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Forest Health & Biosecurity Working Papers

Case Studies
on the Status of Invasive Woody Plant Species
in the Western Indian Ocean

2. The Comoros Archipelago
(Union of the Comoros and Mayotte)

By

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Kueffer, C., Vos, P., Lavergne, C. and Mauremootoo, J. 2004. *Case Studies on the Status of Invasive Woody Plant Species in the Western Indian Ocean. 1. Synthesis*. Forest Health and Biosecurity Working Papers FBS/4-1E. Forestry Department, Food and Agriculture Organization of the United Nations, Rome, Italy.

For detailed studies on individual countries and territories, please refer to:

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TABLE OF CONTENTS

List of figures, tables and boxes

Tables

Boxes

DATA COLLECTION AND REVIEW

Reliable data are limited in the Comoros archipelago. Most information comes from unpublished reports or from common knowledge and observations of local environmentalists. The only published data are found in Mayotte. To our knowledge, there is still no official list of invasive woody plant species and the concept of 'invasiveness' is only used by environmental protection specialists. Elsewhere in the Comoros archipelago, awareness of the potential danger of invasive plant species to biodiversity and agriculture is low, especially in comparison with the other small islands of the Western Indian Ocean.

The methodology applied to Seychelles was adapted for the Comoros archipelago. Based on existing literature, the questionnaire devised for Seychelles was modified to take into account the specific habitats and ecological conditions of the Comoros. Interviews conducted in the Comoros with officials (from NGOs, public institutions, research centres) who had filled in the questionnaire allowed further detail to be added to answers already given. A 15-day site visit helped to confirm or reject some information collected through the questionnaire.

Given the limited time spent on each island, this report does not aim to provide a comprehensive list of invasive woody plant species in the Comoros. Rather, it aims to give a general overview of the problems arising from invasive species on each of the islands and to inform stakeholders about potential activities that could be developed and adapted to local conditions to help the islands tackle invasive species.

1. GENERAL BACKGROUND

The Comoros archipelago is located in the northern region of the Mozambique Channel, between latitudes 11°20' and 13° South and between longitudes 43°10' and 45°0' East. There are four main islands: Grande Comore (1 024 km²), Anjouan (424 km²), Mayotte (374 km²) and Mohéli (211 km²).

The archipelago has been permanently inhabited since the ninth century (Moulaert 1998) and may have been known by navigators since the time of the ancient Egyptians (Gevrey 1870).

The population of the archipelago was estimated at 615 000 inhabitants in 2000 (UNDP/GEF/IOC 2000). The soaring growth rate of 2.7 percent per year from 1981 to 1991 means that the population is doubling every 20 years. With a density of 598 inhabitants per square kilometre, Anjouan has one of the greatest densities of population in the world.

In 1975, Grande Comore, Anjouan and Mohéli were united into the Independent Islamic Republic of Comoros and later the Union of the Comoros. Mayotte is a French Territorial Collectivity. This political discrepancy has great impact on the management of natural resources as Mayotte benefits from high subsidies from mainland France.

At a distance of 280 km from Mozambique, Grande Comore is the westernmost island and hosts the last active volcano (Karthala) of the archipelago which reaches 2 361 m asl (above sea level), the highest point of all the islands. Mayotte, the easternmost island of the archipelago, is located 320 km from Madagascar. Between these two islands are Anjouan, with a hilly landscape (up to 1 561 m asl), and Mohéli (up to 790 m asl). The islands are the result of the separation of the Malagasy and African plates and originate from sublithospheric magma (Nougier *et al*. 1976). They lie on an oceanic and basaltic platform and are the emerged slopes of volcanoes. Mayotte is the most ancient island at 5.4 million years old whereas Mohéli is 2.8 million years old, Anjouan 1.5 million years old and Grande Comore 130 000 years old (Emerick and Duncan 1982). The older the islands are, the more they have been eroded (morphogenesis). Harsh climate, low soil permeability, high soil runoff, heavy deforestation and lack of agricultural technology all lead to erosion. Erosion results in the degradation of the topsoil layer, ravines, masses of fallen rock and landslides and leads to the formation of 'padzas' (badlands).

The climate is tropical and humid. The annual average temperature is 26°C at sea level and there are two seasons: a wet and hot season with a northwest wind from November to April and a dry cooler season with a southeast wind from May to October. However, temperature and rainfall can vary dramatically according to altitude, topography and exposure to the sun. The annual rainfall varies locally from 1 000 to 6 000 mm and the minimum temperature can go down to 0°C on the summit of Karthala.

The Comoros flora has not been studied in detail and literature on the subject is scarce. The only botanical list for the Comoros was published at the beginning of the twentieth century (Voeltskow 1917): 935 vascular plant species were listed including 416 considered as indigenous and 136 (i.e. 14.5 percent) as endemic to the archipelago. According to this list, exotic plants (383 species) therefore represent one-third of vascular plant species. More recent publications cite those figures (Lebrun 1976; White 1986; Morat and Lowry 1997). However, the on-going survey of the flora in Mayotte has already recorded 404 indigenous vascular plant species. A study of the existing literature as well as previous plant collections shows that 225 additional species have not yet been collected during the current survey. This brings the total indigenous vascular plant species for Mayotte alone to 629, which is far higher than the previous estimate for the entire archipelago. There is also a non-exhaustive list of 350 plant species (cultivated and spontaneous) introduced to Mayotte (Pascal 2002). Given the size of Grande Comore and the fact that some ecosystems on Grande Comore are different from those of Mayotte, the number of vascular plant species (indigenous and introduced) there could reach 1 500 (Pascal 2002).

As a result of the diverse topography, the archipelago exhibits a great variety of habitats. Four main zones of vegetation can be distinguished based on altitude: semi-dry vegetation at low/intermediate altitude and along the coast (grass meadow, grass savanna on plateaux and shrub savanna in patches within forests from intermediate altitude down to sea level), intermediate-altitude humid forest, high-altitude cloud forest, and ericaceous vegetation at more than 1 800 m asl. Where factors such as soil, sun exposure or human activities make it appropriate, this report also considers mangroves and other coastal vegetation of humid zones, secondary forests and cultivated zones as well as successive pioneer vegetation on recent volcanic lava flows.

The coastal and low-altitude vegetation has been almost totally destroyed by human activities. The high-altitude forest is the best preserved although there are few reliable estimates of its actual area on each island. By studying aerial pictures, Moulaert (1998) estimated that the area of remaining high-altitude forest area on Mohéli fell 26 percent in the 13 years between 1983 and 1996 because of plots being cleared for cultivation. On Anjouan, only slopes too steep for cultivation remain more or less unspoilt.

Knowledge of the forest fauna is incomplete. Mammal fauna is scarce: there are two species of lemurs (*Eulemur* spp.) and one species of bat (*Pteropus livingstonii*) which is endangered (the world's remaining 400 individuals are all on Anjouan and Mohéli). The bird fauna comprises 101 species, the insect fauna totals 1 106 species and the reptile and amphibian fauna amounts to 21 species of which ten are endemic (Moulaert 1998). According to IUCN (World Conservation Union), 15 species found in the Comoros archipelago, including representatives of all groups, are considered as vulnerable or even highly endangered (*Eretmochelys imbricata, Pteropus livingstonii, Otus capnodes, Otus moheliensis, Otus pauliani, Zosterops mouroniensis, Dicrurus fuscipennis*) (Moulaert 1998).

Because of the population boom on the limited land area, the main threat to the fauna and flora of the Union of the Comoros is the progressive loss of natural habitat to human settlement. Various studies (including IUCN 1990) have forecast that primary forests will disappear in the Union of the Comoros within the next 15 years if the deforestation rate stays as it is now. The second threat is the invasion by exotic species. In Mayotte, although the economic situation differs from that of the Union of the Comoros, the uncontrolled migration of people from neighbouring islands might pose a similar risk.

2. INVASIVENESS AND DEGREE OF INVASION

This section gives a brief history of invasions by the main exotic woody plant species in the Comoros archipelago, notes the main invasive non-woody plant species, and examines the rates of invasiveness in some habitats.

2.1. A brief history of invasions

Data on exotic plant introductions in the archipelago are of varying reliability. All the introductions were of course entirely linked to the presence of humans.

- Permanent human settlement preceded that of the other small islands of the Western Indian Ocean as the archipelago is close to the African continent. The first people to settle were Bantu people who came from the eastern coast of Africa between the seventh and tenth centuries. Rival sultanates also settled the islands but the populations remained small because of numerous conflicts and wars, such as the frequent Malagasy incursions.

- The impact of human settlement can be measured only from when the French started to manage the land in the nineteenth century. Between 1846 and 1886, planters coming mainly from Réunion introduced sugar cane (*Saccharum officinarum*) monocultivation and, to a lesser extent, coffee (*Coffea* spp.) and cocoa (*Theobroma cacao*) cultivation. At the peak of the sugar cane era in 1869, the island of Mayotte was producing 3 000 tonnes of sugar annually. In order to cultivate the cane, they had to deforest almost all low-lying land. Villages, together with plots for growing food crops, had to be established on steep slopes. Since they used a steam-based sugar extraction technique, the sugar cane factories were consuming large quantities of fuelwood obtained from the forests nearby (Pascal 2002).

- In 1870, Gevrey estimated that forests covered just one-sixth of the area of the islands (Gevrey 1870). He listed 60 species of introduced and cultivated ornamental plants, of which *Agave sisalana* (sisal), *Albizia lebbeck*, *Casuarina equisetifolia*, *Syzygium aromaticum* (cloves), *Syzygium jambos*, *Acacia* sp., *Psidium* sp. and *Cinnamomum verum* (cinnamon) are all invasive today.

- Around 1910, the fall in the price of sugar in addition to other factors (full prohibition of the slave trade, uncontrolled multiplication of destructive insects) led to the decline of the sugar cane industry.

- Colonial agroindustrial companies took over the land and diversified production. Cultivation of *Vanilla planifolia* (vanilla), *Syzygium aromaticum*, *Agave sisalana* and especially plants used in perfume production such as *Cananga odorata* (ylang ylang) expanded greatly.

- Following decolonization and under strong pressure for land linked to the soaring population, the large companies sold their land little by little to small farmers. Today, about 70–80 percent of the Comorian population work in agriculture (UNDP/GEF/IOC 2000). The rate of deforestation is high and the surviving forests are located in inaccessible areas at high altitude. The forests of Karthala and La Grille on Grande Comore as well as the Mzé Koukoulé forest on Mohéli are becoming increasingly damaged. On Anjouan, there are no forests left on slopes with gradients of less than 110 percent.

- In Mayotte, 70 percent of the households work in agriculture but most of them have an additional occupation. Indeed, households working only in agriculture represent only 19 percent of the active population. However, there are estimated to be 20 000 illegal immigrants, mainly farmers, in Mayotte.

- In Mayotte, only the forests on the hilltops remain, having survived the long period of agricultural and forest exploitation. These surviving forests concentrate the majority of the archipelago's floral richness on a very small proportion of the whole land area (15 km^2 out of 374 km^2). The 294 species of woody plant species native to Mayotte are found on only five percent of the territory (Pascal 2002).

2.2. Status of invasiveness

No official list of invasive plant species has ever been produced for Mayotte or the Union of the Comoros. This section has been prepared from the existing literature, from interviews with local experts and from the author's personal observations made during a field visit to the archipelago.

Field observations were made mainly in the following areas: in the forests on La Grille and Karthala on Grande Comore (humid forest above 1 000 m asl); on the coast between Fomboni and Nioumachoua and in the mountainous area (following a North–South transect ending at Nioumachoua) on Mohéli; on the coast around Sima/Bimbini, in the humid Moya Forest (between 1 000 and 1 100 m asl) and between Mutsamoudou and Lake Dzialandzé including the summit of T'zsingi (1 596 m asl) on Anjouan; at Pointe Saziley, at Bénara between the two peaks (humid forest, 600 m asl), at Sohoa (low-altitude forest), Combani and Convalescence in Mayotte (humid forest, 500 m asl).

The following lists do not pretend to be exhaustive. They were prepared following a single week spent in the field and on the basis of some interviews with local stakeholders.

The best information on invasive plants was found in Mayotte where the Forest Service (Service des eaux et forêts, SEF) functions well. However this information cannot be compared in quality and quantity to that from Réunion or Mauritius, which is cited in other Parts of this publication. Experts in the Union of the Comoros do have a wide knowledge of invasive plants but this knowledge remains untapped.

2.2.1. Main invasive woody plant species

If we consider as 'invasive' the plant species mentioned by at least 50 percent of the people interviewed, the total for the Comoros archipelago is 16 species. All of these species were considered by Binggeli *et al*. (1998) as moderately to highly invasive in the tropics. They have been introduced in the Comoros archipelago as timber trees (one species), fruit trees (three) and spice crops (two), for erosion control (two), as ornamentals (one), for multiple purposes such as fuelwood, forage and/or stakes for *Vanilla planifolia* (three) or for unknown reasons (four). Some of the species were introduced during the nineteenth century, in particular the fruit tree species, the spice crops and some of the multipurpose, high-growth-rate species such as *Litsea glutinosa*. The other species (for reforestation, erosion control ...) were introduced later, during the twentieth century.

About two-thirds of these species are trees, the remainder being shrubs (*Litsea glutinosa, Leucaena leucocephala, Jatropha curcas, Gliricidia sepium, Lantana camara, Clidemia hirta, Senna* sp.).

It is interesting to note that the *Acacia* species introduced massively since the 1970s in the Comoros archipelago in order to reforest the padzas and control erosion, in particular in Mayotte, are naturalized and are now regenerating. SEF in Mayotte very recently discovered this phenomenon, which could become catastrophic as these species have very low ecological requirements and their regeneration rates are high.

Albizia lebbeck is widespread in dry areas where, particularly in Mayotte, it becomes dominant in the landscape. *Cinnamomum verum* causes some serious problems in disturbed cool and humid areas such as Combani in Mayotte and on Mohéli mountain tops. However, this plant has cultural value and is used widely as a herbal tea or spice.

Clidemia hirta is considered as a main invasive plant although it is still not well known on all the islands visited. Pascal (1997) did not mention it in his list of introduced plant species in Mayotte although it is now widespread in the Convalescence forest around the Governor's house. On Grande Comore, *C. hirta* is dominant in the foothills of Karthala but has not been found in the forest on La Grille. It is widespread throughout Mohéli, from the humid coastal areas, along roads, to the mountain summits. On Anjouan, this species has been noted along the Moya road in the coastal area as well as above Lake Dzialandzé where the humid habitat suits it very well.

TABLE 1: MAIN INVASIVE WOODY PLANT SPECIES IN THE COMOROS ARCHIPELAGO

Species	Refs.[a]	Invaded islands[b]	Invaded habitats[c]	Introduction[d]
Acacia auriculiformis	1, 3, 4, 6	Ma, Mo, A	IH, plasticity	1980s (reforestation)
Acacia mangium	1, 3, 4, 6	Ma, Mo, A	P, C, ID, plasticity	1870 or before? 1980s (reforestation)
Albizia lebbeck	1, 5, 6	Ma, Mo	C, ID, plasticity	1841 or before (1767 in Mauritius)
Cinnamomum verum	1, 3, 5, 6	Ma, Mo	IH	1870 or before
Clidemia hirta	2, 3, 4, 6	All	IH, HA	Not in Mayotte until 1997?
Gliricidia sepium	2, 3, 4, 6	Mo, A, GC	ID	Mentioned in 1962 (stake for *Vanilla planifolia*)
Jatropha curcas	4, 5, 6	All	C, ID	
Lantana camara	1, 2, 3, 4, 5, 6	All	C, ID	
Leucaena leucocephala	1, 3, 6	All	C, ID	Mentioned in 1962
Litsea glutinosa	1, 2, 3, 4, 5, 6	All	IH	After 1841
Psidium cattleianum	1, 2, 3, 4, 6	A, GC	IH, M, HA	
Psidium guajava	1, 3, 6	All	C, ID	1870 or before
Senna sp.	1, 3, 4, 5, 6	All	ID, plasticity	
Spathodea campanulata	1, 5, 6	All	IH, plasticity	
Syzygium aromaticum	3, 4, 6	A, Mo	IH	19th century
Syzygium jambos	1, 2, 3, 5, 6	All	IH, HA, mainly valleys	1870 or before

[a] 1: F. Barthelat, personal communication; 2: I. Yahaya, personal communication; 3: Experts on Mohéli, personal communications; 4: Experts on Anjouan, personal communications; 5: Pascal (1997); 6: Author's observations.
[b] All: all islands; A: Anjouan; GC: Grande Comore; Ma: Mayotte; Mo: Mohéli.
[c] C: Coastal forest; HA: High-altitude forest; ID: Intermediate-altitude dry forest; IH: Intermediate-altitude humid forest; M: Mountain cloud forest; P: Padzas (badlands).
[d] 1870 or before: Gevrey (1870); 1841 or before: Gachet (1969); After 1841: Jacq (2001); Mentioned in 1962: IRAT (1968); Other dates from personal communications. *Clidemia hirta* is not mentioned in the list of introduced plants by Pascal.

The multipurpose woody plant species considered as invasive show extreme vigour. Although they are used intensively for their fruits, or as forage or wood for fuel and other purposes, the species continue to proliferate. This is especially the case for *Litsea glutinosa* in Mayotte and *Gliricidia sepium*, *Jatropha curcas* and *Psidium cattleianum* in the Union of the Comoros. In Mayotte, agricultural activities are likely to decrease and these species could become dramatically more profuse if their use were to be reduced or cease altogether.

Lantana camara spreads easily wherever there is an open area; it is even more prominent in dry areas where it seems impossible to stop its proliferation. *Psidium cattleianum* and *Syzygium jambos* are a clear threat to the remnants of the humid forest. A dense monospecific stand of *P. cattleianum* has been developing on the western slope of Karthala (Grande Comore), between the cultivated areas and the natural forest. It represents a potential source of seed for further invasion of the natural forest each time an open area is created for cultivating a new plot of land. *Spathodea campanulata* has naturalized in humid forests where it is sometimes the main species in secondary forest. It is an equal threat to natural humid forests.

Among the 16 main invasive woody plant species, there are eight considered to be highly problematic which should be managed first: *Acacia auriculiformis, Acacia mangium, Clidemia hirta, Lantana camara, Litsea glutinosa, Psidium cattleianum, Spathodea campanulata* and *Syzygium jambos*. All these species are found at high densities in disturbed areas and in secondary forests, but they have also been found in undisturbed habitats indicating that they seem to be able to invade these too.

2.2.2. Potentially invasive woody plant species

Fourteen species were singled out by some of the experts interviewed as potentially invasive (Table 2). However, we cannot assess the expansion of these species because of the lack of historical data or past reliable observations. Nonetheless, the high number of these species found during the field visit combined with their recognized invasive status in other parts of the world lead us to believe that they are also probably invasive in the Comoros archipelago.

Adenanthera pavonina is frequently seen in secondary humid forests where it represents a potential invasive threat. *Rubus alceifolius* has only been found in high numbers at Coconi in Mayotte, where it has started to spread in monospecific carpets in various places. In accordance with its highly invasive status in neighbouring Western Indian Ocean small islands, such as Réunion, it should be monitored carefully. SEF in Mayotte is concerned by the expansion in the past few years of *Albizia chinensis* which produces many young trees along the roads. *Tectona grandis* develops in patches in dry areas, especially on Mohéli. *Terminalia catappa* grows everywhere in coastal areas.

TABLE 2: POTENTIALLY INVASIVE WOODY PLANT SPECIES KNOWN IN THE COMOROS ARCHIPELAGO

Species	Reference[a]	Invaded habitats[b]	Introduction
Adenanthera pavonina	1, 3	IH	20th century (reforestation)
Albizia chinensis	1	IH	
Aleurites moluccana	1	IH	
Anacardium occidentale	2, 4	C, ID	
Annona squamosa	1	ID	
Casuarina equisetifolia	1	C	
Citrus reticulata	3	IH	
Duranta erecta	1	Along roads	
Kleinhovia hospita	1	?	
Rubus alceifolius	1, 4	IH	
Sapindus saponaria	1	?	
Solanum sp.	1, 4	ID, IH	
Tectona grandis	1, 2	C, ID	Before 1965
Terminalia catappa	1, 4	C	

[a] 1: F. Barthelat, personal communication; 2: Experts on Mohéli, personal communications; 3: Pascal (1997); 4: Author's observations.
[b] C: Coastal forest; ID: Intermediate-altitude dry forest; IH: Intermediate-altitude humid forest.

2.2.3. Non-consensus woody plant species

These are species whose dates of introduction are unknown but which seem to have naturalized. They fall into two categories:

- Species that have not so far been cited as invasive in the Comoros archipelago, but are invasive in other parts of the tropics; for example: *Artocarpus altilis*, *Artocarpus heterophyllus*, *Cananga odorata*, *Eugenia dombeyi* [syn. *E. brasiliensis*], *Eugenia uniflora*, *Eucalyptus* sp., *Ricinus communis*, *Rubus* sp., *Samanea saman*, *Swietenia* sp., *Syzygium cumini* and *Tribulus cistoides*.

- Species whose invasiveness worldwide needs to be confirmed and the data from the Comoros archipelago are insufficient to accord them invasive status at the present time: *Barleria* cf *flavia*, *Litsea tersa*, *Lantana montevidensis* and *Tecoma stans*.

These lists are not exhaustive and need to be completed.

2.2.4. Main invasive non-woody plant species

Although non-woody species are not considered in this survey, it is important to highlight the threat they present to the biodiversity of the Comoros archipelago.

The main species cited by the experts interviewed or in the existing literature were:

- Creepers: the only study available (Caballé 1996) lists 50 species of creepers in Mayotte. This diversity was considered by the author to be high for an island of its size (37 500 ha). The 50 species belong to more than 20 families. Creepers are found all over the Comoros archipelago, from the hilltops to the coasts, and in various habitats (dry and humid, in Mayotte and on Mohéli especially). However, they tend to invade mostly disturbed or open areas where they can form monospecific carpets (at Sohoa, Dapani, the Andilabé Pass, Convalescence and Bénara, for instance, in Mayotte). The main invasive species are: *Ancylobothrys petersiana, Antigonon leptopus, Cissus quadrangularis, Entada gigas, Entada rheedii, Ipomoea quamoclit, Ipomoea pes-caprae, Merremia peltata, Piper betle, Pueraria lobata, Quisqualis indica, Saba comorensis* (indigenous), *Solanum mauritianum* [syn. *S. auriculatum*] and *Solanum torvum*. Creepers are one of the main threats to the biodiversity of the Comoros archipelago (also see Section 3.2.2. Impacts on ecosystem function and biodiversity).

- Ferns: *Dicranopteris linearis* and *Nephrolepis* sp.

- Grasses: *Bambusa glaucescens, Imperata cylindrica* and *Pennisetum* sp.

- Aquatic plants: *Eichhornia crassipes* and *Pistia stratiotes*.

- Other herbaceous plants: *Achyranthes aspera, Agave sisalana, Ananas comosus, , Bidens* sp., *Desmodium incanum, Elephantopus scaber, Furcraea foetida, Hedychium gardnerianum, Hedychium flavescens, Hibiscus surattensis, Mimosa pudica, Ocimum* spp., *Pentas lanceolata, Plectranthus* spp., *Sida* spp., *Solanum macranthum, Stachytarpheta* sp., *Teramnus labialis, Turnera angustifolia* and *Urena lobata;* this list is not exhaustive.

2.3. Invasion of habitats

There are very few quantitative data on the degree of invasion of habitats except for the very interesting report by Pascal (1997) for Mayotte which covers, unfortunately, only the humid forests. There are some qualitative studies or studies on the ecology of a specific invasive species such as *Lantana camara* (Mas 1999) and *Litsea glutinosa* (Jacq 2001), and on the ecology of weed species (often exotic) in agricultural areas (Vandamme 2001). However, these studies deal only with Mayotte.

2.3.1. Coastal vegetation

The main invasive woody plant species found in coastal areas are the shrubs *Leucaena leucocephala, Lantana camara, Psidium guajava* and *Jatropha curcas* and the tree *Terminalia catappa*. *Casuarina equisetifolia* is also found in some areas. In accordance with its invasive status in other Western Indian Ocean small islands, it should be carefully monitored.

The non-woody invasive species are particularly numerous, such as the creepers *Ipomoea pes-caprae* and *Cissus quadrangularis*, the succulents *Agave sisalana* and *Furcraea foetida*, the fern *Dicranopteris linearis* and numerous grass species.

2.3.2. Dry vegetation

Dry vegetation starts at sea level and can be found up to 700 m asl, depending on the exposure of the area (e.g. on the eastern side of Karthala on Grande Comore). This habitat is characterized by grass or shrub savanna, which is interspersed with dense forests at higher altitudes. It is shaped by human activities, in particular pasture, deforestation, deliberate fire and urbanization.

Savannas are composed of the same species as the coastal vegetation, with the addition of *Senna* sp. and the trees *Anacardium occidentale, Annona squamosa, Acacia mangium, Acacia auriculiformis, Albizia lebbeck* and *Gliricidia sepium*.

2.3.3. Intermediate-altitude humid forest

Intermediate-altitude humid forest can be found at various altitudes depending on the exposure of the area, starting at 200 m asl (e.g. Sohoa forest in Mayotte). Rainfall is between 1 700 and 2 200 mm per year with between five and seven humid months. Out of six sites of this forest type studied in Mayotte, exotic species represented about ten percent of the trees with a trunk diameter of 10 cm or more (Pascal 1997).

The main exotic woody invasive species are *Albizia lebbeck, Adenanthera pavonina, Clidemia hirta, Cinnamomum verum, Citrus reticulata, Jatropha curcas, Litsea glutinosa, Psidium cattleianum, Spathodea campanulata, Syzygium aromaticum* and *Syzygium jambos*.

At higher altitudes, this habitat is widely populated by *Psidium cattleianum*. This species is highly valued for its fruit, for the timber properties of its solid wood and as fuelwood. For these reasons, the species is favoured but is also subjected to high pressure. It is sufficiently vigourous to colonize all areas, especially disturbed forest. *Psidium cattleianum* is less common on Mohéli. Unfortunately, as it is appreciated by the population, it seems likely that it will now be planted there.

Litsea glutinosa can be found throughout this type of forest. It colonizes all open areas but survives in more shaded areas as well. It is also found in undisturbed forest, especially in Mayotte where undisturbed forests are located at lower altitude and where the pressure on this species is decreasing as agriculture declines. Box 1 gives additional information on the population dynamics, ecology and control of *Litsea glutinosa* in the Comoros archipelago and especially Mayotte.

2.3.4. Mountain cloud forest

Mountain cloud forests start at about 500 m asl in some areas in Mayotte and on Mohéli, and go up to 1 800 m asl on Grande Comore. These are the least disturbed forests as they are also the least accessible. At higher altitudes (higher than the maximum altitude in Mayotte), they can be composed of tree ferns (*Cyathea* sp.) or of a high density of palm trees, some of which are endemic.

In areas disturbed by human activities and especially in fallow land and in open deforested areas planted with banana (*Musa* spp.) and taro (*Colocasia esculenta*), species such as *Cinnamomum verum*, *Clidemia hirta* and *Syzygium jambos* can be found along with the highly dominant *Psidium cattleianum*. *Psidium cattleianum* can form monospecific thickets of undergrowth (especially on Grande Comore and to a lesser extent Anjouan) dense enough to be difficult to penetrate and prevent regeneration of the natural flora.

2.3.5. High-altitude ericaceous moor

These moors lie between 1 800 and 2 300 m asl on Karthala on Grande Comore and are characterized by ericaceous species, notably *Philippia* sp. This species occurs mixed with other species at lower altitudes but is the only species at higher altitudes. On Anjouan, ericaceous species mixed with other species are found from 1 500 m asl to the summit of the island.

Herbaceous species such as *Hortensia* sp. are found at lower altitudes in this habitat on Grande Comore (where they were introduced by colonizers). It is a flowering plant, but invasive all the same!

The main threat at this level is forest fire, both deliberate and accidental.

BOX 1: *LITSEA GLUTINOSA* IN THE COMOROS ARCHIPELAGO: DYNAMICS, ECOLOGY AND CONTROL

The work on which this study is based (Jacq 2001) was conducted in Mayotte. However, many of the results are valid for the Union of the Comoros where *Litsea glutinosa* is particularly invasive.

Natural distribution

The area of origin of *L. glutinosa* extends from the east coast of China to northern Australia, and includes Southeast Asia and the eastern coasts of India and Sri Lanka. Originally, it was not found in Africa or in the Indian Ocean small islands, where it is today a main invasive species (in Réunion, the Comoros archipelago and the islands of Mauritius and Rodrigues).

Biology

Litsea glutinosa is a member of the Lauraceae. Four species of this family have been described as currently invasive in the tropics: *Cinnamomum camphora*, *Cinnamomum verum*, *Litsea monopetala* and *Litsea glutinosa* (Binggeli *et al.* 1998).

In its natural range, *L. glutinosa* shows great plasticity: it is found in humid areas from sea level to high altitude (it is common up to 1 900 m asl in China). It shows similar plasticity in the Comoros archipelago where it is found from 200 m asl in Mayotte to 900 m asl on Anjouan in open and humid areas (author's observation).

The leaves, bark, and fruit pulp of *L. glutinosa* are all aromatic. Some secondary metabolites such as phenols and tannins may limit parasitism and, in particular, termite infestation (F. Jacq, personal observation). Screening of phenols and tannins conducted by the National History Museum in Paris should soon confirm this hypothesis.

Litsea glutinosa has various successful methods of multiplication and spread, including effective dissemination by frugivores, efficient vegetative multiplication, and a large and long-lasting seed bank. In addition, its juvenile period is short, its fruiting period is long and frequent, and its growth is fast.

The main results of the study in Mayotte are as follows:

- Preliminary results on the theoretical conservation of the seed show that it has an orthodox behaviour and could survive at least 10 years in the soil.
- Vegetative multiplication is spectacular (there was a 52 percent success rate in vegetative propagation on experimental plots). Young shoots (trees) remain attached to the mother tree, which provides nutrient as well as support for the young plants until they reach the canopy where light is sufficient to ensure their survival. Planting of cuttings is a frequent and effective agricultural practice.
- Growth of shoots after planting of experimental cuttings was rapid: shoots emerged an average of 10 days after planting, and subsequent growth was 0.46 cm/day.
- There are ten known disseminators including six bird species. Lemurs (*Eulemur* spp.), the bat *Pteropus seychellensis* subsp. *comorensis* and snails (*Achatina fulica*) are among efficient disseminators of the seeds.
- Two varieties of *L. glutinosa* are found in Mayotte ('bois rouge' and 'bois blanc'). The 'bois rouge' variety seems to contain more secondary metabolites, which would explain the absence of attack by termites.
- Dormancy of *L. glutinosa* seeds is not influenced by light. Seeds can germinate under leaf litter and the plants even grow in thickets such as those formed by *Lantana camara* in Mayotte. However, *Litsea glutinosa* favours high light regimes and establishes best in open areas.

Introduction in the Comoros Archipelago

Litsea glutinosa was introduced as a source of fuelwood in all islands of the Comoros archipelago during the second half of the nineteenth century to meet the high demand of the sugar cane distilleries, and later the cinnamon, ylang-ylang and citronella distilleries.

BOX 1 (CONT.): *LITSEA GLUTINOSA* IN THE COMOROS ARCHIPELAGO: DYNAMICS, ECOLOGY AND CONTROL

Economic importance

Litsea glutinosa is a multipurpose plant in the Comoros archipelago, although its main use is animal feed. Young shoots are used as forage in the humid season, and the leaves serve the same purpose in the dry season.

It is used in traditional medicine, the berries in a decoction for painful menstruation, and the leaves and bark as an external antiseptic to cure wounds, as a diarrhoea treatment, and as an emollient for sprains.

The plant is also used as a support for *Vanilla planifolia*.

The wood is used as structural timber (for traditional roofs, or 'bangas') and is excellent for fuelwood. (In the Union of the Comoros it is still mainly used for domestic purposes.)

Distribution and extent of the invasion

In Mayotte, Pascal (1997) estimated that new shoots of *L. glutinosa* cover nine percent of the land area, mainly in the most humid northern two-thirds of the island. It can form up to 15 percent of the trees in some disturbed forests (e.g. Dapani forest).

It has established throughout the Comoros archipelago in all disturbed humid areas. However, more worrying is the fact that in Mayotte it has proved capable of establishing in summit areas above previously undisturbed forest .

In the Union of the Comoros, this plant is very heavily exploited but it continues to spread. No measure of its invasiveness exists.

Were the impact of agricultural activities on the maintenance of the landscape to be reduced (as could well happen in Mayotte in the future), it could lead to an explosion in the population of *L. glutinosa*.

Invasion control and conclusions

No action has been or is being undertaken in the Comoros archipelago to control *L. glutinosa*. The plant is, on the contrary, often still sown or planted. There are two reasons for this:

- There is a lack of consensus on the danger posed by this plant, which is often considered as useful because of its various uses, especially in the Union of the Comoros where it remains a main forage and fuelwood species.
- Because of its efficient vegetative multiplication, this plant provides good soil cover and helps to control erosion. Large-scale eradication would have to be accompanied by the planting of an indigenous species that exhibited the same capacity for multiplication and soil coverage, which would not be easy to achieve.

Nonetheless, *L. glutinosa* presents a clear threat to humid forests of intermediate altitude in the Comoros archielago and action should be undertaken to protect those forests. Research on competitive indigenous species – such as *Grisollea myriantha* which lives in similar habitats – and on methods for their mass multiplication should be encouraged at least in Mayotte where the Forest Service (Service des eaux et forêts, SEF) is well aware of the *L. glutinosa* problem.

3. ECONOMIC AND ENVIRONMENTAL IMPACTS

3.1. Positive impacts

Table 3 lists the uses to which the main invasive woody plant species in the Comoros archipelago are put. Unlike the other Western Indian Ocean small islands, 70–80 percent of the Comoros archipelago's working population are farmers. Activities associated with all the uses of species cited in Table 3 take place daily but despite the high pressure these species are still proliferating. It is interesting to note that the most invasive species such as *Psidium cattleianum*, *Litsea glutinosa* and *Albizia lebbeck* are among the most used species.

Although all the various uses cannot be detailed, it is interesting to note the medicinal use of the plant species. In the Union of the Comoros, traditional medicine is still used frequently. All the species cited as being used for medicinal purposes are used by more than 20 percent of households in the Union of the Comoros to treat specific illnesses (malaria, diarrhoea, burns, influenza, wounds ...). This high percentage is the result of low wages, which prevent access to 'modern' medicine, as well as the trust placed in traditional medicine and the rich heritage of the African/Bantu and Arabic/Muslim cultures. In the Union of the Comoros, a sick person is first treated with traditional medicine by housewives before being sent to a doctor (Faujour 2002).

3.2. Negative impacts

Four main types of negative impact have been noted:

- Impacts on agriculture and habitats that are highly humanized;
- Impacts on the functioning of ecosystems: increases in the risk of erosion or fire, changes in water resources at river or water table levels, changes in vegetation structure, changes in soil nutrients;
- Impacts on species: disappearance of indigenous species; impacts on frugivorous, herbivorous and insectivorous populations;
- Genetic impacts linked to hybridization or to the progressive decrease in the genetic pool of species through population reduction.

Data on these various impacts are scarce or do not exist at all in the Comoros archipelago, and methodical studies and databases on the environment are required. Therefore, only the first two categories of negative impacts are described below.

TABLE 3: USES FOR THE MAIN INVASIVE WOODY PLANT SPECIES IN THE COMOROS ARCHIPELAGO

Species	Use							
	Forage	**Fruit/ spice**	**Medicine**	**Timber**	**Fuel wood**	**Reforestation**	**Crop stake**	**Ornamental**
Acacia spp.						+		
Adenanthera pavonina						+		
Albizia lebbeck	+			+	+	+		
Aleurites moluccana			+					
Anacardium occidentale		+	+					
Annona squamosa		+						
Cinnamomum verum		+	+					
Citrus spp.		+	+					
Gliricidia sepium	+						+	
Jatropha curcas			+				+	
Lantana camara			+					+
Leucaena leucocephala	+							
Litsea glutinosa	+		+	+	+	+	+	+
Psidium cattleianum		+		+	+			
Psidium guajava		+						
Senna sp.	+		+					
Solanum spp.								+
Spathodea campanulata	+							+
Syzygium aromaticum		+	+					
Syzygium jambos		+						
Tectona grandis				+				
Terminalia catappa			+			+		

3.2.1. Impacts on agriculture

This is one of the most striking impacts given the importance of the agricultural working population in Mayotte and Union of the Comoros.

Access to agricultural equipment and herbicides is limited. Weed control is therefore carried out manually which is laborious and this is one of the main limiting factors in agriculture and for soil productivity.

The main invasive plants in fields are non-woody species: *Panicum umbellatum, Bidens pilosa, Mimosa pudica, Achyranthes aspera, Cyperus esculentus, Imperata cylindrica, Mucuna pruriens, Commelina diffusa* and *Hibiscus surattensis* (Vandamme 2001).

Spontaneaous invasive woody plant species are less frequent in fields (the main species are *Senna obtusifolia, Albizia lebbeck, Spathodea campanulata, Psidium cattleianum, Litsea glutinosa, Lantana camara* and *Clidemia hirta*) but their growth could become particularly disruptive.

Weeds create problems for agriculture because of:

- Strong competition between weeds and crops (mainly with grass species such as *Panicum* sp.).

- Extremely rapid multiplication of weeds (particularly during the wet season).

- Difficulty of weed control as the weeds can be deeply rooted in the soil, or they can bear thorns (e.g. *Mimosa pudica* or *Hibiscus surattensis*) or they can be irritant (e.g. *Mucuna pruriens*).

Looking specifically at the invasive woody plant species:

- *Litsea glutinosa* is present in all cultivated areas. This plant was recorded in 53 percent of CIRAD's (Centre international de recherche pour le développement) 110 experimental plots in Mayotte (Vandamme 2001). It has a powerful root system and a rapid growth rate. To cut *L. glutinosa* down and prepare the ground for cultivation as well as preventing *L. glutinosa* from growing again is very time consuming. Its high production of woody parts means the slash-and-burn technique has to be used for cultivating fallow land.

- *Psidium cattleianum, Senna obtusifolia* and *Albizia lebbeck* are extremely difficult to uproot using the traditional equipment for mechanical control ('chombo'). The fallow land on La Grille and Karthala (Grande Comore) on which *P. cattleianum* has been grown for its fruit would require a great deal of effort to restore to agricultural cultivation. Such fallow land quickly becomes impenetrable monospecific thickets of undergrowth.

- *Senna obtusifolia* has extremely rapid multiplication and growth which makes it difficult to hoe although its life cycle is short.

- *Lantana camara* has no value as either a crop or animal feed, and it seems easier than other species to eradicate, particularly by the slash-and-burn technique.

- *Clidemia hirta* also has no practical use. When young, the plant is easy to eradicate. However, if farmers cut it down, the regrowing plant produces a woody base which is difficult to uproot. Its wide spread on Karthala on Grande Comore and on Mohéli is worrying and irreversible. On the other islands, it is still manageable.

3.2.2. Impacts on ecosystem function and biodiversity

As outlined above, these impacts include increased erosion and fire risks, changes in water resources in rivers and water table levels, changes in vegetation structure, modifications in soil nutrients and reduction or even eradication of the indigenous fauna and flora.

According to discussions with local stakeholders on this subject and data collection in the Comoros archipelago, it seems that knowledge of these impacts is low and they have not been methodically measured. The following observations are the result of the field visit:

- The fern *Dicranopteris linearis* burns easily and quickly and could be difficult to manage in areas where the slash-and-burn technique is still undertaken. The lack of vegetation cover after a fire increases the risk of erosion on these mountainous islands and particularly on Grande Comore and Anjouan.

- Species able to form monospecific cover, such as *Syzygium jambos, Clidemia hirta* (especially on Karthala on Grande Comore or at Convalescence in Mayotte) and *Lantana camara* as well as the ferns *Dicranopteris linearis* and *Nephrolepis* sp., prevent the self regeneration of open areas in the forest and hence modify the structure of the forest.

- Creepers such as the non-woody plant species *Saba comorensis* (which is indigenous), *Merremia peltata, Entada gigas* and *Entada rheedii* have a similar impact on forest regeneration and structure to that described above. Their impact is particularly noticeable in Mayotte and on the southern slopes of Mohéli where they smother the underlying vegetation through the dual action of their weight (which breaks the trees) and a reduction in light intensity (which prevents photosynthesis in the underlying vegetation). In the long run, irreversible impacts on the fauna can also be predicted. At Nioumachoua on Mohéli, for instance, creepers are a direct threat to the resting places and feeding grounds of the bat *Pteropus livingstonii* which is highly endangered according to IUCN.

- On steep slopes, the vegetation plays an essential role in maintaining the equilibrium of the water resources. On Anjouan, there are less than ten rivers today compared with 40 in the middle of the nineteenth century and the exact link between the development of invasive species and the decrease in water resources should be investigated.

Studies should be undertaken and databases created in the Comoros archipelago to characterize better the impacts of invasive woody plant species on the environment. The direct impact of exotic invasions on the population level of plant species as well as the genetic integrity of plant populations is totally unknown.

4. CONTROL MEASURES AND HABITAT RESTORATION

Voluntary control and habitat restoration activities are undertaken only in Mayotte. In the Union of the Comoros, given the economic situation, such activities could be envisaged only if they could be linked to other activities that would alleviate deforestation and promote more intensive and sustainable agriculture.

4.1. Control measures

4.1.1. Biological control

To date, no attempt at biological control (by introducing an insect or fungus) has been undertaken in Mayotte or in the Union of the Comoros.

However, the use of plants in animal feed provides some kind of control of invasive plant species such as *Gliricidia sepium, Leucaena leucocephala, Spathodea campanulata* and, especially, *Litsea glutinosa*. Indeed, in 2001 the ovine herd amounted to more than 15 000 head and the bovine herd to more than 23 000 head in Mayotte alone (Vandamme 2001). In 2000, in the Union of the Comoros, a total of 234 000 head of livestock was counted (UNDP/GEF/IOC 2000). This large livestock population puts a high pressure on forage plants, yet these invasive plants continue to proliferate. In Mayotte, the strong expansion of *Litsea glutinosa* may be further increased by a fall in agricultural activities. A reduction in agriculture in the archipelago would mean an explosion in the development of invasive plant species currently used as forage.

4.1.2. Chemical control

No trials of chemical control of invasive species have been reported. Herbicide use is rare in Mayotte as well as in the Union of the Comoros. The main reasons for this are:

- Supply difficulties (even in Mayotte).
- High costs of inputs (when not donated in the Union of the Comoros or when not subsidized in Mayotte).
- Availability of low-cost labour (in both the Union of the Comoros and Mayotte, which has numerous illegal workers from Anjouan).

4.1.3. Mechanical control

This is the main control activity undertaken on cultivated land to limit the populations of invasive species in the Union of the Comoros and Mayotte. Control is based on a traditional technique. Some species that are not used as forage are often used as mulch on cultivated plots. Vandamme (2001) showed that farmers are well aware of the effects of invasive species. Among the 22 main invasive plant species found in the fields, seven are not used as mulch by farmers as they know that these species reproduce efficiently by vegetative multiplication; among these species are *Lantana camara, Mimosa pudica* and *Senna* sp. The use of invasive plants as mulch is a concept of agroecology which is spontaneously used by farmers. It is a clever way to recycle biomass.

Projects for mechanical control in natural areas or in areas with high biodiversity are undertaken in Mayotte only. The high cost of these projects prevents any being implemented by the Union of the Comoros. The work in Mayotte is mainly aimed at controlling the population of *Lantana camara* (at Pointe Saziley) and of invasive non-woody creepers (*Merremia peltata, Saba comorensis, Ipomoea* spp.) in forestry reserves.

4.2. Restoration activities

In recent years, Mayotte alone has undertaken some forestry restoration activities, and these were in ecologically rich areas.

In 1995–1996, an attempt to eradicate *Rubus alceifolius* was not successful. The uprooting of *R. alceifolius* followed by the immediate planting of woody species (at a cost of €85 000 for a few hectares) failed, among other reasons, because farmers immediately let their cattle graze on the newly planted seedlings. This is regrettable as *R. alceifolius* remains restricted to the region of Coconi where it could feasibly be controlled.

In addition to this attempt, there are two other main types of restoration projects at present.

4.2.1. Forestry reserves

Restoration of the original habitat following the mechanical control of exotic invasive plant species (*Lantana camara* and creepers) is being undertaken in some forestry reserves.

In 2002, 10 ha of *L. camara* (out of 115 ha infested) were eradicated in a highly ecologically valuable dry forest at Pointe Saziley in Mayotte (see Section 7.1. Case Study: Land-use planning for areas of Pointe Saziley (Mayotte) invaded by *Lantana camara*). Similar activities were undertaken in other areas of the island (Mavingoni, Ajambua). Plantation of young trees followed the eradication of *L. camara*. In 2002, 5 ha were replanted with *Pterocarpus indicus, Calophyllum inophyllum, Gliricidia sepium* and *Mimusops comorensis* in preference to *Acacia mangium* which is known to be invasive. Unfortunately, *Gliricidia sepium* seems to be also invasive in the archipelago and its plantation should be avoided.

In 2002, invasive non-woody creepers (*Saba comorensis* and *Merremia peltata*) were eradicated on 15 ha of reserve in Sohoa, Bouyouni and Mavingoni.

The creeper eradication was undertaken on a regular basis between 1992 and 1997. However, it seems that 70 percent of the areas where creeper eradication was undertaken between 1992 and 1997 is now conquered by them again (Ali Andi, personal communication) because of a lack of monitoring and replanting. The creeper eradication project is very expensive and should be the subject of long-term monitoring. Given the extent of creeper invasions in Mayotte (and in the Union of the Comoros), their eradication can be envisaged on a long-term basis only in restricted areas.

4.2.2. Padzas (badlands)

Padzas are highly eroded areas from which the soil has entirely disappeared. They cover 2 600 ha (i.e. seven percent) of Mayotte. Erosion is caused by the slash-and-burn technique used on steep slopes, as well as by overgrazing of poor quality pasture.

Restoration projects since 1992 have aimed to stabilize the soil in the short run by increasing the vegetation cover, and in the mid term to promote more sustainable agricultural techniques.

These techniques involve civil engineering (dam construction in ravines, walls to support banks of ravines, renewal of unstable micro-topography), agronomic engineering (bringing, spreading and stabilizing soil, incorporating organic compost, planting and protecting plants with mulch) and biological engineering (researching and planting species adapted to specific conditions).

The work undertaken is very expensive, ranging in cost from €20 000 to €60 000 per hectare depending on the accessibility of the area, the initial state of the land and the aims for the future development of the area. Civil engineering amounts to 70 percent of the final cost.

Up to 30 ha of padzas can be rehabilitated each year. *Acacia mangium* has long been the main species used to reforest the padzas, but the recent recording of its natural regeneration has led SEF to search for new species to replace it. In nurseries this year, *A. mangium* represents only 45 percent of production (the rest being *Mimusops comorensis* and *Calophyllum inophyllum*). In the operational management plan for Pointe Saziley, the authors recommended the use of local species such as *Erythroxylum platycladum*, *Ochna ciliata* and the palm *Phoenix reclinata*. These three species seem to grow naturally on padzas (F. Barthelat, personal communication).

SEF is now aware that species used until now for reforestation can show such high growth and multiplication in Mayotte that native species cannot compete. Replanting native species is the priority for nurseries today.

5. AWARENESS AND CONFLICTS OF INTEREST

5.1. Conflicts of interest

Even more than in other Western Indian Ocean small islands, the control of invasive species in Mayotte and the Union of the Comoros could lead to conflicts of interest. Indeed, a large number of the invasive species are used by the population.

According to local stakeholders, conflicts of interest could appear for *Psidium cattleianum* (especially on Grande Comore), *Litsea glutinosa* (especially in Mayotte) and *Cinnamomum verum* (everywhere in the Union of the Comoros where people are proud to have a cinnamon tree).

On Anjouan, invasive species are over-exploited and cannot meet the demand for charcoal production. Mango (*Mangifera indica*) trees are felled to top up production. For this reason, a project limiting the spread of exotic species would not be popular.

The only known and acknowledged conflict of interest occurs on Mohéli, where the environmental offices would like farmers to uproot and even avoid planting *Gliricidia sepium* which multiplies very easily by vegetative means. However, farmers like this plant which is a good support for *Vanilla planifolia* and a useful forage easily grown in hedges.

In the Comoros archipelago, any attempt to limit the populations of invasive exotic plant species would only stand a chance of success if *both*:

- Financial compensation is given to farmers who eradicate these plants that they find useful and substitute them with other species *and*

- An awareness campaign on the problem of invasive plants is undertaken, covering: What is the problem? What does it mean? What are the impacts?

5.2. Awareness

5.2.1. Degree of awareness

Awareness differs between the two political entities of the Comoros archipelago.

In Mayotte, awareness within SEF of the threat of invasive species seems to date back to the early 1990s and the launch of the first projects for creeper eradication. Pascal (1997) published an up-to-date list of introduced plant species in Mayotte, analysed the vegetation on the island and the degree of invasiveness of exotic species, and proposed additional activities to limit invasions. SEF continues this work, especially through the collection of an exhaustive herbarium of the flora of Mayotte in close collaboration with the Natural History Museum of Paris (France) so that new species can be identified (F. Barthelat, personal communication). Scientific studies of invasiveness by trainees are becoming more and more numerous (Mas 1999; Jacq 2001; Vandamme 2001).

In the Union of the Comoros, the low awareness of the population is a result of the weakening authority of the Forest Services (Services des eaux et forêts) for each island, which do not function properly. Links between the population and officials are therefore weak. However, village associations are very active and seem eager to acquire information and support. Some awareness campaigns could be undertaken through these associations.

5.2.2. Awareness campaigns

The situation once again differs between Mayotte and the Union of the Comoros.

In Mayotte, there is an emerging general awareness of the problems arising from invasive species and their potential impact. The problems are therefore explicitly referred to in reports on the flora of Mayotte (Pascal 2002). Invasive species are described as such. However, compared to other small islands of the Western Indian Ocean (Seychelles, Réunion, Mauritius), local information on invasiveness is recent and still scarce. There is little media coverage and the general population has limited knowledge of the subject.

In the Union of the Comoros, there is no awareness campaign dealing directly with the problems associated with invasive species. The problems they create are raised in more general awareness campaigns on environmental themes such as the economic importance of the forestry ecosystem or the management of water reserves, etc. Two interesting media outputs seem to be widely distributed in the islands: the *Ulanga* magazine of the Comorian NGO 'Ulanga-Ngazidjia' and *Mwana Wa Nyamba*, an information leaflet produced by the Mohéli marine park (under a GEF/FFEM/IUCN project). Except for these information leaflets, there are few other initiatives to raise awareness about the environment as a whole or the problems arising from invasive species.

6. LEGISLATIVE FRAMEWORK TO CONTROL INVASIVE WOODY PLANT SPECIES

6.1. Legislation and boundary control

6.1.1. Mayotte

The French legal framework and therefore the European Union legal framework apply in Mayotte.

There is no specific law relating to the management of invasive plant species either at their entry point to the territory or once established in the territory. Regulation of invasive plant species is currently dealt with by the Plant Protection Section of the Department of Agriculture and Forestry (Direction de l'agriculture et de la forêt, DAF).

Plant imports are regulated by a local decree (1995). For any import, a permit (from countries outside the European Union) or a phytosanitary certificate (from countries of the European Union) is required to ensure that the plants are not contaminated by pest organisms.

Air travellers are forbidden to bring into the territory any plant material prohibited under the decree. They have to fill in a form declaring that their luggage contains no such plant material. Upon arrival, a proportion of the luggage is screened. The decree also stipulates that some products may be placed under quarantine. Local environmentalists, however, believe that human resources are insufficient for the decree to be implemented effectively, especially when it comes to quarantine issues.

The 1995 decree does not seem entirely relevant to invasive plant species as it is aimed mainly at controlling the import of pathogens in plant hosts as well as a few known agricultural pests. It does not adequately regulate the introduction of plant species which could threaten the native flora. Annex 2 of the decree provides a list of prohibited species but does not prohibit the introduction of seeds of most of the listed species and it does not prevent the import of some species recognized as invasive in the region or in the tropics.

6.1.2. The Union of the Comoros

A regulatory framework for environment protection is currently being developed, which would forbid the introduction of some animal and plant species. However, the decree to allow the law to be implemented has not yet been voted on.

A proposal for regulatory measures for plant protection has also been drawn up by a consultant, but has not yet been adopted.

Regulatory problems in the Union of the Comoros seem two-fold:

- Institutions do not function adequately for political reasons (since the federation of the state in 1997, each island has tended to have more autonomous management) and for financial reasons (the forest and agriculture services have very limited budgets with which to initiate field activities).

- There is no plant protection office and no quarantine office and therefore there is no boundary control.

Institutional strengthening should be undertaken prior to any initiative to introduce regulation of invasive woody plant species.

6.2. Absence of proper planning policy

The impacts of invasive plant species are not taken into account in planning. Efficient control of plant invasion on each island of the archipelago and between each of them can exist only if the country planning policies take seriously into account the invasion phenomenon. In order to avoid further invasions by invasive species, areas that have been opened up should be closed as much as possible within sites that are rich in terms of biodiversity.

In Mayotte, land-use plans will probably be drawn up for each village, as in required by the French legislation. Better land-use planning would help to limit the development of invasive plant species. As yet, though, the legal protection given to forest areas does not seem strong enough to prevent abuse, as there are no designated nature reserves or national parks. The establishment of nature reserves (Ilôt Bouzi, Pointe Saziley) is under consideration; if these come about that should help to improve the situation.

In the Union of the Comoros, land use remains uncontrolled. Landownership is not properly defined (derived from French, traditional and Muslim laws), which is highly damaging to the forests as people can still become landowners by clearing forested land and planting taros and bananas. This creates numerous open areas in the forests, which are subsequently invaded by the woody plant species identified earlier. Although nature protection is emerging thanks to activities implemented by NGOs such as Action Comores and the National Center for Scientific Research (Centre National de la Recherche Scientifique, CNDRS) and through the GEF marine park project on Mohéli, there are still no designated protected areas.

7. CASE STUDIES

7.1. Case Study: Land-use planning for areas of Pointe Saziley (Mayotte) invaded by *Lantana camara*

This case study is based on Mas (1999) and an operational management plan for Pointe Saziley drawn up in 1998. *Lantana camara* is the most common invasive plant species in open areas of the southern, dryer parts of Mayotte. The study carried out by Mas (1999) contributed to a better knowledge of the ecology of this plant in the area of Pointe Saziley located in a coastal massif reaching 233 m asl and protected since 1991, among other reasons, for its botanical characteristics. However, the results and recommendations are applicable outside the Pointe Saziley area.

7.1.1. Invasive attributes

The results of the study confirmed the potential for invasion by *L. camara* on the basis of the following attributes:

- Great biological adaptability. Although this species grows mainly in dry areas, it can also colonize humid areas. At Pointe Saziley, it is found at all altitudes.

- High light tolerance. Plants develop very well under direct sunlight, which characterizes open disturbed areas and the bushy natural vegetation of the drier sites. At Pointe Saziley, the plant does not grow in the forest understorey but can account for 15 percent of the plants in bushy vegetation.

- Toxic to many mammals. Cattle do not eat the plant, and thus have no impact on its populations.

- Efficient vegetative multiplication in addition to high potential seed dissemination by birds and rats.

- Capacity to form dense, impenetrable thickets which present strong competition to other plant species, and lead to the disappearance of endemic species. Ultimately, the plants can form a monospecific carpet.

- Allelopathy. This prevents other plants from developing within/near *L. camara* thickets.

7.1.2. Spread of Lantana camara *at Pointe Saziley*

The main purpose of the study was to analyse the invasion strategy of *L. camara* by looking at how its ground coverage changed in space and time at Pointe Saziley.

- First stage of establishment: development of a nucleus. This began in the middle of a plot newly left as fallow. *Lantana camara* appeared next to trees able to resist drought (usually *Mimusops comorensis*, *Ochna ciliata*, *Erythoxylum* sp., *Tarenna supra-axillaris*). *Lantana camara,* which is disseminated by animals, grew like a ring around the trees. It benefited from the direct sunlight and the local enrichment of the soil by organic litter from the trees.

- Second stage: spread. The branches of the first plants to establish bend down to the ground and produce roots. These become new plants with the necrosis of the link with the mother plant. The old plants provide organic matter for the younger ones, which go on to establish a larger ring of plants around the trees.

- Third stage: invasion through zoochory. The seed bank of *L. camara* increases in the soil.

- Fourth stage: ageing of the invasive stage. The plant has by now spread widely. Mature plants are scattered every 2–3 m with a discernible vertical organization of stems. From ground level to a height of 1 m, absence of light means that living branches bear no leaves and are mixed in a tangle of dead branches. From 1 to 3 m, branches compete for light and tend to grow higher and higher. The population is stable.

7.1.3. Degree of invasion

At Pointe Saziley the degree of invasion depends on:

- Pasture use. If there is heavy use of the land for cattle pasture, grass species such as *Panicum umbellatum* develop to the detriment of *L. camara*. However, *L. camara* benefits if pasturing is discontinued: *L. camara* suffers less competition from *P. umbellatum* and in the absence of trampling by cattle, which can prevent its regeneration, the plant is able to spread further.

- The natural regeneration potential of the area. If the fallow land contains a large variety of species including, especially, *Ochna ciliata*, *Mimusops comorensis* and *Tarenna supra-axillaris*, the eventual spread of these species will mean the progressive closure of vegetation cover and stabilization of the *L. camara* invasion.

7.1.4. Recommendations for land-use planning of invaded areas

- *Lantana camara* plants should be uprooted at the nucleus stage.

- In forest areas, the main stem of *L. camara* should be cut at the peak of the dry season.

- In bushy areas, forests where small trees are dominant and areas where *L. camara* forms monospecific cover, *L. camara* should be uprooted. In open areas, cutting the plant at ground level does not always prevent it from regenerating.

- In all cases, replanting with appropriate species of trees and shrubs should be implemented immediately. All techniques that promote closure of vegetation cover should be undertaken: producing young plants locally, planting as soon as the rainy season starts, limiting shrub growth by applying systemic herbicides to young exotic shrubs, managing the plantation (hoeing during the rainy season, pruning plants to encourage growth in height).

- The main species for planting should be indigenous: *Mimusops comorensis*, *Poupartia gummifera*, *Ehretia cymosa*, *Commiphora arafy*, *Ochna ciliata*, *Ficus antandronarum*, *Trianolepsis africana* and *Sterculia madagascariensis*.

7.1.5. Control

The eradication and rehabilitation work at Pointe Saziley is being undertaken on 115 ha invaded by *L. camara,* together with other exotic species.

In 2002, 10 ha of *L. camara* were eradicated at Pointe Saziley using the above methods. However, indigenous species were not replanted as these species have proved difficult to manage in a nursery. *Calophyllum inophyllum*, *Pterocarpus indicus* and particularly *Gliricidia sepium,* which can be very invasive in the Comoros archipelago, have been used. Trials in nurseries of indigenous species are part of the short-term objectives of the Forest Service (Service des eaux et forêts, SEF) to speed up restoration of the vegetation.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

From the (non-exhaustive) list drawn up by Pascal (1997), of 350 woody plant species introduced in Mayotte, about thirty have become invasive, i.e. ten percent. This proportion seems to be particularly high compared with the general rule of Williamson (1996) which states that about one percent of introduced plant species become invasive. Furthermore, this estimate does not include non-woody plant species, and consideration of these would further increase the proportion of invasive species in Mayotte.

8.1.1. Degree of invasion

- There are only a few isolated studies for the Comoros archipelago on this subject. According to these studies and from discussions with local environmental specialists, 16 woody species are estimated to be highly invasive in the Comoros archipelago: *Acacia auriculiformis, Acacia mangium, Albizia lebbeck, Cinnamomum verum, Clidemia hirta, Gliricidia sepium, Jatropha curcas, Lantana camara, Leucaena leucocephala, Litsea glutinosa, Psidium guajava, Psidium cattleianum, Senna* sp., *Spathodea campanulata, Syzygium aromaticum* and *Syzygium jambos*.

- The introduction dates of these species are unknown and could date back many centuries, as the archipelago has been inhabited on a permanent basis since the ninth century. However, many introductions seem to date from the nineteenth century and the massive settlement by colonists associated with the sugar cane industry followed by the increase in production of spices and essential oils. These species naturalized and spread on deforested land.

- Identifying new invasive or potentially invasive species has been difficult during this study. *Clidemia hirta* is a newly invasive plant in Mayotte and on Anjouan whereas its devastating effect is already obvious on Grande Comore and Mohéli. All the species which have been less frequently mentioned in this Part need to be monitored, for example *Albizia chinensis, Solanum* sp. and *Rubus alceifolius*. This last species is present in Mayotte only, but given its negative impact in Réunion, it could become invasive in the entire archipelago.

- In the Comoros archipelago, the least invaded habitats are the more inaccessible high-altitude humid forests, which are therefore less disturbed and less exposed to invasion by sun-tolerant pioneer species. Other habitats have already been invaded either moderately or highly.

- It should be remembered also that non-woody plant species can also be very invasive. Creepers, especially, represent an important threat to local biodiversity.

8.1.2. Economic and environmental impacts

- These impacts should be more carefully studied.

- In Mayotte and the Union of the Comoros, 70–80 percent of the population are farmers. The impact of invasive plant species in crops is the primary economic concern. The main spontaneous woody invasive plant species on agricultural land are *Senna obtusifolia, Albizia lebbeck, Spathodea campanulata, Psidium cattleianum, Litsea glutinosa, Lantana camara* and *Clidemia hirta*. Problems can present as: strong competition between the weed and the crop, excessively rapid growth (e.g. *L. glutinosa*, especially in the humid season), and obstacles to weeding where the invasive plants are deeply rooted (e.g. *P. cattleianum, Senna obtusifolia, A. lebbeck*). Some grass species have thorns (*Mimosa pudica, Hibiscus surattensis*) or cause skin irritation (*Mucuna pruriens*). All of these reduce access to land and consequently agricultural land productivity.

- There are only a few data (mainly for Mayotte) on the impacts on ecosystems. In the Union of the Comoros, the impacts on ecosystems are still not a priority for the population which is preocccupied with a dire economic situation.

8.1.3. Habitat control and restoration

- Some biological control is effected, especially of forage species, by the 272 000 head of livestock in the archipelago.

- No reports on trials of chemical control have been found. The high cost of inputs and inadequacies of supply make chemical measures difficult to undertake.

- Mechanical control is undertaken mainly on cultivated land but also in Mayotte in natural areas in order to protect biodiversity. In Mayotte, long-term activities have been undertaken mainly to control *Lantana camara* on the coast and creepers in the forests.

- The success of the projects depends upon the long-term commitment of the authorities responsible for land management and the village associations.

8.1.4. Conflict of interest and awareness

- SEF in Mayotte has undertaken control and rehabilitation activities since the beginning of the 1990s in forest reserve areas. In the Union of the Comoros, awareness remains low among the population because of poor functioning or absence of institutions (e.g. forest offices dismantled and the absence of a plant protection office on Grande Comore).

- Public awareness of invasive woody plant species is still low especially regarding their impacts on biodiversity. Woody invasive plant species are often regarded as useful, with good reason as they are used for food, forage, wood, etc. Awareness activities are undertaken through the publication of information leaflets. In Mayotte, there are already some books on the local flora which specifically mention invasive plant species. In the Union of the Comoros, invasive plant species are not yet an issue as such and they are considered as a component of threats to the environment (water resources preservation, endangered medicinal plant species ...).

- The commitment of village associations and farmers groups should be a prerequisite to any control activity against invasive woody plant species in the Union of the Comoros as there are obvious conflicts of interest. Invasive woody plant species are resources for farmers. They are considered as harmful only when they are weeds on cultivated land.

8.1.5. Legal framework

- The overall legal framework to prevent the introduction of new invasive woody plant species is partly outdated and partly incomplete in Mayotte as well as in the Union of the Comoros.

- Human resources and infrastructure needed to control the introduction of exotic plant species are either lacking or insufficient in the Union of the Comoros.

8.2. Recommendations

8.2.1. Improving knowledge of local/indigenous plants and the invasiveness phenomenon

- Existing studies on the dynamics and ecology of invasive woody plant species as well as their impact on the local flora and fauna are few and more should be undertaken. These studies should help Mayotte and the Union of the Comoros to develop a prevention and rapid detection system for invasive woody plant species. This work should be undertaken in cooperation with other Western Indian Ocean small islands and should follow the model of the system already used in Australia and which is in development in South Africa.

- Knowledge about the multiplication and development of indigenous plant species in the Comoros archipelago should be improved to allow the selection of other species, according to the habitat, to replace the traditional ones used for replanting. For instance, the indigenous plant *Grisollea myriantha* could replace *Litsea glutinosa* in the forest; *Mimusops comorensis, Erythroxylum platycladum, Ochna ciliata* and the palm *Phoenix reclinata* could replace *Acacia mangium* on padzas (badlands).

8.2.2. Continuing awareness campaigns

- Before addressing the problem of invasive woody plant species in natural areas, it would be better to undertake first some awareness activities targeted at farmer groups and village associations, which are the managers of plots and forests. Awareness raising should aim to show the impact of invasive woody plant species on cultivated land (especially on soil productivity and labour requirements), as well as promote proper mechanical control methods.

- A ‘pay for planting’ project could help to close up abandoned open areas in the forest by facilitating the planting of useful non-invasive species such as fruit trees.

- The state authorities should be made aware of the importance of solving the problems of land regulation in the Union of the Comoros, which would limit the development of invasive woody plant species.

8.2.3. Promoting habitat restoration

- A prerequisite should be the development of land-use planning which would create areas where habitats and species are protected.

- For restoration projects to succeed, there should be small-scale projects undertaken over the long term with continuous financial support from the relevant institutions (state authorities in Mayotte) or from donor agencies (in the Union of the Comoros).

8.2.4. Improving regulations and capacity building in control

- Regulations should be modernized and completed to address directly the issue of invasive plant species.

- A rapid detection system should be developed in both Mayotte and the Union of the Comoros.

- A prerequisite for better management of invasive species would be the development of control and quarantine infrastructures and the allocation of more adequately trained human resources.

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APPENDICES

Appendix 1: list of abbreviations and acronyms

CIRAD	Centre international de recherche pour le développement
CNDRS	Centre national de recherche scientifique
DAF	Direction de l'agriculture et de la forêt
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
IUCN	World Conservation Union
NGO	Non-governmental organization
SEF	Service des eaux et forêts
SPV	Service de la protection des végétaux

Appendix 2: some common names of cited plants

Species name	Common name(s)
Acacia spp.	Acacias, Wattles
Adenanthera pavonina	Agati
Agave sisalana	Sisal
Albizia lebbeck	Bois noir, Siris tree
Aleurites moluccana	Bancoulier
Anacardium occidentale	Cashew
Ananas comosus	Pineapple
Annona squamosa	Sugar apple
Artocarpus altilis	Breadfruit, Fruit à pain
Artocarpus heterophyllus	Jackfruit, Jacquier
Calophyllum inophyllum	Takamaka
Cananga odorata	Ylang-ylang
Casuarina equisetifolia	Casuarina, Filao
Cinnamomum verum	Cinnamon
Citrus reticulata	Mandarin
Clidemia hirta	Désirée
Coffea spp.	Coffee
Colocasia esculenta	Taro
Dicranopteris linearis	Bracken fern
Eichhornia crassipes	Water hyacinth
Eucalyptus spp.	Eucalypts
Hedychium gardnerianum	Wild ginger
Imperata cylindrica	Lalang
Lantana camara	Lantana
Leucaena leucocephala	Leucaena
Mangifera indica	Mango
Panicum umbellatum	Gazon chinois
Pistia stratiotes	Water lettuce
Psidium cattleianum	Cherry/Chinese/Strawberry guava, Goyavier
Psidium guajava	Guava
Pterocarpus indicus	Sandragon
Pueraria lobata	Kudzu
Ricinus communis	Castor
Rubus alceifolius	Giant bramble, Raisin marron
Saccharum officinarum	Sugar cane
Samanea saman	Arbre à confiture
Swietenia spp.	Mahogany
Syzygium aromaticum	Clove
Syzygium jambos	Rose apple, Jambrosa
Tectona grandis	Teak
Terminalia catappa	Badamier, Tropical almond
Theobroma cacao	Cocoa
Vanilla planifolia	Vanilla