and land bridge formation, the cold and dry conditions prevalent at the end of the last Pleistocene glaciation facilitated the interchange of temperate elements from both North and South America across the bridge. With the end of the Pleistocene glaciation ca. 10,000 years ago, strictly neotropical elements invaded the Central American tropics, and the large mammal megafauna went extinct due to increasingly warmer and humid conditions that decreased the area covered by open savannas. The "natural" invaders from both sides dispersed, preyed upon, and competed, leading to the extinction of many species, the diversification of some groups (e.g., cricetid rodents), and the overall change of communities and ecosystems (Simpson 1980; Marshall et al. 1982; Leigh et al. 2014).

The current configuration of the Central American biota is not only the result of biological exchanges, but it has also been significantly affected by the arrival of humans ca.13,500 BP (Braje et al. 2017). Humans functioned as top predators and modified the landscape through the transportation of their associated species, including both animals and plants, in a manner similar to the now extinct megafauna (Levis et al. 2018). After humans arrived and spread throughout the continent, three migration waves brought in more species to the isthmus. The first wave resulted in the establishment of human settlements over the entire continent, including the pre-Columbian trade (Dressler 1953). The second wave comprised the arrival of and conquest by the Europeans. The third wave occurred when African slaves were forcibly resettled by the colonial powers. In all of these cases, humans have introduced domesticated species and others that incidentally came with them as a result of the global commercial trade. The crop interchange has modified the landscape and culture ever since. Nowadays, the main crops in the region are non-native species, including coffee (*Coffea arabica*), sugarcane (*Saccharum officinarum*), bananas (*Musa* spp.), rice (*Oryza sativa*), pineapple (*Ananas comosus*), and African oil palm (*Elaeis guineensis*). These species dominate agricultural lands and thus have significantly influenced the history and culture of Central America. Among these crops, coffee has already become invasive within forest fragments and is hard to eliminate from abandoned agricultural fields. Taken together, the establishment of invasive species is a result of anthropogenic economy due to trade and transport of agricultural goods, as well as climatic, geographic, and socioeconomic characteristics of the recipient region.

Central America is a land of contrasts regarding its climatic and geographic features. The geomorphology between the Pacific and Atlantic coasts mirrors their different geological origins (much of the Pacific rim of Central America corresponds to the subduction zone of the Cocos Plate under the Caribbean Plate) (Coates 1997). The Atlantic coast is sinuous and has an extensive continental shelf of gentle slope towards the Antilles and is separated from them by a few hundred kilometers. In contrast, the continental shelf of the Pacific coast is narrow and rounded by the Middle American Trench, reaching great depths at a short distance from the shore. The trade winds and their interaction with the intertropical convergence zone determine rainfall distribution and the overall climatic seasonality (Coates 1997; Jackson and D'Croz 1997). Temperature differences are not evident with latitude but rather vary with topography due to the interaction between wind masses (mostly Northeasterly Trade Winds) and the presence of mountain ranges in a predominantly Northeast-Southeast direction. These wind and rainfall distribution patterns have influenced the history of human colonization, as well as the location of agricultural fields. The climate of the Pacific slope is strongly seasonal with a 3–6-month-long dry season. In contrast, the Caribbean slope is humid, has a weak seasonality, and is often exposed to hurricanes and tropical storms.

The elevation ranges from 0 m.a.s.l. to the summit of the Tajumulco Volcano in Guatemala at 4220 m.a.s.l. Areas below 1000 m.a.s.l. are hot, typically reaching 30 °C. Between 1000 and 2500 m a.s.l., the average temperature ranges between 15 and 25 °C. Above 2500 m a.s.l., the average temperature rarely reaches 20 °C, and over 3000 m a.s.l. night temperatures may fall below zero (Taylor and Alfaro 2005) (Fig. 10.1). Throughout the isthmus, an intermittent mountain range chain divides the Pacific slope from the Caribbean slope, leaving fertile valleys between the mountains. The average annual rainfall varies widely as a result of changes in topography and elevation. For instance, El Salvador, certain areas in Guatemala, Honduras, and Nicaragua show average rainfall of less than 1000 mm per year. In contrast, some other areas in Guatemala, Panama, and a large portion of Costa Rica receive large amounts of rainfall exceeding 2500 mm per year (Fig. 10.1). These contrasting weather and topographic conditions have determined the patterns of human settlement and, consequently, the use, spread, and establishment of non-native plants.

In this chapter, we have compiled a list of exotic species, which have been reviewed by specialists from Central American countries. We also reviewed the information available in previous publications and in the Global Naturalized Alien Flora database (Pyšek et al. 2017; Van Kleunen et al. 2019). When possible, we have classified the species as cultivated or naturalized. We have considered non-native species as "cultivated" if they remained cultivated in fields, parks, or gardens, whereas the ones that persist and maintain populations over multiple reproductive cycles were considered as "naturalized." We present species as "invasive" if they were indicated as such in the respective reference; however, we only included those species that are exotic following the definition of invasive alien species of the Convention on Biological Diversity. Although the issue of invasive species has so far been neglected in the Central American region, some cases of invasive plant species are examined in the available literature, which we are reporting in this chapter. We furthermore discuss key ecosystems in Central America that have been critically affected by invasive plants and describe the number of non-native species and their current knowledge about invasive species by country. Finally, we examine policies and strategies to control the spread and impacts of invasive species, which have been established by governments of the region.

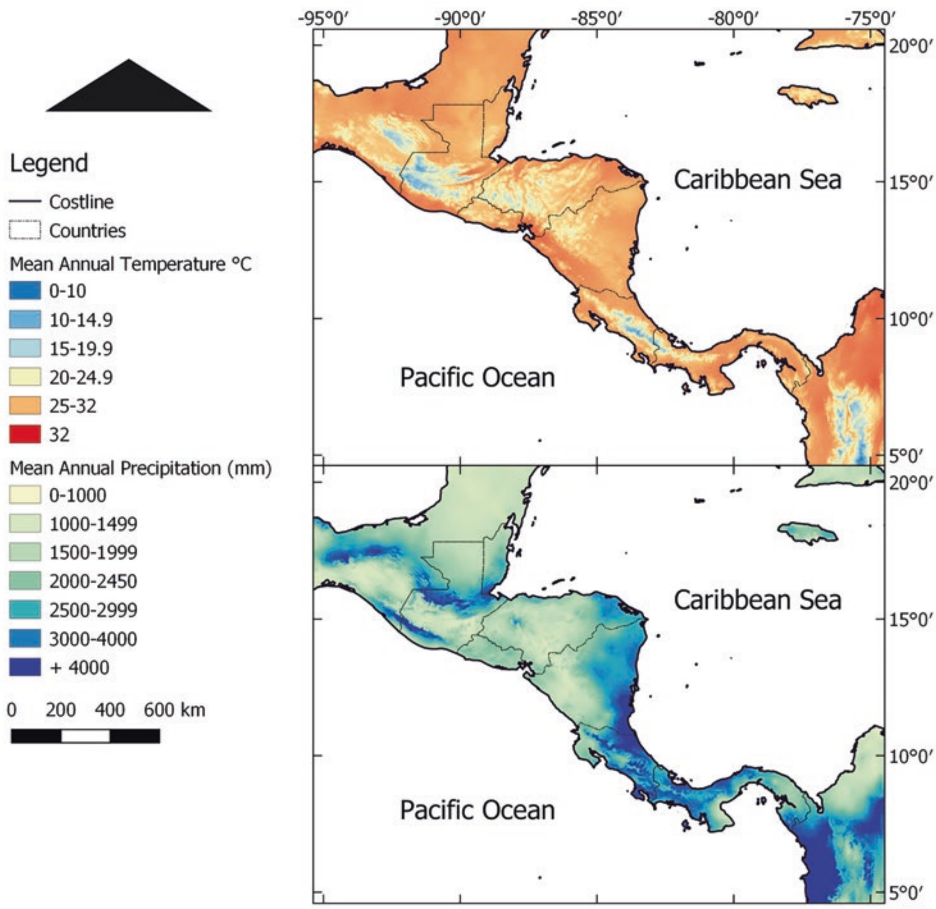


**Fig. 10.1** Map of Central America with mean annual temperature and mean annual precipitation. (Data according to Hijmans et al. 2005)

## 10.2 Diversity by Country

The final list we compiled comprises 1555 non-native plant taxa (species and varieties) introduced in Central America (Table 10.1), classified within 178 families. Only 4.43% (69 species) of the overall list are common to all countries. A total of 678 taxa are naturalized in at least one country. However, there is no detailed information about the invasion stages of non-native species for most countries. Therefore, the previously available information on naturalized species requires a complete revision.

### 10.2.1 Belize

The information about the alien plant species for Belize varies according to the reference. In a specialized website of Belize's biodiversity, we found a list of 258 non-native species (Meerman 2016). The Global Naturalized Alien Flora (GloNAF) database (Van Kleunen et al. 2019) lists 61 species as naturalized (Table 10.1); however, Williams (2010) reported there are 237 alien species, but he only lists 46 species. No other reference about a particular invasive plant species was found for Belize. We considered the Meerman (2016) list with 258 non-native species to be more accurate.

**Table 10.1** Diversity of the total vascular plants and naturalized species for each Central American country

| Country | Continental area ($Km^2$) | Total vascular plant species | Total exotic species | Total naturalized species | Total invasive species | Sources |
|---|---|---|---|---|---|---|
| Belize | 22,966 | 2894 | 258 | 107 | 11 | Van Kleunen et al. (2019), Pyšek et al. (2017) and Meerman (2016) |
| Costa Rica | 51,100 | 10,712 | 1048 | 280 | 47 | Chacón and Saborío-R (2006), Avalos (2019), own data |
| El Salvador | 21,041 | 2911 | 352 | 90 | 4 | Own data |
| Guatemala | 108,889 | 8681 | 536 | 300 | 10 | CONAP (2011), own data |
| Honduras | 112,090 | 5680 | 497 | 79 | 20 | Own data |
| Nicaragua | 130,370 | 7590 | 369 | 95 | 7 | Own data |
| Panama | 75,420 | 9520 | 373 | 263 | 8 | Lopez (2012) |

### 10.2.2 Guatemala

The Consejo Nacional de Áreas Protegidas (National Council of Protected Areas) of Guatemala elaborated a list of exotic species (CONAP 2011). We have reviewed this list and classified the species included there as naturalized or cultivated. In total, we found 536 non-native plant species, from which 300 are naturalized. The CONAP list also classified the species into three categories: species without risk (white list), species with moderate risk or without information (gray list), and species with a high risk (blacklist). In the case of plants, CONAP listed 13 species in the blacklist. Although the information about the diversity of invasive species in Guatemala is better than in other Central American countries, there is little information about specific cases of invasions (Veblen 1975; Monterroso et al. 2011; Rejmánková et al. 2018).

### 10.2.3 Honduras

Honduras has limited information about invasive plant species. We compiled a list of 502 non-native plants, of which we classified 79 species as naturalized and 397 as cultivated, 20 as invasive, while for 6 species, there is no information. The SENASA (Department of Plant Quarantine) proposed a list of 472 plant species commonly imported into Honduras; it includes exotic and native plants used as ornamentals, crops, and forestry, among others (SENASA 2019). Currently, there are no assessments of the impact that alien invasive species are having on biodiversity and human well-being (DiBio 2017). The literature does not report specific invasive species cases; however, according to our perception, the number of non-native species introduced to Honduras has increased during the last three decades. Invasive species such as *Egeria densa*, *Eichhornia crassipes*, *Myriophyllum aquaticum*, and *Ottelia alismoides* are exotic aquatic plants colonizing natural areas, particularly protected areas, and threatening lagoons and lakes across the country. The rose apple (*Syzygium jambos*), the jambolan (*Syzygium cumini*), and the Ceylon blackberry (*Rubus niveus*) have been cultivated and naturalized, invading all types of forest across the country.

### 10.2.4 El Salvador

A preliminary revision of invasive plant species was conducted for El Salvador in 2002 (Ventura-Centeno 2002). That revision presented 50 species, including several natives, corresponding more to a list of weedy species. Our list comprised 352 non-native plant species introduced to El Salvador, of which 244 are cultivated, 90 were classified as naturalized, and 18 do not have sufficient information. More information is required on the invasion status of plant species in El

Salvador. We have detected populations of the terrestrial orchid, *Oeceoclades maculata*, growing aggressively in forest fragments in protected areas, where it has been controlled through manual removal. Another herb, *Sansevieria trifasciata*, is a very common weed within coffee plantations. Morales (2006) reported the introduced African tree *Funtumia elastica*, as naturalized after having escaped areas near La Libertad Botanical Garden. Daniel and Rodríguez (2016) also reported *Hypoestes phyllostachya*, *Thunbergia alata*, and *Thunbergia fragrans* as naturalized in secondary growth and tropical deciduous forest.

### 10.2.5 Nicaragua

The GloNAF database (Van Kleunen et al. 2019) reported 624 taxa as naturalized for Nicaragua. However, we suspect this number probably refers to the most common exotic (cultivated and naturalized) plants in the country. Our list includes 369 non-native species in total, from which 95 were classified as naturalized species and 274 as cultivated species. There are not many references for invasive plants in Nicaragua. There is only one study reporting two species, *Azadirachta indica* and *Spathodea campanulata*, as invasive within forestry plantations in León, Nicaragua (García-Lara 2017).

### 10.2.6 Costa Rica

In Costa Rica, Chacón and Saborío-R (2006) compiled a list of 1048 alien plant species. They found 22% of the species naturalized and 78% cultivated or with unknown status. A high percentage of exotic species (59%) were introduced for ornamental purposes, with continental Asia as the geographic region of origin for most of the introduced species. The plant families Poaceae, Fabaceae, and Asteraceae exhibit most species. New records have been added to the list of non-native species (e.g., Gómez-Laurito and Chacón 2008). The study of Chacón and Saborío-R (2006) was used in an invasive species workshop, which led to the classification of 63 species as invasive (Herrera and Sierra 2005), which were included in an online database of invasive species (Chacón-Madrigal 2009a). This research was linked to the Inter-American Biodiversity Information Network (IABIN), an initiative supported by the Organization of American States (OAS). The network aimed to share information on invasive species across the Americas. Initially, several Central American countries participated in the network, but over time the network lost support, and thus, the websites and their databases are no longer available. Despite ample knowledge of biodiversity, in Costa Rica few studies have focused on invasive species (Chacón-Madrigal 2009b). Some studies have analyzed specific invasion cases (Di Stéfano et al. 1998; Avalos et al. 2006; Castillo-Cruz and Rodríguez-Arrieta 2009; Morera and Granados 2013); however, more research is needed to facilitate their management and control. Many economic activities in the country facilitate the dispersion of exotic species, including the use of alien plants as ornamentals in landscaping and gardening and in agricultural operations as living fences, sources of fuel, timber and firewood.

### 10.2.7 Panama

Lopez (2012) analyzed an annotated plant list from Panama published by Correa et al. (2004). That list included a total of 9520 species of vascular plants for Panama, with 373 considered alien species. According to Lopez (2012), the number of alien species per region (provinces) was correlated with human population size and density. In contrast, the proportion of alien/native species was negatively correlated with forest cover. The study further identified 18 invasive species and listed 13 with the potential of becoming invasive. Other studies from Panama described specific cases of invasions by wild sugarcane and palms (Hammond 1999; Svenning 2002).

## 10.3 Invasive Plants by Ecosystem

We consider five types of major ecosystems (tropical dry forests, tropical rainforests, highland ecosystems, coastal lands, and wetlands) and examine how non-native species have impacted them. We also examine human-maintained ecosystems, specifically agricultural fields and tree plantations, since they have been some of the main foci for introduction of alien species, including species that later became invaders and are now causing economic and ecological problems. We present a list of the species mentioned in the next part in Table 10.2.

### 10.3.1 Agriculture Fields

Although weeds include both native and non-native species, the latter species commonly make up a significant portion of weeds in agricultural fields (Espinosa-García et al. 2004). Among them, grasses (Poaceae and Asteraceae) are common weeds. For instance, itchgrass (*Rottboellia cochinchinensis*) is an aggressive alien weed from Old World, common to most of the crops cultivated in Central America, including bananas, rice, sugarcane, maize, and pineapple (CABI 2019a). Each adult plant can produce up to 16,000 seeds. In the United States, itchgrass is frequently found as a contaminant in crops coming from Central America, such as beans, false coriander, flax seeds, sorghum, and turkey berry fruit (CABI 2019a). This weed causes major economic losses for farmers, who are forced to invest a significant amount of their income controlling this pest (Valverde et al. 1999). In 1992, FAO estimated that itch-grass affected more than 3.5 million ha in Central America and the Caribbean (FAO 1992). In Mexico, it is considered the most harmful weed in the country (Vibrans 1992).

The rose apple or "manzana rosa" (*Syzygium jambos*), native to the Indo-Malaysian Archipelago, was introduced to Jamaica in 1762, and from there, it got dispersed to the rest of the Neotropics as a fruiting and ornamental tree (CABI 2019b). Despite its ornamental use, the rose apple is commonly used as a shade tree and living fence in coffee plantations. In Costa Rica, it has become an invasive species in forest fragments and secondary forests (Di Stéfano et al. 1998; Avalos et al. 2006) where it interferes with natural regeneration by creating monospecific stands. Often, it is the most frequent seedling (up to 50%) found within small secondary-forest fragments in Costa Rica; it also negatively affects the abundance of native tree species in regeneration (Avalos et al. 2006). Unfortunately, many farmers continue dispersing this species and, in some instances, use it to reforest disturbed lands.

A tall grass (3–4 height) from Asia, the wild sugarcane ("Paja Blanca" or "Paja Canalera") (*Saccharum spontaneum*), apparently arrived by accident in the Panama Canal region before 1960 (Hammond 1999). However, a more feasible hypothesis indicates that it was deliberately introduced for the genetic improvement of sugarcane in the experimental Canal garden before 1940 (Cerezo 2010). This wild sugarcane has spread aggressively throughout agricultural fields using roads and river edges, reaching northern Costa Rica in 1992 (Palencia-Pineda 2000). About 3% of the Panama Canal Watershed is now occupied by this species (ACP and ANAM 2006). Wild sugarcane rapidly colonizes deforested lands and agricultural fields. It inhibits succession forming monospecific stands making the lands without value for agriculture or native wildlife (Hammond 1999). Different control methods, such as mowing, burning, pesticides, shading, and intensive reforestation, have been applied (Palencia-Pineda 2000). Controlled fires have been the most common method, being applied by approximately 50% of the farmers (Palencia-Pineda 2000); however, it has been demonstrated that fire facilitates its spread. Fire promotes shoot growth, which increases flowering shoot density favoring seed production. By removing leaf litter, fire gives way to newly available habitat for seedling recruitment (Saltonstall and Bonnett 2012).

Wild sugarcane crossed into Costa Rica from the Pacific Slope, and can be now found in the Caribbean region. Experimentally, it has been shown that *S. spontaneum* stems have a high sprouting capacity after drying out for up to 6 weeks (Bonnett et al. 2014). Wild sugarcane

**Table 10.2** Invasive plant species mentioned in the text as problematic in Central American countries

| Family | Species | Growth form | Ecosystems | Countries |
|---|---|---|---|---|
| Arecaceae | | | | |
| | *Aiphanes aculeata* | Palm | Tropical wet forest, secondary growth | H, P |
| | *Caryota mitis* | Palm | Tropical wet forest, secondary growth | CR, ES, G, H |
| | *Cocos nucifera* | Palm | Coastlines | All CA |
| Bignoniaceae | | | | |
| | *Spathodea campanulata* | Tree | Tropical wet forest, secondary growth, forest plantations, pastures, agriculture fields | All CA |
| Combretaceae | | | | |
| | *Terminalia catappa* | Tree | Coastlines | All CA |
| Fabaceae | | | | |
| | *Pueraria phaseoloides* | Vine | Tropical wet forest, secondary growth, forest plantations, pastures, agriculture fields | B,CR, H, N, P |
| | *Ulex europaeus* | Shrub | Pastures, disturbed areas, agriculture fields, and forest edge in highlands | CR, P |
| Hydrocharitaceae | | | | |
| | *Egeria densa* | Herb | Wetlands | CR, ES, G, H, N |
| | *Hydrilla verticillata* | Herb | Wetlands | All CA |
| Marattiaceae | | | | |
| | *Angiopteris evecta* | Fern | Tropical wet forest, secondary growth | CR |
| Meliaceae | | | | |
| | *Azadirachta indica* | Tree | Forest plantations, secondary growth, pastures | CR, ES, G, H, N |
| Moraceae | | | | |
| | *Artocarpus altilis* | Tree | Tropical wet forest, secondary growth | CR, ES, G, H, N, P |
| Musaceae | | | | |
| | *Musa velutina* | Herb | Tropical wet forest, secondary growth, forest plantations, pastures, agriculture fields | CR, ES |
| Myrtaceae | | | | |
| | *Syzygium jambos* | Tree | Agriculture fields, secondary growth | All CA |
| Orchidaceae | | | | |
| | *Oeceoclades maculata* | Herb | Tropical dry and wet forest, secondary growth | All CA |
| Poaceae | | | | |
| | *Hyparrhenia rufa* | Herb | Agriculture fields, pastures, savannas, tropical dry forest | All CA |
| | *Melinis minutiflora* | Herb | Secondary growth, forest plantations, pastures, agriculture fields in lowlands | All CA |
| | *Panicum maximum* | Herb | Secondary growth, forest plantations, pastures, agriculture fields in lowlands | All CA |
| | *Pennisetum clandestinum* | Herb | Agriculture fields and pastures in highlands | CR, G, H, N, P |
| | *Rottboellia cochinchinensis* | Herb | Agriculture fields, pastures, savannas | All CA |
| | *Saccharum spontaneum* | Herb | Pastures, disturbed areas, agriculture fields, and forest plantations | CR, P |
| Pontederiaceae | | | | |
| | *Eichhornia crassipes* | Herb | Wetlands | All CA |
| Rubiaceae | | | | |
| | *Morinda citrifolia* | Tree | Coastlines | All CA |
| Zingiberaceae | | | | |

(continued)

**Table 10.2** (continued)

| Family | Species | Growth form | Ecosystems | Countries |
|---|---|---|---|---|
| | *Etlingera elatior* | Herb | Tropical wet forest, secondary growth | CR, H, P |
| | *Hedychium coronarium* | Herb | Secondary growth, forest plantations, pastures, agriculture fields, and wetlands | All CA |
| | *Zingiber spectabile* | Herb | Tropical wet forest, secondary growth | CR, ES, H |

Abbreviations: *B* Belize, *CR* Costa Rica, *ES* El Salvador, *G* Guatemala, *H* Honduras, *N* Nicaragua, *P* Panama, *CA* Central America

poses a serious economic problem to agricultural fields because of the cost and difficulties in controlling it. Some primary exportation products from Costa Rica, like pineapple, have been rejected after finding seeds of *S. spontaneum* in container trailers (Palencia-Pineda 2000). Shading out young grasses in open fields by reforesting with fast-growing trees could effectively control this very aggressive invasive species (Jones et al. 2004; Joo-Kim et al. 2008).

### 10.3.2 Forestry Plantations

Like many tropical countries, a substantial area in Central America is suitable and dedicated to forestry plantations. Across Central America, plantations have been established mainly in the lowlands, using native species and exotic species, such as beechwood (*Gmelina arborea*), teak (*Tectona grandis*), neem (*Azadirachta indica*), river red gum (*Eucalyptus camaldulensis*), and mangium (*Acacia mangium*), among others. Among non-native forestry plantation species, beechwood and teak occupy the highest proportion of land dedicated to forestry plantations in Central America. Teak is commonly used as living fences in silvopastoral systems. Several of these species used in forestry have become invasive and are difficult to eliminate from fields. Tree stumps of beechwood re-sprout quickly after harvest, and sometimes the seeds germinate outside plantations, persisting for a long time in abandoned plantations and their edges. The species *A. indica* has been reported as invasive in León, Nicaragua, where neem has been extensively used to reforest highly degraded lands. It grows fast and is intensively used as a source of firewood. However, it colonizes the understory of forestry plantations of native species (García-Lara 2017), decreasing timber yield, and is particularly difficult to control. Within forestry plantations, some herbs are also common non-native weeds, such as the hairy banana (*Musa velutina*) and white garland lily (*Hedychium coronarium*); they also are invasive in forests, pastures, and wetlands (Morera and Granados 2013; Morera-Chacón 2015).

The African tulip tree (*Spathodea campanulata*) is a species with multiple uses, including ornamental, timber, living fence, and shade tree in coffee plantations. Currently, it is reported as invasive in El Salvador, Honduras, and Nicaragua (García-Lara 2017). Although the ecological impact of this species has not been adequately measured, there is evidence showing that it could significantly impact populations of native bees in Costa Rica. The nectar of *S. campanulata* contains toxic alkaloids capable of killing native bees and birds (Trigo and dos Santos 2005). Jiménez (2008) explored 692 flowers of *S. campanulata* in Costa Rica and found more than 200 dead stingless bees belonging to 14 different species. The spread of this species in coffee plantations could significantly impact coffee productivity by decreasing bee populations and related coffee pollinators.

### 10.3.3 Tropical Dry Forests

In Central America, tropical dry forests are found along the Pacific slope, which also has the highest concentration of human settlement. They once covered 20% of Central America, but today most of the original area has been converted into agriculture fields, grasslands, savanna, or cities (Portillo-Quintero and Sánchez-Azofeifa 2010). It is estimated that only 2% of the original tropical dry forest remains in small isolated patches. Although it was initially harvested for timber, most of the transformation in the last century (1930–1970) occurred when the dry forest was converted to human-maintained pastures (Griscom and Ashton 2011). The grasses used for livestock were mainly exotic species introduced from Africa. At least three species have been intensively used as pastures: guinea grass (*Panicum maximum*), molasses grass (*Melinis minutiflora*), and jaragua (*Hyparrhenia rufa*). Guinea grass was first reported in the Lesser Antilles in the seventeenth century and reached Central America in the mid-nineteenth century. The introduction of molasses grass is less documented; however, it probably arrived in America early in the nineteenth century and was first reported in Central America (Costa Rica) in 1908. The jaragua arrived late to Central America compared to other African grasses, and it was first reported in Costa Rica in 1920 (Parsons 1972).

The cattle-ranching industry based on the use of extensive areas cultivated with African grasses reached its maximum development in Guanacaste (Costa Rica) and Nicaragua in the late 1960s and 1970s. In these countries, jaragua is the most common pasture grass, and it has invaded savannas and forests and has created a barrier for forest restoration when pastures were abandoned after meat prices fell in the 1980s. Jaragua grass has demonstrated a high capacity to outcompete native grasses, preventing germination and establishment of native seedlings while increasing the frequency and intensity of fires and halting succession (Janzen and Hallwachs 2016). It forms tall and dense stands (1–2 m), decreasing the light reaching the soil in the wet season and crushing natural regeneration when it dries in the dry season (Griscom et al. 2009). At the ecosystem level, grasses can also alter the productivity or trophic structure, the microclimate conditions, sunlight interception, water and nutrients availability, and competitive interactions, all of which compromise ecosystem stability (Williams and Baruch 2000).

Furthermore, the African orchid (*Oeceoclades maculata*) represents a particular case among invasive plants in Central America. Firstly, orchids rarely are considered as invasive species at the global scale (Pyšek et al. 2017). Secondly, it is invasive both in tropical dry forests and in tropical wet forest across the neotropics (Kolanowska 2014). Thirdly, only few herb species are invasive in the understory of tropical forests.

### 10.3.4 Tropical Wet Forests

Tropical forests with high diversity, like tropical rainforests, have high biotic resistance and are rarely invaded by plants (Martin et al. 2009). However, it is not always what we observe in the field. For instance, in Gamboa, Panama, eight palm species (*Aiphanes aculeata*, *Areca triandra*, *Bentinckia nicobarica*, *Dypsis madagascariensis*, *Livistona saribus*, *Ptychosperma macarthurii*, *Roystonea oleracea*, *Roystonea regia*) have been reported as naturalized (Svenning 2002). Other four palm species (*Caryota mitis*, *Palandra aequatorialis*, *Pigafetta filaria*, and *Pinanga kuhlii*) (OET 2012) have been reported as problematic in Las Cruces, Costa Rica. In both places, the invasive plants escaped from botanical gardens introducing species as ornamentals. Indeed, ornamental plants are frequently naturalized in the tropical rainforest. For instance, several exotic species of gingers, such as the ginger wort (*Zingiber spectabile*) or the torch ginger (*Etlingera elatior*), are abundant within the forest or along the forest edge at sites near botanical gardens or experimental agricultural stations in Costa Rica (Fernández 2008; OET 2012). In the Wilson Botanical Garden in Costa Rica, a giant fern from Australasia (*Angiopteris evecta*) with fronds measuring up to 9 m has naturalized in the forest fragments close to the garden. Although the invasion of this fern is incipient, it has the potential to colonize more sites in Central America, as it has been predicted by models (Christenhusz and Toivonen 2008).

The introduction of fodder plants also might facilitate invasive species to colonize tropical rainforest. For example, the tropical kudzu (*Pueraria phaseoloides*) is a vine widely introduced as fodder in almost all Central American countries. It has propagated quickly, and it is common in forests along rivers, forest edges, pastures, and secondary growth. The effect of kudzu on the ecosystems is still unknown; however, in Mexico, it has been considered as a species with the potential to have a high impact in agricultural fields according to an assessment of introduced legumes (Sánchez Blanco et al. 2012).

Within tropical wet forests, trees naturalize less frequently than palms, herbs, or vines. However, increasing populations of breadfruit (*Artocarpus altilis*) have been observed in the wet forest in the southern Pacific region of Costa Rica. In secondary regrowth sites along riparian habitats, densities of 1053 trees/ha have been registered (ECM, unpublished data). The effect of breadfruit tree on forest ecosystems is still unknown and thus merits further investigation.

### 10.3.5 Highlands

In one of the oldest references of alien species for Central America, Veblen (1975) compared the invasive species between the Guatemala highlands and California. He reported 68 alien species in the highlands of Guatemala. Among the species reported, he mentioned kikuyu grass (*Pennisetum clandestinum*), which commonly occurs along roadsides (Veblen 1975). In Costa Rica, the kikuyu grass was introduced about 1928 on the slopes of Irazú Volcano; it outcompetes other native grasses and is considered as a pest. After the eruptions of Irazú Volcano (1964–1965), kikuyu grass was favored by ash and the absence of the other grasses, which were removed by volcanic eruptions (Parsons 1972). Nowadays, it still is very common in the mountains in Costa Rica.

Many species reported by Veblen (1975) in the highlands of Guatemala are native to Europe. Similarly, Bernhardt and Koch (1994) found many European weeds in the highlands of Costa Rica. This is not a mere coincidence but seems to result from the fact that the climate of the Central American highlands was more familiar to European settlers than the hot and humid climate in lowland regions. The Europeans introduced crops and plants to support livestock, which was also introduced very early after arriving to America. Many weeds also came with the "new" crops and established in the middle elevations and highlands. For instance, gorse (*Ulex europaeus*), an invasive species elsewhere, grows in the forest edge and pastures in the highlands of the Poás and Barva volcanoes in Costa Rica (Standley 1937). Intriguingly, unlike in many other regions of the world, gorse did not become as invasive in Central America, where it has been reported for more than 85 years and populations seem to be stable in recent years (CABI 2019c).

### 10.3.6 Coastal Ecosystems

Two exotic species have dramatically changed the landscape of the coastlines along Central America in such a way that they became intertwined with the culture. Nowadays, it is difficult to imagine Central American beaches without them: the coconut tree (*Cocos nucifera*) and the Indian almond tree (*Terminalia catappa*) (Harries 1978). The two species were introduced very soon after contact with Europeans. We will never know the impacts of these two species in coastal ecosystems because they are found everywhere, although the effect of coconuts on communities and ecosystems has been long established (Young et al. 2017). More recently, the great morinda (*Morinda citrifolia*) has also become very frequent in the Caribbean, probably introduced due to the use of seeds in traditional medicine.

### 10.3.7 Wetlands

Ellison (2004) estimated that wetlands in Central America cover ca. 40,000 $km^2$ (~8%) of the land area. Wetlands include several aquatic ecosystems such as lakes, rivers, estuaries, and artificial reservoirs. Although Ellison (2004) made a complete revision of environmental issues of wetlands, invasive species were only briefly described. Aquatic plants tend to have widespread distributions and long-distance dispersal mechanisms, and sometimes they are difficult to classify as exotic due to their natural range extensions. Several native species have been classified as "invasive" because their populations have increased dramatically after disturbances. For instance, in Costa Rica, southern cattail (*Typha domingensis*) increased in coverage from below 5% to over 95% in the Palo Verde marsh after cattle removal (McCoy and Rodríguez 1994). Moreover, the pantropical golden leather fern (*Acrostichum aureum*) has been considered an invasive species because it thrives after the mangrove is disturbed. In both cases, the two native species were favored by alterations in the ecosystems. Other exotic species have invaded wetlands in several Central American countries, and they have become problematic. Water thyme (*Hydrilla verticillata*) is an aquatic plant from the Old World, which is naturalized in all Central American countries. The invasion of this plant has been studied in the Lake Izabal and Lake Atitlán in Guatemala (Binimelis et al. 2007; Barrientos and Allen 2008; Monterroso et al. 2011; Rejmánková et al. 2018) and in ponds on pastures in Costa Rica (Haider et al. 2016). In Guatemala, the presence of water thyme has been suggested to impact fisheries, recreation, and tourism by hindering the movement of boats and reducing the aesthetic value of the lake. Several studies have focused on the impact of water thyme on fish communities, although the results have been equivocal (Arrivillaga 2003; Barrientos and Allen 2008). Other species, such as large-flowered waterweed (*Egeria densa*) and common water hyacinth (*Eichhornia crassipes*) are abundant in lakes, reservoirs, rivers, estuaries, and other wetlands. Water hyacinth causes physical interference with navigation and fishing and reduces water volume of reservoirs during the dry season (CABI 2019d).

## 10.4 Policies and Management

In general, the issue of invasive species has been neglected by governmental offices in Central America, although some initiatives have been launched to prevent the uncontrolled spread of invasive species (e.g., CONAP 2011). Such efforts are promoted to enforce the goals of the Convention on Biological Diversity or by monitoring very problematic invasive species (e.g., *Saccharum spontaneum* in Panama or *Hydrilla verticillata* in Guatemala) in Central American countries. However, this is mainly since some invasive species are weeds in agricultural fields, but management practices are rarely implemented in natural areas. Although specific biosecurity policies to prevent the arrival of invasive species do exist, the implementation of those regulations is weak (Allen et al. 2017). Universities and NGOs should give more support to initiatives focused on preventing and controlling invasive species and educating people about the issue. For instance, botanical gardens are fundamental for the conservation of biodiversity, management strategies and the education of the general public; however, they have also become focal points for the dispersal of exotic species (e.g., Svenning 2002; OET 2012). If not managed well, plant collections can favor the dispersal of introduced species with the potential to become invasive. Some entities keeping live plant collections include botanical gardens, urban planning companies keeping nurseries to establish gardens, hotels maintaining arboretums, and universities and educational institutions maintaining plant collections. More recently, the commercialization of genetic material also takes place over the Internet, through the sale of seeds and other propagules (Chacón-Madrigal 2009b). So far, quarantines, customs control and internal regulations for the management of diversity are weak or nonexistent. Even when control policies do exist, they are difficult to enforce. Given this scenario, the most practical solution should be to educate the general public about the risks of spreading non-native species. It might be illusory to expect that there will be greater control of the dispersion of alien species through implementation of laws or regulations in the short term. However, in order to obtain the attention of governmental agencies, it will be necessary to quantify the economic costs of plant invasions for local economies. Therefore, it is crucial to generate research aiming to understand the impact of exotic plants on natural and managed ecosystems.

## 10.5 Conclusions

The last report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Díaz et al. 2019) lists invasive species as one of the five most important drivers of biodiversity loss and associated loss of ecosystem function. The report also alerts about the destruction of the ecosystem functionality by climate change and asks for immediate and significant action from all governments to slow down its catastrophic consequences. Therefore, an important recommendation from that report is the request to identify and prioritize invasive alien species within all signatory countries. However, as the general tendency is a continuous increase of naturalized plants (Van Kleunen et al. 2015), stronger and firm actions need to be taken to monitor this trend. Despite preliminary efforts to elaborate lists of exotic plants in Central American countries, there has been no consistent report.

Central America is one of the world regions most seriously impacted by climate change, so that a baseline must be generated to measure the negative aspects of invasive plant species. Although most of the consequences remain unknown, many invasive plants could replace native plant species, which have been displaced by climate change but have been carrying out crucial ecosystem functions. Universities and NGOs should be involved in invasive plant research, to gather the crucial knowledge that could be used to derive conservation and management policies in compliance with governmental offices. Considering the significant effects of invading organisms on biodiversity, the functionality of the natural and managed ecosystems, and the economic impact that they generate, their registration is not only of scientific importance but also of economic relevance. The data presented in this chapter should serve as a starting point for analysis, aiming to explore these aspects and fill some of the information gaps that currently exist regarding the impacts of invasive plants on Central American ecosystems.

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