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# *Eucalyptus globulus* in Ethiopian forestry

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ABSTRACT

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*Eucalyptus globulus* Labill. has been planted as the main tree species in the central highlands of Ethiopia since 1895. The success of the 100 000 ha planted so far is based on the adaptability of *E. globulus* to the highland climate and soil conditions, its vigorous coppicing and non-palatability for livestock, and its suitability for fuel and small construction poles. The mean annual growth of *E. globulus* in fuelwood plantations varies between 10 and 30 $m^3$ $ha^{-1}$ $year^{-1}$. Other equally productive fuelwood species have not been identified for the Ethiopian highlands. Despite alleged ecological demerits, like high consumption of water, additional planting of *E. globulus* is justified until the current fuelwood shortage is eliminated. In the long run, parts of Ethiopian *Eucalyptus* plantations may naturally alter in composition into stands of indigenous highland species, e.g. *Juniperus procera, Podocarpus gracilior* and *Olea africana*.

## INTRODUCTION

*Eucalyptus globulus* Labill. was imported into Ethiopia in 1894–1895. The introduction was an immediate success. The new species was quickly adopted by farmers who first started to plant it in the surroundings of Addis Ababa and soon thereafter everywhere in the central highlands of the country. 'Bahir Zaf', as it is locally known ('tree behind the ocean'), is now the most widely planted tree species in Ethiopian forestry: the established plantations total over 100 000 ha. Today and for the near future, *E. globulus* dominates the Ethiopian reforestation program.

It is not entirely coincidental that an exotic tree species, which does not resemble the indigenous trees by appearance, growth or ways of utilization, has become so common. *Eucalyptus globulus* seems to have characteristics that are suited ideally to the requirements of wood users, and to the prevailing ecological, economic and social conditions of the country. This paper addressed the questions: what are these characteristics, and are they still valid

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in the present and future plantation forestry of Ethiopia?; and can planting of *E. globulus* still be justified under the present circumstances?

## HISTORY OF ETHIOPIAN FORESTRY

### *Deforestation and need for fuelwood*

Long-lasting deforestation is typical of Ethiopian forestry (Fig. 1). Deforestation had already started in the 16th Century. The disappearance of the forests has been most drastic during the past 100 years. In the beginning of the 1900s, the forested area was estimated at about 53 million ha, 40% of the land area. In the 1950s the forest coverage had diminished to 16% (21 million ha). During the first half of the century the forests had been cleared at an annual rate of 600 000 ha.

The deforestation rate reached its maximum, 800 000 ha per year, in the 1950s and the early 1960s. By 1965 the forest coverage had decreased to 7% (9 million ha). During the following 20 years the forests disappeared at an average rate of 275 000 ha per year. In 1985 the coverage was 2.7% of total land are (3.5 million ha). The deforestation rate is still about 100 000 ha per year (Bowen, 1985; Anonymous, 1986b). If the trend continues, the remaining forests will be cut down during the next 30 years.

Fig. 1. The central highland of Ethiopia were once covered by a mixed conifer and hardwood forest. The forest cover has now almost totally disappeared as a result of overcutting for fuelwood.

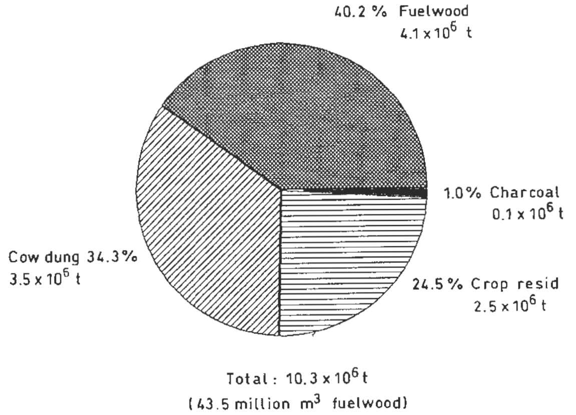


Fig. 2. Share of biomass energy in Ethiopia.

Much of the deforestation is due to overcutting for fuelwood. In the past, all fuel for cooking came from the forest. Wood was also used for heating, lighting, and for small-scale household industry., In 1984, wood and charcoal was sufficient for only 40% of the fuel demand (Fig. 2). The remaining demand was met by other sources of biomass, e.g. cow dung and crop residues (Anonymous, 1984).

*Total drain and plantation needs*

Fuelwood is the dominant component in the total drain from Ethiopian forests. The annual fuelwood cut is about 19 million $m^3$ (Pohjonen and Pukkala, 1987). Timber is also harvested for construction poles (Palm, 1983; Poschen-Eiche, 1987), saw-milling, particle board, fiber board and plywood (Melaku Abegaz and Addis Tsehaye, 1987). There is no chemical wood industry in the country. Counting all the uses of harvested wood, the total drain can be estimated at 21 million $m^3$ per year.

In sustained forestry, the drain of 21 million $m^3$ per year corresponds to about 5 million ha of well-managed indigenous forests. The remaining forests meet only about 65% of the present demand. Plantation forestry is the only way to cease the deforestation and to turn forestry from the current unsustainable mode into a sustainable one.

About 1 million ha of fast-growing plantations alone could satisfy the annual fuelwood demand. The established plantations (310 000 ha; Bowen, 1985) thus, in theory, cover about one-third of the required area. Some of the plantations are, however, poorly stocked and they do not produce fuelwood in substantial quantities. Many of the stands have been planted for industrial use with the slow-growing *Cupressus lusitanica* Mill.

Substitution of cow dung and crop residues for fuelwood is the aim of Ethiopian energy forestry. This would raise the annual fuelwood demand to about 45 million $m^3$. To meet this increase in demand, the plantation area needs to be in the range of 2–3 million ha. These figures correspond to the present population of 45–47 million people. Taking into account the population growth rate of 2.9%, the total fuelwood demand will rise by the year 2000 to 67 million $m^3$ per year, and the area needed for plantations up to 3–4 million ha.

*Choice of indigenous species for the Ethiopian highlands*

A multitude of valuable indigenous trees species, such as *Juniperus procera* Hocht. ex Endl., *Podocarpus gracilior* Pilger, *Pygeum africanum* Hk. f. and *Aningeria adolfii-friederichii* (Engl.) Robyns & Gilbert, grew in the original Ethiopian highland forest. The most valuable timbers were desired for construction and saw-milling, but the tops and branches were always used as firewood. Some other species were harvested only for fuel; *Olea africana* Mill., especially, produced desired fuelwood because, besides its good fire properties, its smoke has a repellent effect on insects.

Unfortunately for planting programs, the most valuable indigenous tree species are found in late-successional forests. Cultivation of Ethiopian climax trees is difficult. They usually only regenerate in the shade of a mature forest. If the seedlings are planted in an open area, they either soon die in the sun, grow slowly during the years of stand establishment, or develop into multistemmed, crooked bushes. Even if plantation establishment could be managed with indigenous species, the long rotations up to 60–100 years do not render them attractive as plantation species. This is especially true in the present fuelwood production, as the new plantations should produce fuelwood quickly.

Productive pioneer tree species suitable for plantation forestry have not been found in the Ethiopian flora. The indigenous pioneer species, such as *Dodonia viscosa* (L.) Jacq., are usually bushes and shrubs, which are not desired in planting. Otherwise feasible pioneer species, e.g. *Erythrina abyssinisa* Lamm. ex DC. and *Cordia africana* R. Br., grow very slowly. Due to the lack of suitable indigenous plantation species, the recommendations of the National Forestry Service for short-rotation forestry rely on exotic pioneer tree species, *Eucalyptus* and wattles (*Acacia decurrens* Willd. and *A. mearnsii* De Wild.) (Anonymous, 1985c, 1986a).

*Arrival of E. globulus in Ethiopia*

Introduction of *E. globulus* in Ethiopia was an immediate success. At the end of the 19th Century there was a fear that the recently established capital city, Addis Ababa, should be abandoned due to the deepening fuelwood shortage. Planting of *Eucalyptus* was suggested as a solution for the problem. The two key persons behind the idea were a French railway engineer named

TABLE 1

Plantation establishment rate (ha $year^{-1}$) in the Addis Ababa *Eucalyptus globulus* forest

| Period | Planting rate | Planted area[1] (ha) |
|---|---|---|
| 1895–1937 | 107 | 4 500 |
| 1937–1957 | 280 | 10 100 |
| 1957–1964 | 485 | 13 500 |
| 1964–1974 | 150 | 15 000 |

[1]At end of each period.

Mondon-Vidaillet and a British army captain named O'Brien (Von Breitenbach, 1961; Horvath, 1968).

Mondon-Vidaillet proposed to Emperor Menelik II the establishment of a trial plantation of *Eucalyptus*. Seed of 15 species were imported. Soon the planting of *E. globulus* and *E. camaldulensis* Dehnh., accompanied with a small number of *E. tereticornis* Sm., spread on a practical scale. In the beginning of the 20th Century, some landowners planted small areas in the suburbs of Addis Ababa in order to sell small poles and fuelwood. Encouragement by the government, such as tax relief for land planted with *Eucalyptus* and free distribution of seed, increased planting. Around 1920 the streets and paths of Addis Ababa resembled clearings in an *Eucalyptus* forest. It was even suggested that the name of the city might appropriately be changed into Eucalyptopolis (Berlan, 1951).

The Italians were the first who surveyed the Addis Ababa *Eucalyptus* plantations during their occupation (1935–1940). The forest area was estimated to be not less than 4000 ha, and more likely over 5000 ha (Giordano, 1938; Horvath, 1968). In 1957 the forest stands covered a gross area of 17 600 ha, with a fully stocked net area of 10 000 ha. By 1964 the gross area had expanded to 24 600 ha and the net area to 13 500 ha (Horvath, 1968). The plantation establishment rate was at its maximum, near to 500 ha per year, between 1957 and 1964 (Table 1).

Establishment of *E. globulus* plantations around Addis Ababa continued for a further 10 years, until the revolution and land reform of 1974–75. The net area of *Eucalyptus* forest reached 15 000 ha (Persson, 1975). Planting had also spread from Addis Ababa to the other highland towns. Altogether the *Eucalyptus* plantations covered about 91 000 ha by the mid 1970's (Henry, 1973; Anonymous, 1981c).

### *New plantations*

The land reform ceased the establishment of plantations for about 10 years. It was restarted in 1984 with international support, when the United Nations

Sudano-Sahelian Office (UNSO) initiated a fuelwood plantation program. During 1984–1988, over 9000 ha were planted in three project sites: Nazret (Anonymous, 1982), Debre Birhan (Anonymous, 1985d) and Dese (Anonymous, 1983).

Besides UNSO plantations there are two large fuelwood projects in the country. The African Development Fund is financing plantation establishment with a total target of 15 000 ha around the capital (Anonymous, 1981a). By the end of 1988, about 10 000 ha of this target was completed. Another fuelwood plantation project is financed by the World Bank (Anonymous, 1985a). First plantings of 500 ha took place in 1988. *Eucalyptus globulus* is the main species in all externally funded planting programs.

The post-revolution establishment of *Eucalyptus* plantations totalled about 20 000 ha by the end of 1988. This is not regarded as sufficient. The Ethiopian Forestry Service has ambitious plans to reforest 2.9 million ha of the highlands (Anonymous, 1981d). Most of this reforestation would be for fuelwood, *E. globulus* being the obvious main species.

### *Uses of E. globulus*

Cooking fuels are the only significant energy use for the majority of the Ethiopian urban population and for nearly all the rural population. Current cooking practices consume much energy, due to the open-fire baking of the national injera bread (made of teff millet of Abyssinia, *Eragrostis tef* (Zucc.) Trotter), which consumes about half of all household cooking fuels (Anonymous, 1984). *Eucalyptus globulus* is a desired fuelwood in households. All the biomass above the ground is collected and utilized. Especially desired are the dry leaves which give a fast, hot fire under the clay discs on which the injera bread is baked.

Another use of *E. globulus* is for poles. Small poles are used in construction. The traditional way of building a house is to erect a frame from poles of 5–10 cm in diameter and about 3 m in height. The frame is covered during the rainy season with a mixture of mud and hay (straw of *Eragrostis tef*). The mud hardens during the dry season, and the walls can be limed and painted. Poles of a larger size are used for telecommunication and electricity transmission lines. The total capacity of the four wood-preservative impregnation plants in the country is 80 000–100 000 *Eucalyptus* poles and posts per year (Melaku Abegaz and Addis Tsehaye, 1987). Although *E. globulus* is not the best species for transmission-line and other poles (straighter *E. saligna* Sm. is more desirable), it is commonly used due to the lack of other species.

*Eucalyptus globulus* is also the main species in the manufacturing of fibre board and particle board. Annual fibre-board production is 1000–2000 t, and particle-board production is about 6000 $m^3$. Sawmills in Eritrea use *Eucalyp-*

*tus* for boxes and crates for fruits, vegetables and beverages (Järvholm and Tivell, 1987).

## PROPERTIES OF *E. GLOBULUS* AS A PLANTATION SPECIES

### *Adaptation to climate and soil*

The central highland plateau of Ethiopia, a few degrees north of the equator, resembles by climate the original growing environment of *E. globulus* in Tasmania. The main part of the plateau has altitudes in the range of 2000–3500 m above sea level. The daily temperature maxima seldom rise above 25 °C, and the nights are chilly. In November–January mild frosts occur, but they seldom cause serious damage to *E. globulus*.

Typical of the highlands is the bimodal rainfall pattern. The total annual precipitation is 1000–1200 mm, of which 20–30% is received during the short rains in February–April and the main part during the heavy rains in July–September (Griffits, 1972).

The main planting season is July. Critical for the survival of the planted seedlings is the duration of the first dry-season between the end of September and the beginning of February. Provided that planting can be completed during the first four weeks of the heavy rains, about 75% of the *E. globulus* seedlings survive over the dry-season. On the drier and lower side of the plateau *E. camaldulensis* succeeds better and is more widely planted.

The soils in the central plateau are either residual soils, or alluvial and colluvial soils moved by rains, erosion and rivers. The fertility of the highland soils varies considerably, especially in the content of phosphorus. Soils fertile enough for *E. globulus* are found, however. Many of the Addis Ababa *Eucalyptus* forests grow on basaltic black soils which are rather rich in original phosphorus content (Ochtman, 1978). The fertile parental origin of the highland soil partly explains why many Ethiopian *Eucalyptus* plantations have been successfully grown in a monoculture for decades, even after complete harvesting of stems, branches and leaves on a short rotation cycle, and without substitutive fertilization.

### *Silvicultural properties*

Under Ethiopian conditions, *E. globulus* is easy to establish, probably the easiest of all plantation species. The seed trees flower soon, starting at the age of 5 years, and they produce seed profusely every year. Seedlings are raised in plastic pots (Fig. 3). Although labor-demanding, this method has been found to be the most secure. The nursery periods takes about four months. *Eucalyptus globulus* does not regenerate naturally in Ethiopia.

*Eucalyptus globulus* seedlings are planted into predug pits of 40 cm diame-

Fig. 3. Filling seedling pots in an Ethiopian nursery. Seedling production, silviculture and harvesting rely on labor-intensive methods.

ter and 40 cm in depth. The seedlings are weeded at least once per year for the first two years. Filling the gaps is necessary over 2–3 years following the planting. After the 3rd year the mortality rate is very low.

Perhaps the most important reason for the popularity of *E. globulus* is the unpalatability of its leaves to cattle. In its juvenile form, *E. globulus* is seldom browsed by cattle, sheep or goats, which gives it an advantage over almost every other tropical plantation species. This feature has been especially important in the Ethiopian highlands, which are grazed by the largest numbers of livestock in Africa, numbering 150 million head.

*Eucalyptus globulus* is the most vigorously coppicing of all the local plantation species; at least 4–5 coppice crops can be harvested from one stool. *Eucalyptus globulus* has traditionally been grown in Ethiopia under short-rotation management, often 3–5 years only. Harvesting is done with axes, producing a stump length of 30–50 cm. The average length of the stump is clearly more than recommended (Anonymous, 1981b), and ax-felling seems often to damage the stump. However, there is a strong opinion among Ethiopian forest workers that felling by axe gives better coppicing than felling by saw (Wessman, 1987).

In the southern regions of Africa, *E. globulus* has been seriously attacked by eucalyptus snout beetle (*Gonipterus scutellatus* Gyll.). This insect pest occurs in all the African highlands south of Kenya. In countries like Lesotho the attack has been so severe that planting of *E. globulus* has been stopped, and more resistant species like *E. rubida* Deane & Maid., *E. macarthurii* Deane & Maid. and *E. nitens* (Deane & Maid.) Maid. are planted instead (Richardson, 1985; Richardson and Meakins, 1986). So far, *Gonipterus scutellatus* has not been recorded in Ethiopia. Maybe the desert zone between Kenya and Ethiopia is wide and dry enough to prevent invasion. Or maybe the Ethiopian highlands are too windy and arid during the dry-season for the snout beetle to survive. *Gonipterus scutellatus* is, however, a continuing, serious threat.

## GROWTH OF *E. GLOBULUS*

The early Ethiopian plantings of *Eucalyptus*, or any other species, were not subject to research; there were no systematic measurements on possible growth differences between eucalyptus and indigenous trees, nor between *E. globulus* and other *Eucalyptus* species. Consequently, for the first 60–70 years there is no documented justification, based on growth performance, as to why *E. globulus* was to be favored as a plantation species.

The first species trial was established in 1956. Twelve potential plantation species, indigenous and exotics, were planted in Holetta Agricultural Research Station, 50 km west of Addis Ababa. This trial confirmed the superior growth of *E. globulus*. Over 31 years *E. globulus* produced a volume of 955 $m^3$ $ha^{-1}$, which corresponds to a mean annual increment of 31 $m^3$ $ha^{-1}$ (Pohjonen and Pukkala, 1989). The growth rate was clearly more than that of the non-eucalypt species, *Pinus radiata* D. Don., *P. patula* Schiede & Deppe, *Cupressus lusitanica, Acacia decurrens* and *Juniperus procera* (Anonymous, 1985c; Örlander, 1986). The only species with a comparable growth was another eucalypt, *E. saligna*.

An important set of trials was established by the Forest Research Center in 1975. Stand-size plots with a number of different eucalypts, other exotic species and some promising indigenous species, were established in three sites. Menagesha (30 km west of Addis Ababa), Hamulo (250 km south) and Bellete (300 km south-west). The sites well represent the central plateau. These trials have been measured twice, at the age of 5 years (Mebratu Mihratu et al., 1983) and at the age of 10 years (Örlander, 1986). The earlier results were confirmed; as far as volume and biomass growth are concerned, eucalypts were superior to the other exotic species and to the tested indigenous species. If the average 10-year growth of the best four eucalypts is denoted by 100%, the corresponding figure for the four best exotic conifers (2 *Cupressus* spp., 2 *Pinus* spp.) is 55, and 18 for the best indigenous species (*Juniperus procera*). In the rainfall zone of 1000–1200 mm $year^{-1}$ (around Addis Ababa), *E. globulus* did best, whereas at the moister western edge of the plateau, in the rainfall zone of 1400–1600 mm $year^{-1}$, best growth was measured for *E. saligna, E. grandis* W. Hill. ex Maid. and *E. viminalis* Labill.

These measurements have been used as the main basis for species recommendation for plantation forestry in the central highlands (Bowen, 1985; Anonymous, 1985c, 1986a). The recommendations are well in line with the Ethiopian highlands reclamation study (Booth, 1985) which denotes that "data from local species trials show that the genus *Eucalyptus* is the most efficient converter of energy into biomass. Since maximum biomass of fuel and poles per unit area is what the country must have urgently, the eucalypts can do this best."

The possible growing sites of *E. globulus* fuelwood plantations have been divided into four site-fertility classes (Pohjonen and Pukkala, 1987). The classification is separate for seedling and coppice crops. According to the yield tables made for fuelwood plantations, the mean annual increment of the best site class is 44 $m^3$ $ha^{-1}$ $year^{-1}$ in seedling stands, and 46 $m^3$ $ha^{-1}$ $year^{-1}$ in coppice stands during the two first coppice rotations. In the poorest site class the corresponding figures are 9 $m^3$ $ha^{-1}$ $year^{-1}$ for the seedling rotation and 13 $m^3$ $ha^{-1}$ $year^{-1}$ for the coppice rotations. Most of the planted fuelwood plantations belong to rather poor site classes, where the expected yield will be between 10 and 20 $m^3$ $ha^{-1}$ $year^{-1}$ (Fig. 4).

Fig. 4. Seven-year-old *Eucalyptus globulus* plantation. The altitude of the site is 2800 m above sea level. The dominant height of the stand is 15 m, and the stand volume 80 $m^3$ $ha^{-1}$.

The rotation that maximizes wood production is 18–19 years for seedling stands and about 14 years for coppice stands. A typical feature of recently planted *E. globulus* plantations, when compared to other countries, is the slow initial growth for the first 3–6 years. This may be due to less-intensive tending of young plantations in Ethiopia than elsewhere. Another reason is probably the lack of nutrients in the topsoil. The plantations are typically established on eroded hillsides or previous farmlands which have been cultivated for prolonged periods without any fertilizers.

According to the economic calculations of Pohjonen and Pukkala (1988), the rotations that maximize the land expectation value of the plantations are 12–20 years for seedling rotation and 8–16 years for the coppice rotations, with discounting rates ranging from 2 to 8%. Thinnings increase the land expectation value by a few percentage points. With the present prices of wood assortments in Ethiopia, the land expectations value is usually much higher in forestry than in agriculture, except in very poor areas or in waterlogged soils unsuitable for *E. globulus*.

## CONCLUSIONS

*Eucalyptus globulus* is the most important plantation species in Ethiopia. It has been planted for a longer period than any other species, indigenous or exotic. The ecological, economic and social risks involved in the planting have become known during the past 100 years. So far the risks have been managed; no serious drawback in plantation forestry has been recorded.

The Ethiopian population has been used to the planting and use of *E. globulus* for 2–3 human generations. In fact, the people commonly believe that the species is indigenous. It is a desired fuel in everyday life, especially for baking and cooking. The poles of *E. globulus* are favored in light construction.

The national species trials have not shown any species for the central highlands which can outyield *E. globulus*. Besides, the next-most-productive species are other eucalypts. Plantation establishment and silviculture with *E. globulus* are easy and well known to the highland people.

The arguments are strong in favor of continuing plantation forestry with *E. globulus*. The species, however, does have disadvantages. The ecological effects of all eucalypts are generally regarded to be negative (Anonymous, 1985b). Eucalypts are alleged to disturb the water and nutrient balance of the soil and promote erosion by preventing the growth of ground vegetation. The displacement of natural, indigenous forests with exotic eucalypt plantations is therefore regarded as harmful. However, this argument does not apply in the afforestation of the bare Ethiopian highland sites, which were deforested a long time ago. In these cases the ecological effects of eucalypt plantations are mostly beneficial when compared to the present barren state of the sites.

Fast-growing eucalypts are neither ideal multi-purpose nor agroforestry trees, but they are efficient producers of biomass. Keeping this in mind, the positive effects outweigh the negative ones in short-rotation fuelwood plantations. As long as more or nearly equally productive alternatives are not found, *E. globulus* should not be eliminated from the Ethiopian energy-forestry program.

The dominance of *E. globulus* is likely to continue as long as there is a need to solve the shortage of fuelwood. The diversification of species composition should, however, be a constant aim, preferably in favor of original *Juniperus/Podocarpus/Olea* highland forest. This will perhaps happen naturally in the present fuelwood plantations. *Juniperus procera* and *Podocarpus gracilior*, especially, start easily to regenerate naturally under *E. globulus* if there are some seed trees in the vicinity and the forest is closed from grazing. This would facilitate a partial restoration of indigenous forests during the 4th and 5th fuelwood rotations of *E. globulus*.

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