

Full Length Research Paper

Forest invasion by alien plant species: The case of neem tree (*Azadirachta indica* A. Juss.) in Southern Togo

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Several forms of degradation reduce the size and the ecological value of forest ecosystems such as the introduction of alien species. In order to study the level of the exotic plant species *Azadirachta indica* invasion in forest fragments of Southern Togo, data collection was carried out in thirteen forests where 65 rectangular plots of 500 m² were set up to record the plant species diversity and other 52 plots of 625 m² to count the tree and to measure their height and diameter. The data analysis was carried out by determining the relative density, the relative dominance and the relative frequency of the plants species. The results show that 414 plant species including 19 identified as alien have been identified in the forest fragments. They are divided into 15 families with an invasion rate of 4.58% and a frequency of 53.85% for *A. indica*. These data reveal the importance of the invasion phenomenon of the local forest flora, especially inside the juvenile population.

Key words: Forest fragments, Southern Togo, alien species, invasion, *Azadirachta indica*.

INTRODUCTION

Forest ecosystems are currently facing various forms of degradation leading to the reduction of their size and even their total destruction. Between 1980 and 1990, tropical forests have been destroyed at a rate of 15.4 million hectares per year and out of 1.7 million known and listed species on the planet, more than 130 are destroyed each day (FAO, 2001). A form of degradation that is less known is the invasion of forests by alien species. An alien species is a plant that originates from another continent or a remote biogeographical region. (Pysek et al., 2004). Introduced purposely or accidentally (Stein and Flack, 1996), it manages to grow up in new environments and develops rapidly, often at the expense of native species (Baridon, 2007). The invasion of indigenous plants by alien species has become one of the most serious threats to the biodiversity and the functioning of ecosystems worldwide (Vitousek et al., 1996; Williamson, 1999). According to Simberloff (2003), alien species invasion represent the second cause of biodiversity disappearance

in addition to the destruction of natural habitat.

The current estimates of the flora of Togo give a figure of 3451 species (Brunel, 1984; Akpagana et al., 1994, Kokou et al., 1999). Radji et al. (2010) state that this flora of Togo contains 612 introduced species from all the five continents. The American continent alone accounts for over half or 52% of the total, Asia (19%), Europe (6%), Oceania (5%) and Africa (18%). Among the species from Asia, the neem tree (*Azadirachta indica*) is a fast growing species spreading easily and dominating large areas to become invasive (Richardson et al., 1990; Richardson, 1998; Wittenberg and Cock, 2001). This study conducted in the forest fragments in the Southern Togo (Kokou and Sokpon, 2006; Kokou and Kokutse, 2007) made it possible to show how the neem tree threatens these forest areas that are the only forest remnants in this part of Togo, fully open and dominated by crops, fallow lands and savannas (White, 1986). The overall objective of the study is to show the invasion of the forest flora of Southern Togo by alien species. It is specifically a matter to:

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(i) Set up the floristic and the life forms of the forest flora in Southern Togo,

(ii) Show the invasion of the forest flora by alien species, especially the neem tree.

MATERIALS AND METHODS

Study zone

Togo (56600 km²) is situated between 0° and 1° of east longitude and between 6° and 11° of north latitude. Subdivided into five ecological zones (Ern, 1979), the coastal plain (zone V; 6500 km²) is the study zone (Figure 1). This plain is dominated by the sedimentary coastal basin situated at the southern territory (Seddoh, 1981) and has a sub-equatorial climate with two rainy seasons (April to July, September-October) and two dry seasons (November to March; August).

The average temperature during this period is 27°C and the average relative humidity is constantly high, varying between 80 and 90%. The annual average temperature range is flattened (3 to 4°C) and kept within 25 to 29°C. The potential evapotranspiration (ETP Penman) is from 1610 mm per year. The vegetation of the coastal plain is a mosaic landscape (Batawila, 1997). Crops and fallow lands, thickets, shrubs, derived savannah (Ern, 1979; Brunel et al., 1984), coastal grassland, savanna with bushy termite mounds coexisting with forest fragments are encountered (Kokou, 1998).

Data collection

Thirteen randomized forest fragments were surveyed and their geographic coordinates recorded by means of a GPS. The choice of these forests is based on the ease of access because most of them are sacred and strictly out of bound. In each forest, floristic surveys have been carried out on 65 rectangular plots of 500 m² (50 m × 10 m). The number of plots in each forest is proportional to the size of the forest. The average area of the forest fragment is 17,88 ha. In each plot, all flowering plant species have been recorded. The species not identified on the field were harvested for a determination at the Herbarium of the University of Lomé. The nomenclature used is that of Brunel et al. (1984), Hutchinson and Dalziel (1972) for the scientific name of the species and the Angiosperm Phylogeny Group III (APGIII) classification (2009) for botanic family. In addition, forest inventories have been performed in the same forests in 52 plots of 625 m² (25 m × 25 m) each. All trees with a circumference greater than or equal to 10 cm were measured with a tape and their height estimated. The regeneration was evaluated on a plot of 25 m² (5 m × 5 m) on each of the 52 plots. In each plot, all the stems whose circumference is less than 10 cm are routinely counted.

Data processing

The geographic coordinates/data are used to map the forest fragments surveyed with a Geographic Information System (GIS) MapInfo 7.0. The floristic richness (S) expressed by the total number of species observed (in absolute value or per unit area) is determined. The family, the biological type (Raunkiaer, 1934) and the phytogeographical affinity (White, 1986; Aké, 1984) of each species are associated with the floristic list established for the construction of different spectra. The average diameters and heights of the trees as well as their density were calculated and histograms were drawn to express the distribution of the species by classes. In the juvenile population, the density of each group of species has been determined. The groups of species considered

are:

(i) Native species: These are species that grow naturally in a given area of the overall allocation of the species and whose genetic material has been adapted to this particular location. It is a species that is present in its natural area and grows up there. It is currently still present, destroyed or perhaps regenerated after a momentary disappearance (Pellote et al., 2009). According to the Invasive Species Specialist Group (ISSG) of the International Union for Conservation of Nature (IUCN), the species that increase their natural allocation area without the human intervention are indigenous even if this increase is generally induced by a change of environment by human activities,

(ii) Alien species: These are species introduced into new areas outside their original allocation area. These introductions can be intentional or accidental (Stein and Flack, 1996);

(iii) Species with contrasting ecology: Which are native species that are found in an ecosystem where they are not native; e.g. forest species in savanna area and vice versa (Kokou, University of Lomé, personal communication).

The structure of the forest flora was determined by calculating the relative density, relative dominance, relative frequency and Importance Value Index (IVI) of the species:

(i) Relative density (De): $De = n_i / N_i \times 100$ [Equation 1]

n_i = number of species individuals i ; N_i = total number of individuals of all species,

(ii) Relative dominance (Di): $Di = G_i / G_j \times 100$ [Equation 2]

G_i : total basal area of a species; G_j : total basal area of all species,

(iii) Frequency of the species i (Fi): $Fi = r_i / R \times 100$ [Equation 3]

r_i = number of surveys with the species i ; R = total number of surveys,

(iv) $IVI = Di + De + Fi$ [Equation 4] (Curtis and McIntosh, 1950).

RESULTS

Floristic diversity of forest fragments and importance of *Azadirachta indica*

Floristic surveys conducted within the 13 forest fragments of study made it possible to enumerate 414 species belonging to 76 families and 289 genera. The nine families (Figure 2) that are the best represented are Fabaceae (10%), Rubiaceae (8%), Apocynaceae (7%), Euphorbiaceae (5%), Asteraceae (5%), Poaceae (4%), Malvaceae (3%), Moraceae (3%) and Sapindaceae (3%). The study made it possible to set up the general floristic affluence of each surveyed forest fragment (Table 1). The forest flora of the ecological zone V is dominated by the afro tropical species (38.12%) followed by the Guinean-Congolese species (26%). The Sudano-Guinean species represent 19.67%; the pantropical plants, that is, common to the old tropical world are represented by 3.66% and the paleotropical species by 2.88%. The Sudano-Zambezian species representing 3.52% are classified as contrasting ecology species and the alien species represent 4.59% (Figure 3). In the forest flora of Southern Togo, 19 (4.59%) classified into 15 families were identified as alien species. The most frequent (53.85%) is *A. indica* (Photo 1). This species also has the largest Importance Value Index (IVI) 99.84% (Table 2).

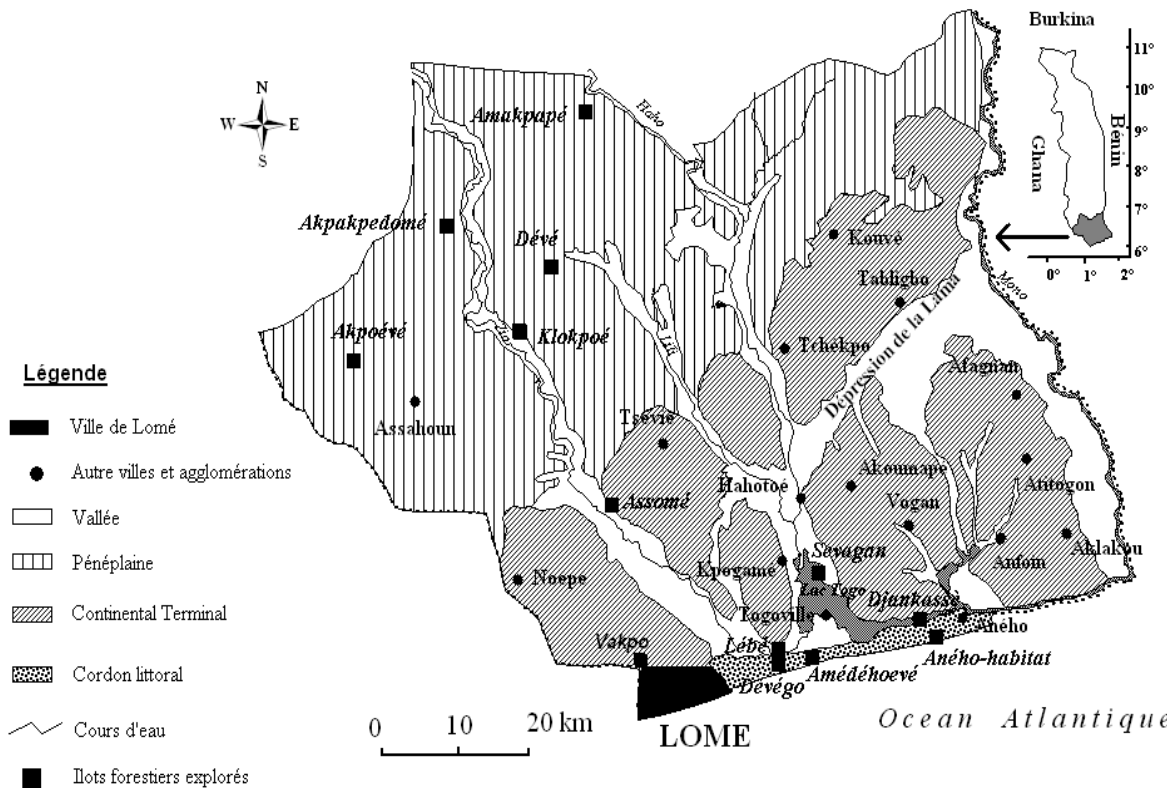


Figure1. Location of study zone.

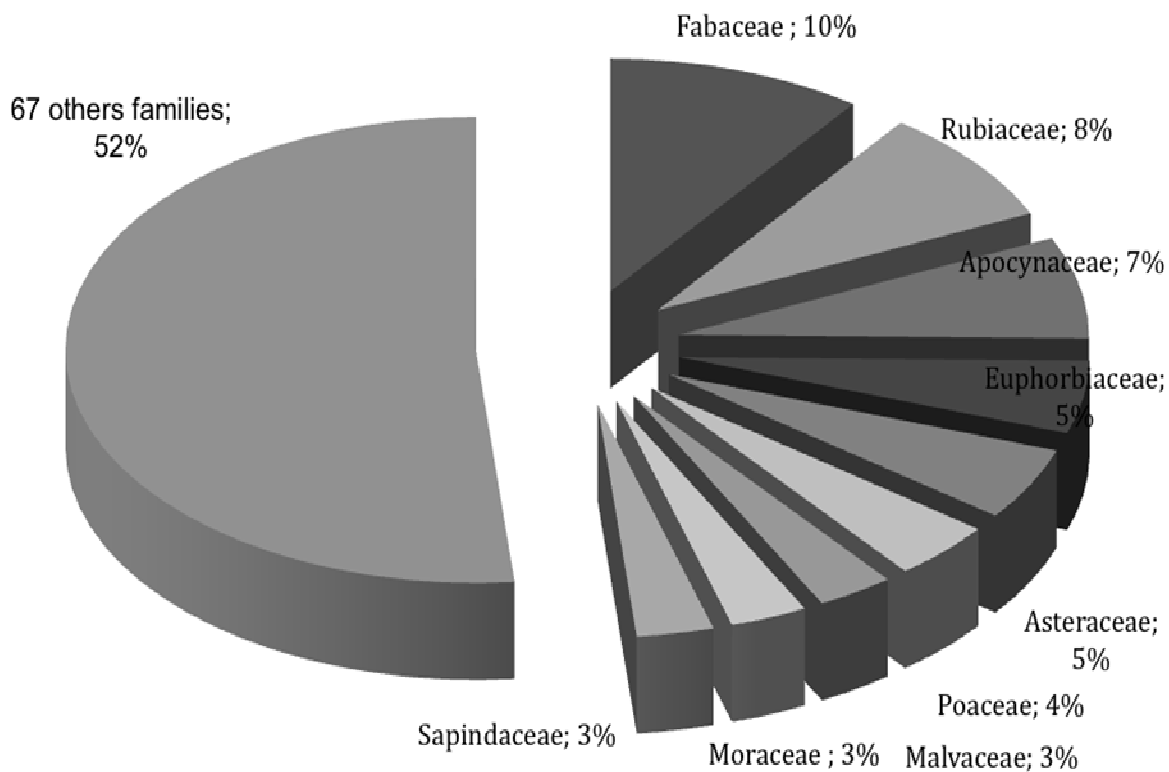


Figure 2. Specific spectrum of families.

Table 1. Specific affluence by forest Island.

Forest island	Total number of species	Number of alien species
Akpakpedome	100	8
Akpoeve	90	5
Amakpape	141	6
Amedehoeve	161	9
Aného-Habitat	33	2
Assome	98	3
Deve	69	2
Devego	32	2
Djankasse	41	4
Klokpoe	152	7
Lebe	59	6
Sevagan	84	3
Vakpo	124	8

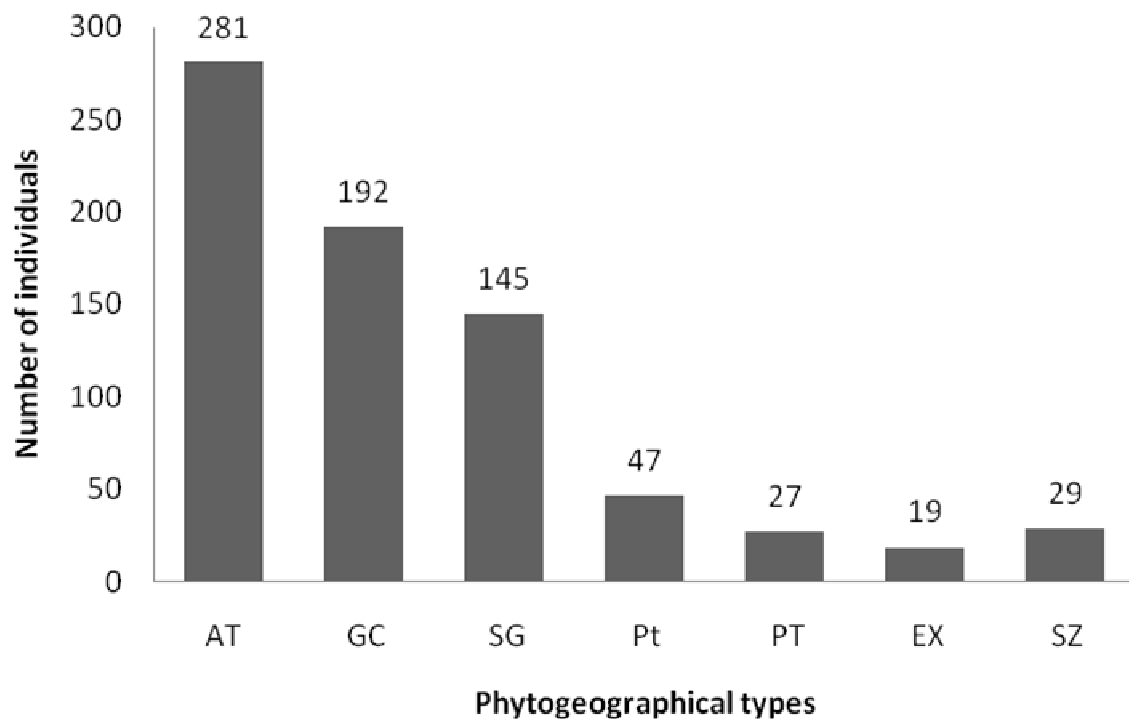


Figure 3. Phytogeographical spectrum of all identified species. AT: Afrotropical species, GC: Guinean-Congolese species, SG: Sudano-Guinean species, Pt: pantropical species, PT: paleotropical species, EX: Alien species, SZ: Sudano-Zambian species.

Structural features, juvenile population and regeneration

The calculation of densities shows that in 54% of surveyed forests, the native species are larger than the alien species. In 31% of forests, the densities of both native and alien species are similar. Out of 15% of the forests, alien species have densities higher than those of

native species. Among trees of larger diameter (>15 cm), the density of alien species is lower than that of native species. But among the low diameter classes (3 to 15 cm), alien species dominate native species and contrasted species (Figure 4). This class made of young population shows that alien species are in an invasion dynamics. Therefore, with an average density of the total juvenile population of 4815.30 ± 3153.60 plants/ha, alien



Photo 1. Structural features, juvenile population and regeneration.

Table 2. Alien species and their characteristics.

Name of taxa introduced	Botanical family	Fi (%)	De	Di	IVI	TB	TP
<i>Ananas comosus</i>	Bromeliaceae	15.39	10.62	-	-	H	N
<i>Azadirachta indica</i>	Meliaceae	53.85	29.46	16.53	99.84	Mp	I
<i>Bambusa vulgaris</i>	Poaceae	15.39	10.86	9.24	35.49	H	Jav
<i>Blumea aurita</i>	Asteraceae	7.70	6.76	-	-	Th	Pal
<i>Caesalpinia pulcherima</i>	Fabaceae	7.70	6.03	5.25	18.98	Mp	Pt
<i>Canavalia ensiformis</i>	Fabaceae	23.08	9.42	-	-	LmP	Wi
<i>Carica papaya</i>	Caricaceae	38.47	32.36	13.19	84.02	Np	N
<i>Centrosoma pubescens</i>	Fabaceae	7.70	7.24	-	-	LmP	N
<i>Cocos nucifera</i>	Arecaceae	15.39	12.56	10.67	38.62	mP	Pol
<i>Delonix regia</i>	Fabaceae	7.70	9.66	6.27	23.63	Mp	M
<i>Hibiscus lunarifolius</i>	Malvaceae	38.47	26.81	-	-	LmP	GC-SZ
<i>Jatropha gossypifolia</i>	Euphorbiaceae	7.70	8.45	6.82	22.97	Np	N
<i>Luffa cylindrica</i>	Cucurbitaceae	7.70	9.90	-	-	Np	Pt
<i>Manihot glaziovii</i>	Euphorbiaceae	7.70	10.14	7.14	24.98	Mp	N
<i>Psidium guajava</i>	Myrtaceae	7.70	5.79	7.51	21	Mp	N
<i>Senna siamea</i>	Fabaceae	15.39	12.80	9.34	37.52	Np	Pt SZ
<i>Spathodea campanulata</i>	Bignoniaceae	23.08	11.83	8.83	43.74	Mp	A GC
<i>Spondias monbin</i>	Anacardiaceae	23.08	12.31	12.82	48.21	Np	Pt
<i>Thevetia neriifolia</i>	Apocynaceae	15.39	7.72	7.69	30.8	LmP	N

-: Herb with basal area not calculated; TB: Biological type; TP: Phytogeographical type; A: African taxum; Np: Nanophanerophyte; mp: Microphanerophyte; L: Creeper; Th: Therophytes; mP: Mesophanerophyte H: Hemicryptophyte; MP: Megaphanerophyte; I: Indian Taxum; Pt: Pantropical taxum; N: Taxum of Nicaragua; GC: Guinean-Congo Taxum SZ: Sudano-Zambian region taxum; M: Malagasy Taxum; Pol: Polynesia taxum; Wi: Taxum from the West Indies; Jav: Java native Taxum.

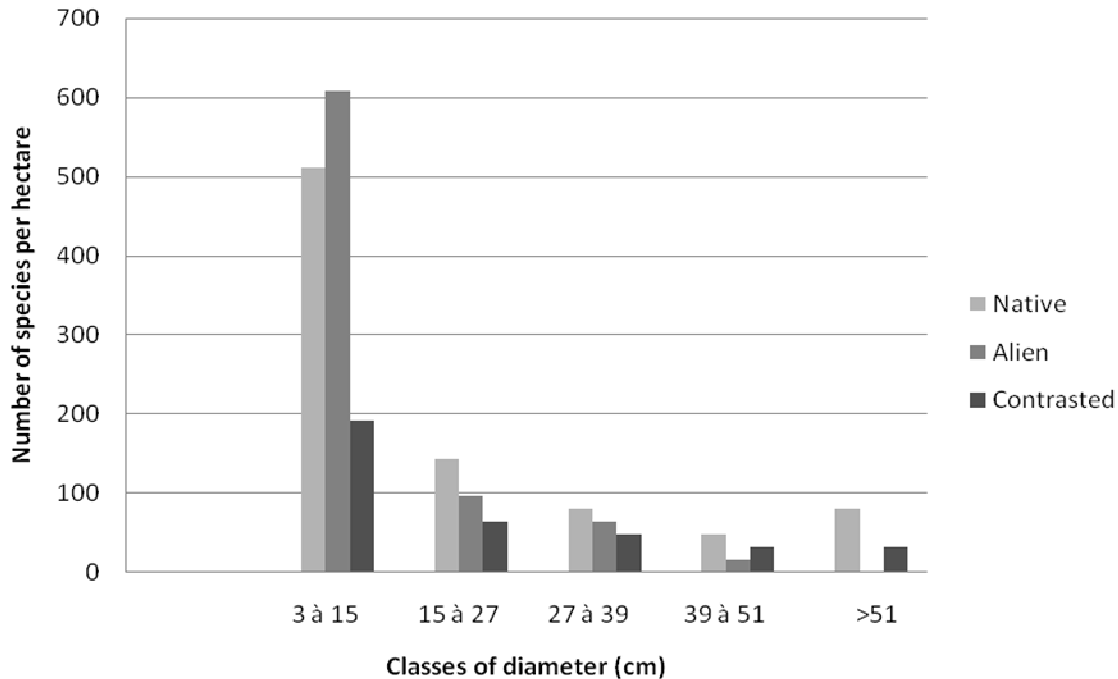


Figure 4. Distribution of species types based on diameter classes.

species (8114.39 plants/ha) exceeds twice the density of native species (4500.76 plants/ha) and 4 times that of contrasting ecology species (1830.76/ha). That of neem is 5597.4 plants/ha more than half the density of alien species.

DISCUSSION

This study shows that out of 414 species recorded in the forest relics in the coastal plain in the southern part of Togo or ecological zone V (Ern, 1979), 4.59% are alien species including *A. indica* potentially very invasive. Adjossou (2009) reveals similar results in the ecological zone IV where out of 928 species recorded, 43 or 4.6% are alien. According to estimates, the flora of Togo records about 3451 species (Brunel et al., 1984; Akpagana et al., 1994; Kokou et al., 1999) with 612 alien species or 17.7% (Radji et al., 2010). The presence of alien species in the local flora is not peculiar to Togo; the estimates were set to 480.000 alien species introduced into the ecosystems throughout the world (Pimentel et al., 2000). In the United States, alien species account only for 6% of the local flora, 3% in Australia and 7% in South Africa (Stein and Flack, 1996). These relatively low values in those countries can be explained by the control and analysis measures taken for the species to be introduced. In Togo, different situations such as forest management and reforestation as well as the Green Revolution policy (since 1975, each Togolese plants a

tree on the 1st June), contributed to the expansion of alien species across the country. In fact, on the 1st June, the species made available to the people are mostly alien plants. The colonial plantations and those of the Forest Service from 1908 to 1970 are mainly formed of Teak (*Tectona grandis*). The large management and reforestation projects of FAO / UNDP in Togo since the 1970s have also resorted to alien species such as *Eucalyptus* spp., *Cassia* spp. *Acacia* spp. and *T. grandis*. These reforestation efforts have fostered and accentuated the phenomenon of invasion of the local flora.

According to the invasion level, three types of forest are identified in the study area. This is about very highly invaded forests (15%), slightly invaded forests (31%) and the non invaded forests (54%). According to Dunbar and Facelli (1999), forests whose alien species density reach 50% compared to the density of native species are classified as highly invaded forests. Many authors showed that the propagation capacity of an alien species depends on the reproduction mode (lighter seeds) and an early reproduction age (Rejmanek and Richardson, 1996; Baruch and Goldstein, 1999; Grottkopp et al., 2002). Hamilton et al. (2005) also found a correlation between the mass of seeds and the invasiveness of alien species. Field observations have shown that the fruits of *A. indica* are eaten by birds and the seeds are disseminated in the ecosystems. This ease of dissemination accounts for the high frequency observed for this species, especially in the juvenile population. In tropical Africa, *Chromolaena*

odorata is a perfect indication of this phenomenon and its propagation is getting proportions that are worrisome (Akpagana et al., 1993). Likewise, *Lythrum salicaria* is reported as a threat to the natural ecosystems of eastern areas of North American continent (FAO, 2001) with an economic burden estimated at 45 million dollars annually (Pimentel et al., 2000). In New Zealand, the destruction of the habitat by alien plants has reduced forest cover from 68 to 14% over a period of 200 years (Kuschel, 1975). In Togo, several species introduced for horticultural or reforestation purposes (*T. grandis*, *Senna siamea*, *Gmelina arborea*, *Clerodendrum inerme*, *Ligustrum ovalifolium*) are fast growing plants and are potentially invasive to the native flora (Radji, 1998). This phenomenon is reported by several authors (Akpagana et al., 1993; Kokou and Caballé, 2000; Kokou et al., 2005).

Conclusion

This study carried out on the impact of alien plants on the forest flora in the coastal plain of the southern part of Togo (ecological zone V), has identified 414 species belonging to 76 families and 289 genera. Among these species, 19 are alien and 29 are of contrasting ecology. The most common of these alien species is *A. indica*. The calculation of the density of alien species in the surveyed forests made it possible to classify the forests studied in three groups: highly invaded forests with a density of alien species reaching 50%, less invaded forests with the density of alien species between 50 and 5% and the non invaded forests with a density of alien species less than 5%. In juvenile population, the invasion of alien species is very obvious with a density reaching twice the density of native species.

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