Chapter 6.4
Growth Results of Five Non-native Fast Growing Species Used to Reforest Sandy and Nutrient Poor Soils

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Abstract

This chapter describes the growth and survival of trees from the initial reforestation project in the Mandromondromotra area, which commenced in 2002. Five fast-growing species were monitored and measured: *Acacia mangium*, *A. crassicarpa*, *Eucalyptus camaldulensis*, *E. robusta*, and *Corymbia citriodora*. Three parameters were measured one year (in 2003) and three years (in 2005) after planting: survival rate, height, and health status. The survival rate of planted trees after three years varied between 60% and 90%, and trees reached a height of 2.0 – 4.9 m. All of the tested species seemed suitable for the tree plantations on nutrient poor, post-mining lands.

Résumé

Résultats de croissance de cinq espèces allogènes à croissance rapide et utilisées pour la reforestation des terrains sableux et pauvres en nutriments. Ce chapitre décrit les aspects relatifs à la croissance et la survie d'arbres du projet initial de reforestation qui avait démarré dans la région de Mandromondromotra en 2002. Cinq espèces à croissance rapide ont été suivies et mesurées, à savoir *Acacia mangium, A. crassicarpa, Eucalyptus camaldulensis, E. robusta* et *Corymbia citriodora*. Les trois paramètres mesurés après un an (2003) et après trois ans suivant la plantation ont été la taux de survie, la hauteur et l'état de santé. Le taux de survie des arbres plantés après trois ans variait entre 60 % et 90 % et les arbres atteignaient une hauteur comprise entre 2,0 et 4,9 m. Toutes les espèces retenues dans les essais semblaient propices aux plantations arborées sur des terrains pauvres en nutriments après exploitation minière.

Introduction

The people of the Tolagnaro region depend on the forest's natural resources and especially on its wood products. Nearly 90% of the population uses wood and charcoal, which provide almost all of the domestic energy consumed. Most of these products, as well as materials for house construction, come from the native forests (QMM 2001). Population growth (see Vincelette *et al.* Chapter 2.1) and an increased need since 1990 for agricultural lands have put added pressure on these forests. In certain places near urban centers, deforestation levels approach or surpass 50% of the original cover (see Vincelette *et al.*Chapter 2.4). As a result, certain native species used as energy wood are becoming increasingly rare. Associated with various factors including the current remoteness of native forests, the unfavorable context for using other sources of domestic energy, and the lack of extensive replanting efforts over the past few decades, regional domestic energy needs can only be met by considerably augmenting the number of new plantations and the associated research on the appropriate trees to be planted.

In the context of the QIT Madagascar Minerals (QMM) project, reforestation research has been carried-out on state-owned lands outside the proposed mining sites with the help of local communities. In addition, rehabilitation of the mining sites will involve an estimated 6,000 ha of land. This chapter discusses the growth and survival of the initial reforestation project in the Mandromondromotra area near Mandena.

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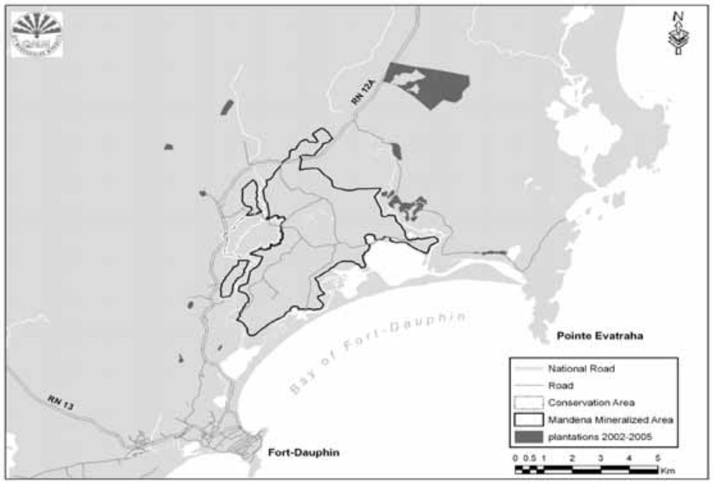

Figure 1. Map of 2002-2005 sites of tree plantations in the Mandena area.

Methods

The reforestation discussed herein was conducted in 2002 at Mandromondromotra (Fig. 1) about 2 km from the sea, and is exposed to prevailing winds from the northeast. Overall, the general landform of the plantation site is flat and the soil is sandy, covered sporadically with a humus layer.

Five exotic species were monitored and measured: *Acacia mangium* (seed source from Ampitambe, Madagascar, with the original stock being from Australia), *A. crassicarpa* (Bensbach, Papua New Guinea), *Eucalyptus camaldulensis* (Petford, Queensland, Australia), *E. robusta* (Noosa State Forest, Queensland, Australia), and *Corymbia citriodora* (Mandena, Madagascar, with the original stock being of unknown Australian origin). The plantations are a mosaic of different-sized parcels, with one species per parcel.

The methodology chosen was a series of randomly distributed rectangular study plots, measuring 18 x 15 m (270 m^2) with six lines of five (= 30) plants per plot, in which the parameters mentioned below and soil color data were gathered. Subsequently, differences were noticed in the soil coloration of the different plots. However, since certain parameters were not available to analyze the effects of soil types, and since there was an unequal number of study plots per soil type, this factor was not taken into consideration. However, one soil type, of which the number of study plots was equally distributed between the species, was analyzed. It was white with a sandy texture and was covered with a thin (2 cm) layer of humus beneath the predominating *Erica* sp. and graminaceous vegetation.

With a reforested surface area of 89 ha for the five equally distributed species, sampling was estimated at 4% of the total surface area of the plantation zone. The following parameters were collected in 2003 and 2005 for each plant: height (cm) from the collar to the crown; health status (good, bad, with burn traces, etc.), which was assessed by signs of desiccation on the foliage and the stem; and stem form (upright, slanted). Estimated growth is based on the calculation of average height per species. In order to estimate the differences in health status and stem form between the species, the χ^2 test was used based on the hypothesis that there are differences between the species tested.

The survival rate for each species was estimated by counting the number of living stems per study plot in 2003 (one year after planting) and in 2005 (3 years after planting) and converting these to percents of the original number of planted trees. It should be noted that a fire passed through the plantation in 2004, affecting 11 ha. A few young trees included in the sampling study plots were touched by the fire, which presumably affected their growth rates. However, these individuals did not die and were included in the statistical analyses.

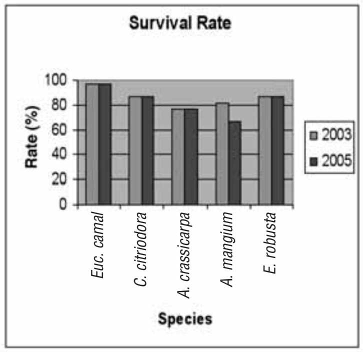

Figure 2. Survival rate for planted species at the Mandromondromotra site.

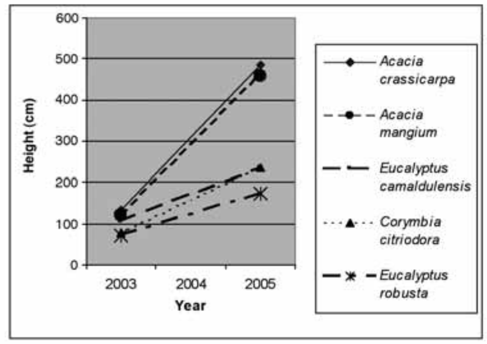

Figure 3. Height growth per species at the Mandromondromotra site.

Table 1. Annual mean growth ± standard deviation of five species reforested in 2002 at the Mandromondromotra site.

Genus	Species	Mean height [cm]		Annual growth [cm]
		2003	2005	
Acacia	*crassicarpa*	134 ± 40	486 ± 79	201
Acacia	*mangium*	118 ± 42	458 ± 55	194
Eucalyptus	*camaldulensis*	114 ± 18	238 ± 47	71
Corymbia	*citriodora*	61 ± 24	236 ± 77	99
Eucalyptus	*robusta*	71 ± 18	202 ± 77	75

Table 2. Number of trees in good health and growing upright of the different planted species as of 2005 at the Mandromondromotra site (n = number of trees sampled).

Species	N	Good health	Growing upright
Eucalyptus camaldulensis	120	98	94
Corymbia citriodora	60	45	53
Acacia crassicarpa	30	23	24
Acacia mangium	60	36	36
Eucalyptus robusta	90	87	87

Results

Survival rate

The survival rate of planted trees varied between 60% and 90%, including individuals that did not grow upright. *Eucalyptus camaldulensis* had the highest survival rate, while *Acacia mangium* and *A. crassicarpa* had the lowest.

Height growth

The annual height growth of the planted tree species averaged between 0.75 and 2 m. *Acacia crassicarpa* and *A. mangium* had the highest growth rates (Table 1, Fig. 3).

Health status

Three years after planting, the species differed in health and growth characteristics (χ^2 = 32.30 and 35.07, respectively; Table 2). *Eucalyptus* species were in good health and grew upright. Many individuals of *Acacia mangium* were not in good health and did not grow upright, even though this was one of the fastest growing species.

Discussion

The level of growth of *Acacia* spp. (2 m/year) illustrates their capacity to adapt to the region's damp climate and poor soil conditions, which, like most sandy soils in the region, has a low pH (4 to 5) and is mineral and organic nitrogen-deficient. The ability of these species to bind atmospheric nitrogen and recycle nutrients through foliage and roots may improve soil fertility. These *Acacia* are also good candidates for firewood and charcoal production (high heating value HHV: 4,619-4,900 kcal/kg, Vale *et al*. 2000). These species are already planted in several countries for industrial papermaking pulp. Our study shows, however, that their survival rate is the lowest of the species tested. This result could be related to the presence of certain diseases likely to affect young *Acacia* trees (Lenné 1992, Mehrotra *et al.* 1996, Old *et al.* 1997). Studies should be done to better define the types of diseases that might be infecting these plants. In certain countries, such as Malaysia, mortality is high (up to 50%) and associated with fungus attacks (Lee 2000). Nevertheless, given their high potential, research has been initiated in Australia, Vietnam, and India in order to select the best seed source areas to improve the viability of plantation trees (shape, vigor, adaptability to certain environmental conditions, etc.). In some cases, experimental results have led to survival rates of up to 80%.

Eucalyptus camaldulensis, the most widespread species of eucalyptus on the Australian continent, and among the first to have been planted outside Australia, has a growth rate on Madagascar lower than that of the other two *Eucalyptus* spp. tested. According to Burren (1994), in the countries where *E. camaldulensis* has been introduced, it develops best in fairly deep alluvial soils, but it also grows in sands and podzols with a damp, clay-like subsurface, conditions which are quite similar to those of the Mandromondromotra site. The experiments conducted in South Africa, Argentina, Israel, Nigeria, Pakistan, Zimbabwe, and Sudan reveal that other *Eucalyptus* species fare better than *E. camaldulensis* in damp conditions with rich soils. Nevertheless, growth rates for this species between two original stock areas may vary by more than 30% (Burren 1994). At an age of eight years, with an average diameter of 10 cm, the volume of usable wood may reach 50 m^3/ha (Burren 1994). Finally, *E. camaldulensis* provides good firewood and charcoal making material (7,900 kcal/kg for charcoal in comparison to 4,700 kcal/kg for firewood, Tanvir 1993). From a management point of view, it is advantageous in that it vigorously coppices from the stem and can sustain water logging as well as drought conditions.

Eucalyptus robusta develops well with upright stems, but has a lower growth rate. It has a heating value of 4,691 kcal/kg (Duke 1983). It is well adapted to the swampy conditions of flooded lands and waterlogged soils. At eight years, with an average diameter of 10 cm, 1 ha may contain 60 m^3 of wood (Burren 1994).

The results obtained from *Corymbia citriodora* appear to confirm the usefulness of this species for acidic and well-drained soils without temporary water-logging. This species appears in the literature among the average-performance eucalyptus trees, but also produces good construction lumber with an important caloric content. At eight years, with an average diameter of 10 cm, 1 ha contains up to 30 m^3 of wood (Burren 1994).

Given the poor quality of the soils in the reforested zones near Mandromondromotra, these results are promising and confirm the need to choose species that are adapted to the local site conditions. Moreover, in order to obtain higher growth rates and maximize other parameters, different seed source areas should be tested for *Eucalyptus camaldulensis* in particular. More in-depth research is needed to determine the suitability of these species in post-mining tree plantations, and the environmental risks associated with their use. Studies conducted in other countries evaluated the effects of exotic species of trees and shrubs on groundwater cycling, soil quality and nutrients, and the regeneration of native species. For example, negative effects, for which *Eucalyptus* spp. are famous, can be mitigated through good soil and tree management practices, cutting methods, etc. (Lima 1993, Mohammad 1996). These types of experiments need to be conducted in the Tolagnaro region to identify possible negative effects and the mitigation measures to implement.

Conclusion

In order to achieve economic growth, a country like Madagascar needs energy and raw material sources available at reasonable costs. Tree plantations are an important partial solution if good source stock for introduced taxa are chosen that adapt well to local environments and have fast growth rates. Further, it is critical that sufficient surface areas are reforested and these plantations are effectively managed.

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