Chapter 6.9
Restoration Trials of the Anony River Estuary Banks by Dune Stabilization and Mangrove Tree Plantation

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Abstract

This chapter describes the methodology and the results obtained in the experimental restoration of the banks of the Anony River close to Tolagnaro. Research consists of restoring an ecosystem of mangroves located at the base of the frontal dune. This dune is highly degraded due to repeated deforestation. As a consequence, erosion of the sandy slopes threatens the curtain of mangroves at the base of the dune. In addition, the wood of the mangroves is used by fishermen in the manufacture of cages for catching shrimp. This represents increased pressure on the natural habitat of shellfish. More than 6000 seedlings of mangroves were grown in a nursery and planted. Furthermore, the dune was stabilized with fascines and plantations of *Scaevola taccada*. Despite interference by human activities and fire, the dune was effectively stabilized. These tests provide options and solutions for the production of mangroves and their afforestation, as well as the stabilization and restoration of vegetation on the steep slopes of the stripped dunes. These results are preliminary and further experiments are required to implement dune stabilization and mangrove restoration on a large scale.

Résumé

Essais de restauration des berges de l'estuaire de la rivière Anony par la stabilisation des dunes et la plantation de palétuviers. Ce chapitre décrit la méthodologie et les résultats obtenus dans des expériences de restauration des berges de la rivière Anony, près de Tolagnaro. La recherche consiste à restaurer un écosystème de mangroves en rideau localisé à la base de la dune frontale. Cette dune est très dégradée suite à des déforestations répétées avec comme conséquence des pentes sableuses en érosion qui menacent les mangroves en rideau en contrebas. Egalement, les bois de palétuviers sont aussi utilisés par les pêcheurs pour la fabrication de cages pour la capture des crevettes, représentant une pression accrue sur l'habitat naturel des crustacés. Plus de 6000 plants de palétuviers ont été produits en pépinière et reboisés et des essais de stabilisation de la dune ont été réalisés. Ces essais permettent d'entrevoir des solutions à court et long terme pour la production en pépinière de palétuviers et leur reboisement ainsi que la revégétalisation de fortes pentes des dunes dénudées. Ces résultats sont préliminaires et doivent être poursuivis pour permettre d'entreprendre des travaux à plus grande échelle.

Introduction

The east coast of Madagascar, in the region from the north of Tolagnaro to Foulpointe, is almost perfectly straight for a distance of 700 km. It is a low-lying coast, bordered along its entire length by a sandy, offshore bar. Behind the bar is a string of lagoons, which are linked by the Canal des Pangalanes for most of this distance (Battistini 1972, Fig. 1). In the Tolagnaro region, this linear coast is interrupted by large bays and rocky promontories that give the area some of its distinctive geophysical attributes. Along this portion of the southeastern coast is a narrow strip of dunes separating the sea from a network of lagoons and rivers, which are a primary source of food and income for the local human populations. The Lanirano-Evatraha Lagoon, near Mandena, has a series of connected lakes, meanders, and rivers that cross the landscape behind the offshore bar up to its mouth at Pointe Evatraha (Fig. 1).

Despite the fact that Madagascar has the largest area of mangroves of any landmass in the western Indian Ocean, the asymmetry of the eastern coast

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landform, as well as the small range of tidal variation, does not encourage the formation of this ecosystem. According to Keiner (1972), only about 2.5% of the 321,000 ha of Madagascar's mangroves occur on the east coast. There are few mangroves in the Anosy Region, and these are small in surface area and are of the type referred to as "curtain mangroves." These predominantly grow next to estuaries and lagoons, following a thin, broken fringe about 1 to 2 m wide. In the Anosy Region, these mangroves occur in four separate areas, Petriky, Mandena, Sainte Luce, and Elodrato, whose total combined surface area is estimated at between 20 and 50 ha (ONE 2003).

The Lanirano-Anony Lagoon is protected by a frontal dune bordering the Tolagnaro Bay. The dune is notably damaged in the area downstream from Lake Ambavarano due to massive deforestation in recent years. The banks have eroded and the mangroves bordering the lagoon are under human pressure.

The curtain mangroves have little in the way of plant diversity and are composed of *Bruguiera gymnorhiza* (Rhizophoraceae) and *Lumnitzera racemosa* (Combretaceae), both of which are mangrove species common to the Indian Ocean. These two species are typical of areas with low salt concentration (Koechlin *et al*. 1974) and occupy the verges of swamps and sand bars (Lebigre 1990). These two species link-up to form thin, broken verges on the southern edge of Lake Ambavarano, the south bank of the Anony River, and the downstream part of the Mandromondromotra River. They alternate with fringes of Cyperaceae and strips of *Acrostichum aureum* (Pteridaceae), both of which dominate areas previously occupied by mangroves. Towards the mouth, *L. racemosa* forms a continuous strip about 300 to 400 m in length, with a strip of Cyperaceae. The mangrove borders, where *B. gymnorhiza* and *L. racemosa* connect, play a relatively important role in river stabilization. The downstream portion of the Mandromondromotra River is bordered on the east bank by a verge of *Acrostichum*, where a few *B. gymnorhiza* individuals occur. On the western bank, there is a continuous strip of *B. gymnorhiza* (QMM 2001).

These mangrove zones are under pressure from the local population for use in constructing shrimp traps. Since the curtain mangrove is not very widespread, the pressure seriously threatens this habitat, which is important to the shrimp and crabs populations of the area. However, overexploitation of these

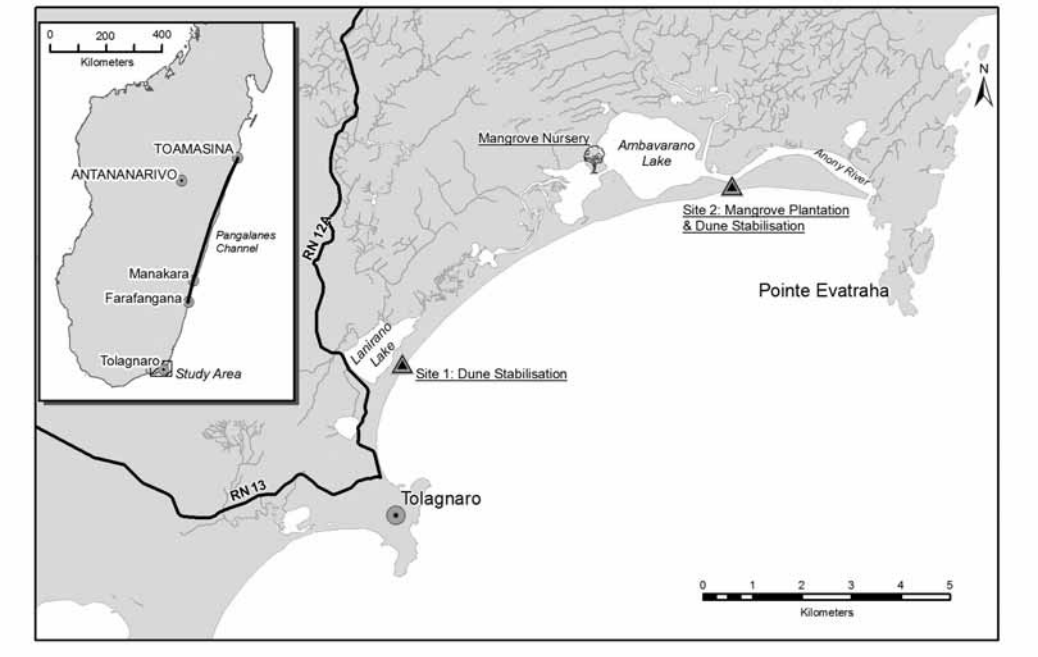

Figure 1. The Lanirano-Evatraha lagoon system and study sites. The inset map shows the relatively straight eastern coastline north of Tolagnaro, and the study area discussed herein.

lagoons and rivers by local human populations, together with destruction of the natural dune vegetation, has resulted in an appreciable loss of productivity in the area (see Réville *et al.* Chapter 5.1). Not only have fishery resources been extremely depleted, but also, at least in the short-term, they seem to have been compromised by the silting-up of the local aquatic habitat due to dune erosion. It was with the intent of curbing this destruction and restoring this ecosystem that research on dune stabilization was initiated on the shores of Lake Lanirano and Lake Ambavarano.

Methods

Mangrove production and plantation

Before restoration, the banks of the Lanirano–Evatraha lagoon system within the zone near 24°58'13"S, 47°03'40"E (Fig. 1), were inventoried and the main problems identified. During the inventories, information was obtained on the percentage of the vegetation left, the slope, and the soil types. After these initial studies, the mangrove tree *Bruguiera gymnorhiza* was selected as the critical plant to regenerate and preserve. This was in part associated with exploitation pressure from villagers due to the hardness of its wood, and the use of its branches in the construction of shrimp traps, for fuel, or for house construction. In its natural habitat, *Bruguiera* easily regenerates when the propagules fall from the tree at maturity. Under favorable conditions (i.e. sandy/silty substrate and permanent humidity created by the proper turning of the tides), the propagules are established easily. Based on our original research, it was clear that, along the banks of the Anony River, the propagules have difficulty germinating because the conditions, associated with sand bank erosion, are not always favorable.

Nursery work

Several *Bruguiera* nurseries were established along the lagoon banks of the Anony River (Fig. 1). These sites were chosen to allow the trees to benefit from tidal movements. The nurseries are set up in basins of different sizes (Table 1). In 2001, three basins were set up, and in 2004, an additional eight basins were set up. In order to propagate *Bruguiera*, the basins have to be of a certain depth so that the water can seep into them at high tide. Basin 1 was located near the water within the high tide zone, and there was no need to dredge the soil. Each basin has two canals, both of which are irrigation canals during high tide and outlet canals during low tide. This system ensures that the soil remains moist.

Table 1. Number and dimension of basins in the *Bruguiera* nurseries along the Anony River.

	Length (m)	Width (m)	Depth (m)
Basin 1	8	4	0.0
Basin 2	3	3	0.7
Basin 3	8	4	0.4
Basin 4	10	4	0.5
Basin 5	15	4	0.5
Basins 6-11	15	4	0.5

Diaspore preparation

At maturity, the diaspores fall directly to the ground or into the water and, through tidal movement, are deposited on the banks where they can germinate. The diaspores are often found on the eastern banks of Lake Ambavarano, about 300 m downstream from Ambatomena. The diaspores were gathered, transported in pails of water, and then potted in plastic pots containing silt. The pots were then placed in the nursery basins. The second method employed involved the diaspores being planted directly into the soil of the basin about 20 cm apart, and then transplanted after germination. The drawback of this method is the fragility of the young roots during transplantation. On average, a diaspore is 17 cm long when it is collected and about 35 cm after 45 to 60 days in the nursery, during which they develop 6 to 8 leaves. Between 2001 and 2005, 6,721 diaspores were planted in the nursery.

Transplanting the mangroves

After two months in the nursery, the seedlings were ready to be moved to their designated sites with appropriate tidal movements and previous mangroves coverage. A hole about 30 cm deep was dug for each plant at 50 cm intervals. Permanent immersion or prolonged dryness (over ten days) may lead to the death of *Bruguiera*.

Dune stabilization

Two experimental sites were set up (Fig. 1): Site 1 - 29 x 20 m plot with a 45° slope that overhangs the fresh to slightly brackish Lake Lanirano; Site 2 - 160 x 40 m plot with a 60° to 70° slope that rises above

the Anony River near a river mouth. Here, the salt content varies considerably depending on the tides. There are mangroves at the base of the barrier dune, but these are highly degraded due to cutting.

Few of the dunes studied retain intact, natural vegetation cover. Only a few remnant trees of the genus *Pandanus* (Pandanaceae) indicate the former vegetation of the shore. The current vegetation is scattered, and consists of a few species of shrubby thicket including *Scaevola* sp. (Goodeniaceae). Due to gradual sand silting, the vegetation is degraded at the foot of Site 2, consisting of a narrow fringe of mangroves.

Selection of the technique

Several parameters determined the selection of techniques to be tested.

1. The sites are inaccessible to earthmoving equipment or cargo carriers. This prohibits the transport of materials by road. Moreover, no rocks or similar materials could be found at the site for strengthening the banks.
2. The use of a "biodegradable" mat made of vegetation was not considered for this trial, given how rare this type of material is in the region. The use of techniques and materials that preserve the natural environment were given priority, particularly local, natural, or naturalized species, and exotic species were avoided in order to prevent the spread of invasive plants.

After conducting inventories of the dune's natural plant species, we opted to use *Scaevola taccada* for soil stabilization. This species, which is often found on dune sand in the coastal areas of western Indian Ocean islands, does not multiply rapidly. It is a shrubby plant that produces abundant fruit every year, has large leaves, and does not exceed 2.5 m in height. It is not used by humans or consumed by livestock, and offers effective protection against erosion. Considering the steep slopes encountered, fascines were also installed to retain the sand and encourage the spontaneous regeneration of vegetation.

For Site 1, three treatments were tested using *Scaevola*: Plants produced in the nursery from seeds gathered that year and the previous year; lignified 20 cm cuttings; and non-lignified 20 cm cuttings.

For Site 2, *Scaevola* was planted from cuttings without having segregating those that were lignified from those that were not. The fascines were made from pieces of wood of the exotic plant *Melaleuca quinquenervia* (Myrtaceae) and bound with galvanized iron wire. They are 1.6 m long x 20 cm in diameter. They were placed perpendicular to the slope, forming more or less parallel lines 1.5 m apart. Each fascine was secured by two 50 cm sticks driven into the sand.

Results

Nursery and mangrove planting

The survival rate of the mangrove seedlings in the nursery was about 95%. Of the 1,120 diaspores planted in the basins in 2001, 53 died after a few weeks of growth. Seedling growth was measured for three individuals that were monitored for nine weeks (Fig. 2). Table 2 presents the level of *Bruguiera* seedling production in the nurseries and reforestation in the lagoon between 2001 and 2005.

Table 2. Number of *Bruguiera gymnorhiza* seedlings planted each year between 2001 and 2005.

Year	2001	2002	2003	2004	2005	TOTAL
Number	1,067	1,214	1,370	1,420	1,650	6,721

The survival rate of transplanted seedlings was calculated for the time between 2002 and 2006. In 2006, only 1,536 of the 6,721 mangrove trees were still alive, representing a survival rate of 23%. Most of the surviving *Bruguiera* were planted at the base of the stabilized dune. A reason for the relatively low survival rates was the prolonged immersion of plants in the water at certain times of the year, which increased plant mortality.

Figure 3 presents the results of monitoring, from 2001 to 2005, the growth rates of a few mangrove samples after plantation in the lagoon. Growth rates of surviving plants were similar, with an average of 40 to 150 cm over the five years.

Dune stabilization

At Site 1, 45 individual plants from the nursery, 20 lignified cuttings, and 70 non-lignified cuttings of *Scaevola* were planted. The survival rate of the plants in the nursery and the non-lignified cuttings was 100%, as compared to 10% for the lignified cuttings. The fascines were, for the most part, destroyed by the actions of local people, and thus, there was little in the way of plant regeneration.

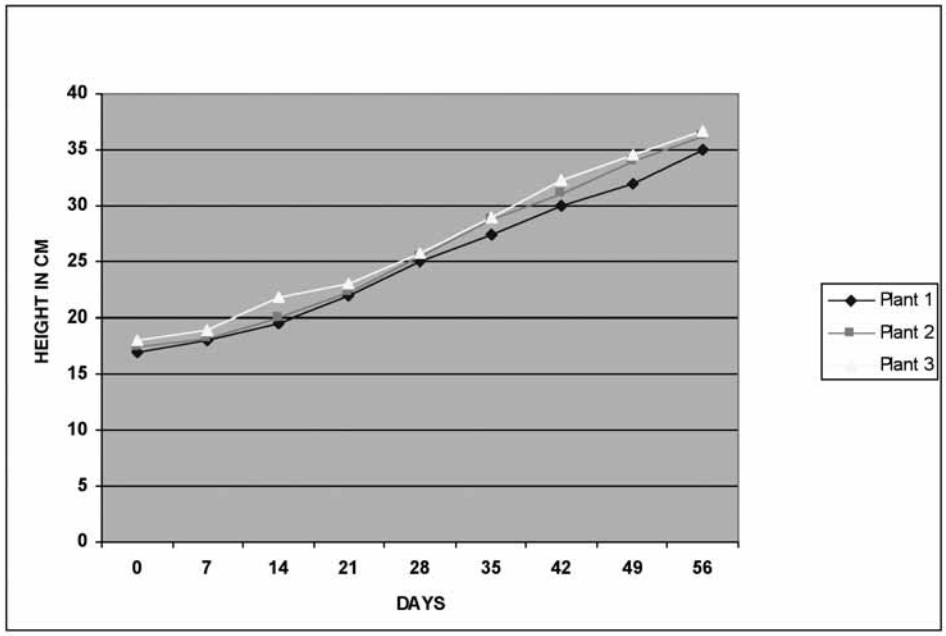

Figure 2. *Bruguiera gymnorhiza* seedling growth in the nursery based on three individuals.

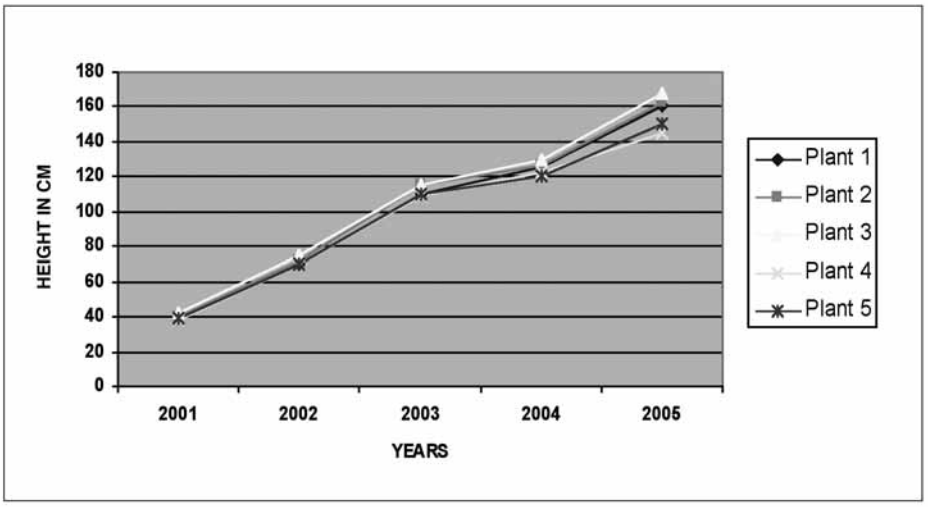

Figure 3. Growth rates of *Bruguiera gymnorhiza* between 2001 and 2005.

A fire ravaged Site 2 and none of the *Scaevola* survived. Subsequently, there was abundant re-establishment of vegetation, consisting mainly of the creeping legumes *Tephrosia purpurea* (Fabaceae), lianas *Ipomoea pes-caprae* (Convolvulaceae), and diverse native graminaceous plants. At this site the fascines remained intact and retained the sand.

Discussion

The installation of fascines on the dune slopes stabilized the sand and prevented erosion, which would have resulted in the siltation of the mangroves and habitat degradation. The results revealed that installing fascines also encouraged the development of moist pockets that promoted the growth of local plants. The mangrove reforestation sites that were able to benefit from stabilization of the upstream dune system produced higher survival rates of replanted *Bruguiera*. At the other sites, the sanding-up of the dune base was associated with low seedling survival. It is clear that dune erosion is a determining factor in the survival of natural and reforested *Bruguiera* plants. Consequently, it is crucial to reduce the erosion of sand and the associated siltation of downstream mangroves. The use of fascines is a simple technique that should be employed before dune reforestation. A mixture of local species and adapted graminaceous plants works well on the stabilized dunes. These procedures can be done on the most degraded portions of the dune, followed by protection against fire, and the prevention of the entry of humans or domestic animals during the first year.

Conclusion

The restoration trials discussed herein made it possible to implement and test simple nursery and steep slope stabilization techniques. The fascines, made out of local materials, are a simple and critical step in the stabilization process. An alternative is the use of *Vetiveria zizanioides* (Poaceae), an introduced species that produces a large root system and enables the sand dunes to be effectively stabilized. Regeneration of *Bruguiera* mangroves is straightforward under the proper soil and tide conditions.

References

Battistini, R. 1972. Madagascar relief and main types of landscape. Pp 1-25 *in*: Battistini, R. and G. Richard-Vindard, eds., *Biogeography and Ecology of Madagascar*. W. Junk B.V., Publishers, The Hague.

Kiener, A. 1972. Ecologie, Biologie et possibilités de mise en valeur des mangroves malgaches. *Bulletin de Madagascar* 308: 49-84.

Koechlin, J., J.L. Guillaumet and P. Morat.1974. *Flore et végétation de Madagascar* Vaduz, Cramer, 687p.

Lebigre. 1990. Les marais maritimes du Gabon et de Madagascar: Contribution géographique à l'étude d'un milieu naturel tropical. Thèse Doctorat d'Etat, Institut de Géographie, Université Bordeaux III, 704 p, (3 livres).

Office National pour l'Environnement (ONE). 2003. Rapport sur l'état de l'environnement, Région de l'Anosy Ministère de l'Environnement et des Eaux et Forêts, 176 p.

QIT Madagascar Minerals (QMM). 2001. Ilmenite Project. Social and Environmental Impact Assessment, Vol. 1 and 2. Presented by QIT Madagascar Minerals S.A. (QMM S.A.) to the Madagascar National Environment Office, May 2001