FACTS ON

GROWING AND USE

OF EUCALYPTUS

IN KENYA

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Cover photographs (Photos by: P. Oballa)

1. Eucalyptus stand with dry twigs for domestic firewood
2. Industrial fuelwood
3. Electricity transmission poles
4. Eucalyptus plantation interspaced with natural forest for biodiversity and riparian conservation

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Foreword

Eucalypts are the most widely cultivated forest trees in the world. The genus Eucalyptus comprises more than 900 species and various hybrids and varieties. Most eucalypts occur naturally in Australia. In Kenya, eucalypts were introduced in 1902 to provide fuelwood for the Kenya-Uganda railway. Currently, eucalypts are used for fuelwood, timber, plywood, transmission poles, pulp, building materials, fencing posts, windbreaks and ornamentals.

Eucalypts are grown in most ecological zones in Kenya and on a variety of soils including infertile sands and heavy clays. The total area under eucalypts in Kenya is about 100 000 ha distributed in gazetted forests, and land owned by large private companies, small scale farmers and local authorities. The area under Eucalyptus is likely to increase as a result of high demand for transmission poles to cater for the ongoing expansion in rural electrification, and for construction, fuelwood, carbon sequestration and mitigation of the effects of climate change.

A ready market for Eucalyptus products has motivated farmers to grow the species to improve their livelihoods through increased income. However, extensive growing of eucalypts has generated controversy on high water use by the species and negative effects on soil fertility and biodiversity. Concerns have also been expressed on adverse effects of growing eucalypts near water sources because of observed drying of streams, rivers and springs. Nevertheless, farmers continue to grow Eucalyptus because of its fast growth and good economic returns.

To address these concerns, the government has recently provided guidelines on growing Eucalyptus trees and is presently working on a policy to guide growing of the species in Kenya. As a third government effort, this booklet presents important facts on growing and use of Eucalyptus in Kenya. The booklet will contribute to effective growing of Eucalyptus with minimum adverse effect on the environment leading to increased forest cover, carbon storage and renewable energy, improved livelihood and creating wealth for the citizens.

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1.0 Introduction

The genus Eucalyptus is in the family Myrtacea. Globally, Eucalyptus comprises more than 900 species and unknown number of hybrids and varieties (Boland *et al.*, 2006). Most Eucalyptus species (eucalypts) occur naturally in Australia. A few species are naturally found in Philippines, Papua New Guinea, Indonesia and Timor. Eucalypts grow in diverse ecological conditions with some hardy species growing in semi-arid areas, while others are able to grow on marshy and swampy sites. Eucalypts also grow under a variety of soils including fertile loamy soils, infertile sands and heavy clays.

Eucalypts are among the most widely cultivated forest trees in the world. The major Eucalyptus growing countries are: China (170 million ha); India (2.5 million ha); and Brazil (3.7 million ha) (Davidson, 1995; Stape *et al.*, 2001; Stape, 2002; Liu and Li, 2010; ICFRE, 2010). In Africa, South Africa has the largest area under Eucalyptus plantations of about half a million hectares (Teketay, 2003).

In Kenya, eucalypts were introduced as early as 1902. About 100 species have since been introduced and 83 have been planted at various times at KEFRI Arboretum, Muguga (Gottneid and Thogo, 1975). Out of the 83 species planted in the arboretum, only 71 have survived. Of these 4 are fast growing, 14 are moderate, and 53 are slow growing (Annex I). The aim of the initial introduction was to identify fast growing Eucalyptus species to supply woodfuel for the Kenya-Uganda railway. The uses of eucalypts have since increased and now include timber, plywood, transmission poles, pulp, building materials, fencing posts, rails (fitos), windbreaks, ornamentals and environmental enhancement. Eucalypts are also important in providing products that would otherwise be sourced from natural forests.

The total area under eucalypts in Kenya is estimated at 100 000 ha comprising: 15 000 ha in gazetted forests; 35 000 ha on private land owned by large companies; and 50 000 ha on land owned by individual farmers and local authorities in form of woodlots, ornamentals, boundary planting, avenue planting and scattered trees on communal land (KFS, 2009). Growing of eucalypts is expected to expand due to high demand for wood for renewable energy, carbon sequestration and mitigating climate change (Ball, 1995; Binkley and Stape, 2004; FAO, 2009). However, it is important that when planting eucalypts, environmentally sensitive areas such as wetlands are excluded (Sonkoyo, 2009). Currently, most of the eucalypts in Kenya are grown as investments for financial gain. Accordingly, financial analysis of growing eucalypts is necessary. This booklet will guide entrepreneurs on eucalypts to make informed decisions on how to grow the appropriate species sustainably and profitably.

2.0 Eucalyptus Species Planted in Kenya

2.1 Distribution

Eucalypts are grown in agro-climatic zones II, III and IV. The major Eucalyptus growing areas in Kenya include Western Region, Central Rift Valley, Central Kenya, parts of Eastern and the Coastal regions (Figure 1).

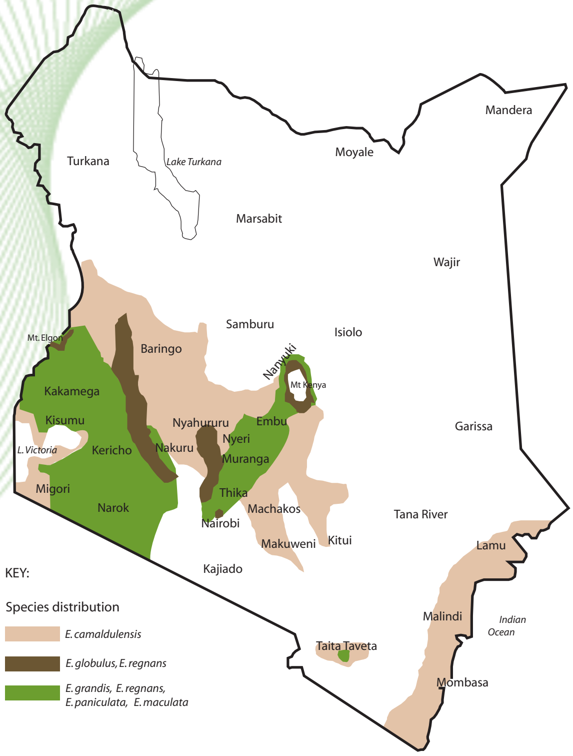

Figure 1. Areas where major Eucalyptus species are grown in Kenya

Although the genus Eucalyptus is spread across diverse ecological conditions, various species thrive under different altitude and rainfall regimes. The recommended areas for growing various Eucalyptus species in Kenya are shown in Table 1.

Table 1. Recommended areas for growing Eucalyptus species in Kenya

Species	Altitude (m)	Minimum annual rainfall (mm)	Recommended areas for planting
E. grandis	1400-2200	1000	Greater districts of Bungoma, Kakamega, Trans Nzoia, Uasin Gishu, Nandi, Kericho, Kisii, Nyeri, Kiambu
E. saligna	1600-2500		
E. globulus	2000-3000	1000	Molo, Nyandarua
E. regnans	2500-3000	1000	South Kinangop, Molo, Timboroa, Londiani
E. paniculata	1600-2000	1000	Nairobi, Nakuru, Nanyuki
E. maculata			Nyeri, Nairobi, Nakuru, Nanyuki
E. camaldulensis	Up to1400	600	Dry areas of Nyanza, Coast, semi-arid lowlands
E. citriodora	1200-2000	1000	Lower areas of Nyanza, Nakuru, Nyeri, Nanyuki
E. urophylla	Up to1400	1000	Coast, Meru, Lower Nyanza
Eucalyptus hybrids	Up to1700	750	Coast, Lower Nyanza, Mid-Eastern, Lower Western

2.2 Attributes of major Eucalyptus species

The main Eucalyptus species grown in Kenya are; *Eucalyptus grandis*, *E. saligna*, *E. camaldulensis* and *E. globulus*. Other species planted on small scale are *E. regnans*, *E. paniculata*, *E. maculata* (presently renamed *Corymbia maculata*) and *E. citriodora* (presently renamed *Corymbia citriodora*). Eucalyptus hybrids are also now planted widely in the country (Muchiri *et al.*, 2005; RELMA, 2006). Attributes of major Eucalyptus species are described below:

Eucalyptus grandis Maiden (Rose gum)

Eucalyptus grandis is a straight fast-growing tree, that can grow to a height of up to 50 m and diameter at breast height (dbh) of 2 m. Occasionally, the species is morphologically confusing due to frequent mixtures of hybrids formed between *E. grandis* and *E. saligna*. In Kenya, the species has high growth rate in the highlands, where altitude ranges from 1400 to 2200 metres above sea level (m.a.s.l.) and mean annual rainfall above 900 mm. The species prefers moist well-drained soils, but grows in a wide range of soil types (FAO, 1979). It has few noted diseases and pests. However, it is sensitive to frost and drought (NAS, 1980). Kenya Forestry Research Institute (KEFRI) through re-introduction, selection and breeding, has developed fast-growing straight trees that attain mean annual volume growth of above 45 $m^3ha^{-1}yr^{-1}$ and height growth of 5 m yr^{-1} at age 3 to 5 years (Oballa and Giathi, 1996). *Eucalyptus grandis* is mainly grown for transmission poles, pulpwood, domestic and industrial woodfuel, and is increasingly becoming a timber species.

Eucalyptus saligna SM (Blue gum)

Eucalyptus saligna is a straight tall tree that grows to a height of 40-50 m and dbh of 1.5 m. Occasionally, it attains a height of 70 m. In Kenya, *E. saligna* grows between altitude of 1600 to 2500 m.a.s.l., but performs better in areas above 2200 m.a.s.l. with cool climate (Maundu and Tengnas, 2005). Under these climatic conditions, the growth is faster than that of *E. grandis*. The heartwood is pink to red and moderately durable and easy to work. The species is widely used for poles, posts, timber, pulpwood, furniture, veneer and shelterbelts.

Eucalyptus camaldulensis Dehnh (River red gum)

Eucalyptus camaldulensis originates from most of the Australian mainland. This species grows to height of 40 m and dbh of 2 m (NAS, 1980). It has wide-spreading branches and flaky bark. Trees from tropical north of Australia are usually slender-stemmed and up to 25 m tall, with erect or bent pink, cream, or white bole. Those from the sub-tropical south have thick-bark. Some provenances of this species are often crooked with weeping branches. The species has marked morphological variations as witnessed in trees grown in Kenya. In Kenya, *E. camaldulensis* grows from sea level to an altitude of 2200 m.a.s.l. (Maundu and Tengnas, 2005).

The best performance in growth is obtained at lower elevations below 1400 m.a.s.l. with mean annual rainfall of 600 to 1000 mm. It has the ability to survive on relatively poor saline soils and in areas with prolonged dry seasons. Trees from various *E. camaldulensis* provenances have shown remarkable variation in growth performance (Eldridge *et al.*, 1994; Maua, 1997). Through re-introduction, selection and breeding, Kenya has developed fast-growing straight trees that attain annual height growth of 4 m. The red heartwood of mature *E. camaldulensis* trees is hard, durable and relatively resistant to termites. The tree is used for poles, posts, construction timber, woodfuel, ornamental, shade, windbreak and swamp reclamation as it tolerates waterlogging.

Eucalyptus globulus Labill (Tasmanian blue gum)

Eucalyptus globulus originates from South-eastern Tasmania and Southern Victoria in Australia. The trees are tall, straight, and attain a height of 70 m and dbh of 2 m under favourable climatic and site conditions. The tree bark is rough, deeply furrowed, gray and persistent at the base of the trunk. Above the base, it sheds the bark in strips leaving the branches and the greater length of the trunk smooth-barked.

The species is called blue gum because of conspicuously broad blue-gray juvenile leaves. Mature leaves are narrow, sickle-shaped and dark shining green with a menthol scent when crushed. In Kenya, it grows well in highlands above 2000 m.a.s.l. (Maundu and Tengnas, 2005). However, Gonoptera beetles often attack *E. globulus* and this has led to its reduced planting in some areas. The light yellowish brown heartwood of mature trees is hard, heavy, strong and moderately durable. The wood is used for poles, posts, veneer and timber. Young leaves are blue-grey and produce pale-yellow oil that is used in making of pharmaceutical products, perfumery and soap. The species is also used as bee forage, windbreak and ornamental.

Eucalyptus urophylla Blake (Timor mountain gum or Timor white gum)

Eucalyptus urophylla is a moderately large tree that can attain a height of 50 m and diameter of 2 m on favourable sites. The bole is straight and clear up from half to two-thirds of tree height. There is considerable variation within the species in terms of rough bark retention which ranges from partial to full bole. The species has a pinkish stem. Some varieties have thick soft corky bark. In Kenya, experimental trials have shown that the species is suitable for Coast, Nyanza and Eastern Provinces, in areas with mean annual rainfall of 1000 mm. The species seeds better in high altitude areas (above 2000 m.a.s.l.) but growth and tree form is poor at such altitudes. *Eucalyptus urophylla* is used for transmission poles, posts, pulpwood, fuelwood and construction timber.

Eucalyptus citriodora Hook (Lemon scented gum)

Eucalyptus citriodora (synonym *Corymbia citriodora)* occurs naturally in Central and Northern coasts of Queensland, Australia. It grows to about 45 m in height and a dbh of 1.3 m. It has attractive white, red, or faintly bluish bark. It has adapted to cultivation in a number of countries with widely differing climate and soil types. Because of its fast growth, excellent bole form, and good timber quality, the species is increasingly being cultivated (NAS, 1980). The leaves have lemon scent hence the species is grown for perfumery oil. It has also been grown for fuelwood at various experimental sites by KEFRI. Some farmers, especially in Kano plains, have planted the species for domestic and commercial use in construction, fuelwood and poles for scaffolding.

Eucalyptus maculata (Hook) K.D Hill & L. A. S. Johnsun (Spotted gum)

Eucalyptus maculata (synonym *Corymbia maculata)* originates from eastern Australia. It is a tall tree that attains a height of 40 m and dbh of over 1.2 m. It has similar characteristics as

E. citriodora, but its leaves lack the lemon scent. It grows in dry highland areas and provides good shade in pasturelands. The wood is heavy, strong, tough and moderately durable. The species has been used for railway line sleepers due to its high density. *Eucalyptus maculata* is also used for shelterbelts, as ornamental and for timber.

Eucalyptus paniculata SM (Grey iron bark gum)

The species origin is New South Wales in Australia. It grows to a height of 30-35 m and produces straight stems and therefore a good species for production of poles. It is hardy and more suited to dry highland sites. Its rate of growth is lower than that of *E. grandis* and *E. saligna*. The mature wood is strong and resistant to decay. It is mainly used for poles, sleepers, house floors, bridge construction, fuelwood and charcoal.

Eucalyptus regnans F. Muell (Mountain ash)

Eucalyptus regnans originates from Tasmania and Victoria in Australia. The species attains a height of 100 m. Mountain ash forests are the tallest hardwood forests in the world. *Eucalyptus regnans* is not widely grown in Kenya. Trees planted in 1927 at South Kinangop Forest Reserve are a show-piece as the tallest trees in Kenya, with an average height of 90 m and dbh of 2 m. Mountain ash is suitable for growing in areas with deep soil at high altitude ranging from 2500 to 3000 m.a.s.l. (KFD, 1996). It is a good species for sawn timber and pulpwood. A major disadvantage with this species is that it does not coppice (Konuche, 1989).

Eucalyptus hybrids and clones

Eucalyptus hybrids are crosses between two different Eucalyptus species. In the late 1990s, Eucalyptus hybrids were introduced to Kenya from South Africa (Muchiri *et al.*, 2005). The most popular hybrids are those of *E. grandis* crossed with *E. camaldulensis* (GCs). Hybrids of these two species combine the fast growth of *E. grandis* and the drought tolerance of *E. camaldulensis*. The GC hybrids are more suited for growing in medium agricultural potential areas of Kenya, receiving annual rainfall above 750 mm and at an elevation of less than 1700 m.a.s.l. The GCs are not suitable for growing in semi-arid areas where *E. camaldulensis* does best or above 1700 m.a.s.l. where *E. grandis* grows best. In high rainfall areas with amounts over 1200 mm a year, the growth rate of GCs is lower than that of widely grown local *E. grandis* (Wamalwa *et al.*, 2007). Table 2 shows the first 12 hybrids and one pure *E. grandis* tested in Kenya. Among the 17 hybrids introduced in Kenya, those that grow best in most sites are GC hybrids GC 581, GC 14 and GC 15 (Oeba *et al.*, 2009). The GC hybrids are most suitable for production of pulpwood, poles and posts.

Table 2. Eucalyptus hybrids and pure clones grown in Kenya

Eucalyptus clones	Variety
Eucalyptus grandis x Eucalyptus camaldulensis (GCs)	CC 3, GC 10, GC 12, GC 14, GC 15, GC 167, GC 514, GC 540, GC 581, GC 584, GC 642, GC 784, GC 785, GC 796
Eucalyptus grandis x Eucalyptus urophylla (GUs)	GU 7, GU 8, GU 21
Others	TAG 5 (pure *E. grandis* clone)

3.0 Propagation of Eucalyptus

Eucalyptus species are propagated from seed and through vegetative means. Planting material is collected from trees with superior characteristics; tall, good form, little taper and healthy.

3.1 Propagation from seed

Seed collection: Eucalyptus fruits ripen at various times of the year depending on the species. Seed is obtained from well-developed mature brownish capsules. The capsules are collected from crowns of standing trees or from felled trees during tree harvesting. There is usually a long interval between seed ripening and opening of the capsules, which offers an opportunity to plan for seed collection. Moreover, wind dispersal of seeds takes place a month or two after the opening of the capsules.

The major challenge in seed collection is how to reach capsules from the tall standing trees. It requires trained tree climbers who can collect the capsules from tall trees. The other challenge is timing when most capsules are ripe as they are usually at different stages of development on the same branch.

Seed extraction, cleaning and drying: After collection, the capsules are sun-dried by spreading them on a thin layer on tarpaulin or plastic sheets to open. The capsules are then threshed lightly to release seeds and unfertilized ovules that are usually referred to as "chaff". The seeds are cleaned by removing large impurities such as capsules, twigs and leaves (Albrecht, 1993). It is not easy to separate the seed and chaff mixture by ordinary means and therefore the mixture is handled together after removal of large impurities. The seeds are further sun-dried to the required moisture content of less than 10% before storage or distribution. The ratio of chaff to seed varies from species to species and ranges between 5:1 to 30:1. The number of seeds per kilogram also varies with species e.g. a kilogram of clean *E. grandis* has about 300,000 seeds, while that of *E. camaldulensis* has about 2 000 000 seeds (Maundu and Tengnas, 2005).

Seed storage: After proper drying, seeds of most Eucalyptus species can be stored in airtight containers at room temperature for 1-2 years without significant loss of viability. For long-term storage, the seeds should be fumigated or treated with various pesticides and stored under cold temperatures, usually about 4°C, at a moisture content of 4 to 6% (Albrecht, 1993).

Seed sowing and germination: Seeds of most eucalypts readily germinate without any pre-treatment. Small sized Eucalyptus seeds are usually mixed with sand, sawdust or fine soil before sowing for even distribution on the seedbed. The mixture is spread thinly and evenly on the seedbed and covered lightly with a thin layer of fine soil. The seeds are kept moist by watering one to two times per day depending on prevailing weather conditions. Germination of most eucalypts will occur within 7 to 14 days after sowing (KFS, 2009). Germinating seedlings require shading to ensure that the top layers of soil on germination beds do not dry out. This can be achieved by placing a sheet of Hessian cloth or some light thatch of vegetation over the seedbed. Seedlings are pricked out into containers or

Swaziland bed when they have two leaves. With proper watering and hygiene, the seedlings are ready for field planting after 3-5 months when they have attained a height of 30 cm and above. Due to sensitivity to desiccation, it is preferred that seedlings are grown in containers such as plastic pots and tubes. Other containers used include dry banana barks, used milk packets and any other appropriate containers. Seedlings that are raised in open beds (bare rooted seedlings), especially in low rainfall areas have high mortality after field planting. It is therefore important to synchronize raising of seedlings with onset of the rainy season.

3.2 Vegetative propagation

The most commonly used method for vegetative propagation of Eucalyptus in Kenya is **cuttings**. Other methods used to a limited scale in Kenya are **grafting** and **tissue culture**. The vegetatively propagated materials are called clones because they are duplicated genetic copies of the original individuals. Eucalyptus species that are raised through vegetative methods include; *E. grandis*, *E. saligna*, *E. camaldulensis* and *E. urophylla*, and their hybrids. Hybrids can only be raised through vegetative methods, widely known as cloning.
Caution: Tree growers are advised not to use seeds of hybrid clones to raise seedlings for planting. Seeds from clones will not produce the same material as the parent.

Cuttings for propagation of Eucalyptus are obtained from seedlings of 1 to 2 years of age. Cuttings can also be obtained from mature trees by felling and allowing them to coppice. The cuttings are dipped into a rooting powder i.e. 0.8% indolebutyric acid (IBA) before staking into the rooting media (Mwaniki *et al.*, 2009). The media used for rooting can be clay, sub-soil, sand or vermiculite. The cuttings are then staked into the beds that are wetted before covering with a polyethylene sheet to keep humidity high through condensation. The widely adopted methods of humidity control in the country are by use of plastic tunneling and mist propagators (Mwaniki *et al.*, 2009).

Tunnels are non-mist propagation structures made of translucent flexible covering such as polyethylene sheets as propagation chambers (Figure 2). The polyethylene sheet is tightly stretched over hoops, semi-circular in shape and buried at the foot of the beds in soil. Thorough watering is done immediately after planting the cuttings and thereafter high-level moisture is maintained by watering every 10 to 14 days depending on climatic conditions. A shade is provided over the tunnel to prevent drying of the cuttings from over-exposure to the sun.

Rooting of cuttings begins after 2 weeks. The rooted cuttings are transferred into containers and watering continued for the next 40 days as they are gradually exposed to full sunlight. The rooted cuttings are then maintained in the open for about 90 days when they are about 20 cm tall and ready for transplanting in the field.

Grafting has been used to clone desired selected parents for seed orchard development, but in most cases the compatibility between the root stock and the scion is poor and the life span of the trees tends to be short. Tissue culture of eucalypts has been successfully undertaken in Kenya but is only used as a starter to propagate clones that are most difficult to root.

Figure 2. Tunnels for non-mist propagation

4.0 Preparation of Planting Site

Planting sites should be cleared and prepared well in advance of the planting date. Young eucalypts are sensitive to weed competition especially from grasses. It is therefore necessary to carry out thorough ground preparation by removing all competing vegetation, creating conditions to improve moisture conservation and rooting conditions for the seedling (KFD, 1996).

The common methods used for ground preparation are complete ploughing, strip cultivation or spot hoeing. The best time to carry out these operations is during the dry season. Complete ploughing can be carried out manually or by use of tractors.

Strip cultivation is mostly practiced in rangelands and sites where some natural vegetation is to be conserved. The width of the strip varies from 1 to 3 m and is spaced 10 to 30 m, depending on the objective of management. The strips are prepared by clearing the bushes and ploughing depending on the site conditions. In areas where complete or strip cultivation is not possible, spot hoeing can be done.

Ground preparation can also be done using herbicides. The most widely used herbicide is commercially known as Round Up. This is a systemic herbicide, which is good in controlling actively growing weeds. Spraying of the site can be done over the whole area, in a strip or in spots. The rate of application varies with the density and type of weeds. In areas with dense grass such as Kikuyu or couch grass, the application rate of the herbicide is about 2.5 l ha^{-1} but in areas with light broad-leaved weeds the application rate is lower. The planting holes for Eucalyptus are usually 30 cm deep with a diameter of 30 to 50 cm depending on the climatic and site conditions.

5.0 Spacing of Eucalyptus in the Field

Initial spacing depends on the objective of planting the eucalypts (KFD, 1996; KFS, 2009). In plantations for production of transmission poles and timber, the spacing is 3 x 3 m, fuelwood and props 2 x 2 m, and for withes and firewood for domestic use 1 x 1 m (Table 3). However, these spacings may vary depending on site and climatic conditions. Wider spacing is used in drylands. Closer spacing results in higher volume yield in early stages of growth but of smaller diameter trees. Large spacing of more than 4 m is usually used where eucalypts are to be mixed with other trees or agricultural crops.

Table 3. Recommended spacing and stocking of Eucalyptus plantations in Kenya

Objective of planting	Initial spacing (m)	Trees per hectare
Withies, domestic firewood	1.0 x 1.0	10 000
Fuelwood, pulpwood	2.0 x 2.0	2500
Fuelwood, light construction poles, pulpwood	2.5 x 2.5	1600
Transmission poles, fencing posts, light construction poles, timber	2.75 x 2.75	1320
Transmission poles, fencing posts, construction wood, timber, plywood	3.0 x 3.0	1100

6.0 Planting

Planting should commence following the onset of rains and wetting of the upper 30 cm of soil (KFD, 1996). Seedlings are planted when they are about 30 cm tall. If the seedlings are in polyethylene tubes, the tubes should be carefully removed before planting to avoid root deformity and to allow quick contact with field soil. Fertilizer applied at planting time improves seedling growth (Cromer *et al.*, 1993). Replacing of dead seedlings (beating-up) should be done within a month or not more than six months after planting. Seedlings planted later than this end up being suppressed if survival is more than 70 %.

7.0 Weeding

Grass and herbaceous weeds can severely reduce growth of young Eucalyptus trees and should therefore be removed until tree canopy closes. Weeding can be done by spot hoeing 1 m around trees and slashing spaces in between. Where Eucalypts are grown together with agricultural crops such as maize, potatoes, peas and beans, trees are weeded as the crops undergo weeding. However, tall crops such as maize should not be planted too close to trees because they shade the young tree seedlings.

8.0 Pruning

It is not necessary to carry out pruning in Eucalyptus plantations, as the species are self-pruning. However, light pruning may be carried out to enhance accessibility and security. Large trees on farms are pruned to reduce competition with agricultural crops and other trees, whereas those in homesteads are pruned to enhance beauty and to minimize risks associated with broken branches.

9.0 Thinning

The general practice in Kenya is not to thin Eucalyptus plantations. However, it is recommended that plantations grown for transmission poles, timber and plywood should be thinned. The recommended thinning schedules for such plantations are presented in Table 4.

Table 4. Thinning schedules of Eucalyptus plantations for production of tramsmission poles, timber and plywood

Age in years	Trees per hectare after thinning	
	Plantations for transmission poles	Plantations for timber and plywood
1	1320	1100
5	750	750
10	750	400
12	Clear fell	150
20		Clear fell

10.0 Harvesting

Eucalyptus are harvested for production of rails and fuelwood from 3 years; poles and pulp from 6 to 8 years; transmission poles from 10 to 12 years; timber from 15 to 20 years; and plywood from 20 to 25 years. The stump heights should be as close to the ground as possible and should not exceed 10 cm in height.

Harvesting of Eucalyptus is done using various tools depending on the age of the crop. The tools range from machetes (pangas), handsaws and power saws. Machetes are widely used for felling small trees for rails and firewood, whereas handsaws are used for cutting medium sized trees for poles and firewood. Power saws and axes are used for felling large trees for production of transmission poles, timber, plywood and fuelwood.

During harvesting, care must be taken not to damage or loosen the bark of the stumps, as this will interfere with coppicing. When cutting with power saws, care should be taken to ensure that engine oil does not spill onto the stump as this will kill them. Stumps should not be left covered with slash as this will obstruct the coppice shoots and may prevent them from growing straight. Areas to be regenerated by coppicing should not be burnt.

11.0 Growth and Yield

Eucalypts are highly productive provided that care is taken to match the species/provenance to the locality, and appropriate site preparation and establishment procedures have been duly followed. Annual production rates in Kenya now range from 20 m^3 ha^{-1} to over 70 m^3 ha^{-1} depending on the species, site quality, management, and climatic conditions (Oballa and Giathi, 1996). At Muguga and Turbo, KEFRI has recorded annual volume growth of 70 m^3 ha^{-1} and mean annual height increment of 5 m for improved *E. grandis* (Oballa, 1989; Oballa and Giathi, 1996), and 3 to 4 m for *E. camaldulensis*, *E. regnans* and *E. globulus* at the age of 3 to 4 years (Konuche, 1989; Maua, 1997). Such high rates of productivity are only sustainable with investments on silviculture and tree breeding research.

There are differences in growth between hybrid clones and local landraces at various sites. *Eucalyptus grandis* x *E. camaldulensis* (GCs) 10, 14, 15, 522, 540, 581, 642 and *E. grandis* x *E. urophyla* (GU) 21 perform better in marginal agricultural areas, whereas *E. grandis* is superior in high potential areas (Wamalwa *et al.*, 2007). There are differences in performance among hybrids at various sites indicating that some hybrid clones are more adaptable to specific sites (Kirongo and Muchiri, 2009). Hybrid clones GCs 581, 14 and 15 have good growth across most sites.

12.0 Regeneration of Eucalyptus Through Coppice Management

Tending of Eucalyptus coppices is done to bring up second and subsequent generations of Eucalyptus. Coppices form from dormant buds on the cambium of cut trees. Coppice shoots, which are dominant and have the best form and good attachment to the stump, should be selected for retention (Kaumi, 1983). The selected shoots should also be as low down the stump as possible and as wide apart as practicable. Shoots on the windward side should be preferred.

The root crowns of some Eucalyptus species are lignotuberous, which enhances coppice production. Lignotubers are swellings at the stem base that consist of a mass of tissue which assist the tree to sprout in case the main stem dies. However, there are two valuable timber species, *E. delegatensis* and *E. regnans* that hardly regenerate from coppices (Konuche, 1989; Wikipedia, 2009).

When coppices are about 6 months old they should be thinned to retain the best 4 to 6 per stump which one year later are thinned to retain the best 2 to 3 (Dyson, 1974; Kaumi, 1983). The resulting stocking (Figure 3) is maintained until the plantation is clear felled. Regeneration of Eucalyptus plantations through coppice management is recommended for production of rails, fuelwood and poles. However, at good sites coppices can be used for regeneration of plantations for production of timber and plywood. It is possible to have 4 coppice cycles for production of rails, fuelwood and poles (Kaumi, 1983). For timber and plywood, 2 coppice cycles are recommended.

Figure 3. A managed young *Eucalyptus grandis* coppice stand (Photo by: P. Oballa)

13.0 Destruction of Stumps

After the last coppice crop has been clear-felled, stumps should either be dug out or killed using arboricides. Frill cuts should be made around the stumps before applying an arboricide. Smearing used engine oil at the cut edge can also kill the stumps. Where these methods prove expensive, coppice shoots should be removed repeatedly when a new crop is planted. Good establishment of a new crop will easily suppress the shoots from previous stumps leading to eventual death of the older stumps.

14.0 Pests and Diseases

In Kenya, Eucalypts have been cultivated with few reported major outbreaks of pests or diseases. The earliest known pests in the country are the snout beetle (*Gonipterus scutellatus*) and termites. *Leptocybe invasa* (Blue gum chalcid) is another pest that has attacked eucalypts in the country since 2002 (Mutitu *et al.*, 2008).

Snout beetle has had devastating effect on *E. globulus* thus leading to reduced planting of the species. Recently, the pest has been observed on other species including; *E. saligna*, *E. grandis*, *E. camaldulensis* and a number of introduced Eucalyptus hybrids, but the effect is manageable. Termites are the most widespread pests attacking most Eucalyptus species in Kenya particularly in dry areas. Termites can be controlled through application of various termiticides including Regent 3G (Fipronil) at a rate of 33 g per tree at planting (Otieno *et al.*, 2009).

Attack of Eucalyptus by *L. invasa* (Blue gum chalcid) is more severe in dry areas of Western, Nyanza, Rift Valley, Coast, Central and Eastern regions of Kenya. The pest mostly attacks seedlings and saplings under 4 years (Figure 4). The most highly susceptible species are *E. grandis*, *E. saligna*, *E. camaldulensis* and their hybrids.

Botryosphaeria is the most widespread disease of Eucalyptus in Kenya (Mutitu *et al.*, 2008; Otieno *et al.*, 2009). It causes cankers (Figure 5), gum production and growth retardation.

Figure 4. Blue gum chalcid damage on stems of young Eucalyptus. (Photo by: E. Mutitu)

Figure 5. Eucalyptus stem attacked by Canker attack (Photo by: E. Mutitu)

The disease attacks *E. grandis* and its hybrids. The other diseases recorded on Eucalyptus include Mycosphaerella, which appears as black and brown spots on leaves. *Mycosphaerella keniensis* is the most widespread disease found on *E. grandis*, *E. urophylla* and *E. camaldulensis*. Powdery mildews have been observed on leaves of Eucalyptus seedlings, especially in the nursery. The affected leaves have a whitish coating and in severe cases the leaves curl. The remedy is to spray the seedlings with ridomil or milraz. Other diseases that affect Eucalyptus in Kenya include *Phytophthora* and *Cylindrocladium* species. The fungi attack the roots causing rotting. The *Cylindrocladium* species is also associated with cankers on young seedlings. The diseases are more pronounced in sites with high humidity.

15.0 Eucalyptus and the Environment

Eucalyptus species have been grown for over 100 years in Kenya and have become very popular with farmers. Tobacco companies and other industrial companies such as Homa Lime are promoting eucalypts as the "best-bet" source of renewable energy for industrial processing of their produce. Large tea estates also manage eucalypts for fuelwood within the tea farms (Figure 6). Industries such as Pan African Paper Mills and Raiply use large volumes of eucalypts as industrial raw material and as fuelwood.

Figure 6. Eucalypts managed as fuelwood within tea estate (Photo by: P. Konuche)

In 1980s, the defunct Permanent Presidential Commission on Soil Conservation and Afforestation (PPCSA) discouraged planting of Eucalyptus. This campaign resulted in reduced planting in state forests. However, currently, there is enthusiasm in planting of eucalypts in areas outside state forests. Farmers grow eucalypts as reliable investment with good financial returns in relatively short rotations, and as sources of products for domestic needs. These trees cushion farmers when the markets for their agricultural produce fail or are low. However, concern has been that eucalypts use a lot of water, reduce soil fertility and are generally bad for biodiversity conservation (FAO, 1998; Sunder, 1995; FAO, 2009). Some information on Eucalyptus and the environment are outlined in the following sections:

15.1 Eucalyptus and hydrological cycle

Natural and plantation forests play an important role in the hydrological cycle as they affect evaporation, runoff and infiltration (Davidson, 1995). Forests are generally known to transpire more water than short rotation crops, scrub or grass. Forests with good ground cover or understorey plants have high rates of infiltration and therefore low runoff. High infiltration may, however, be reduced by activities that reduce ground cover such as weeding, overgrazing, burning, soil compaction, among others. Increased infiltration rates lead to higher soil and groundwater recharge and this increases river flow during the dry season. Eucalyptus species have closed and deep crowns that provide good interception of raindrops thus protecting the soil mantle and allowing for effective infiltration and groundwater recharge.

15.2 Water use by Eucalyptus

Few studies have been carried out in Kenya on water use by Eucalyptus. In other countries with large Eucalyptus plantations, studies have been carried out on water use by various tree species including pines. Assessments have also been conducted on the effects of land use change from grassland or indigenous forests to plantations of fast growing species of pines and eucalypts. Results showed that in high rainfall areas replacement of indigenous bamboo forest in water catchment with plantations of eucalypts, pine and tea did not result in any long-term reduction in water from the catchments. Silva *et al*. (2006), comparing dry biomass fixation of two Eucalyptus species at three levels of soil water contents (20, 23, and 26%) found that, water use efficiency was better at higher level of soil water content at 26%. In dry sites, Eucalyptus adopts various mechanisms for drought avoidance including dynamic changes in leaf area index, near vertical arrangement of leaves, high stomata sensitivity to air saturation deficit, deep rooting ability and osmotic manipulation to maintain turgor in leaves (Kallarackal and Somen, 1997; Whitehead and Beadle, 2004).

Several studies capture some of the concerns of eucalypts that make them more productive and water use efficient. Calder *et al*. (1997) and White *et al*. (2002) reported that roots of Eucalyptus penetrate into deeper soil layers and are able to extract water from reservoirs additional to that available from the rainfall. The additional access to water was found to support increased growth compared to other tree species within the site. Robertson (2005) observed that when the eucalypts and other alien species were cleared from the river systems, the flow of the river was restored to normal within a decade, indicating that the ground water accumulates and springs up. Scott and Welch (1996) reported similar experiences with afforestation scheme with *E. grandis* in one site and *Pinus patula* in another site in Mokobulaan region in South Africa. In both cases, the species dried the stream after some years. After clear felling, the stream flow returned to normal within a period of 5 years. It is important to note that such large-scale clearance can have negative repercussions leading to dryland salinity as observed by Morgan and Barton (2008) when done with the hope that indigenous species will automatically colonize without silvicultural treatment. Munishi (2007) going by the observations at Mbeya, Tanzania, cautions that the approach of large scale clearance is ill advised since the sudden drastic removal of vegetation over large areas on steep slopes invariably leads to increased soil erosion, landslides, and silting of waterways and water bodies, with increased floods on farmlands and other habitats.

In India, Tiwari and Mathur (1993) reported that experiments were conducted to compare water requirements and biomass production of selected tree species. The species studied included *Pongamia pinnata* (slow growing), *Syzgium cuminnii* (Mzambarau) with moderate growth and Eucalyptus hybrid (fast growing), among others. The results are as indicated in Table 5.

Table 5. Water consumed per gram of dry biomass produced for various species

Species	Total biomass produced per litre of water (g)	Water consumed per gram of biomass ($l\ g^{-1}$)
Pongamia pinnata	1.13	0.88
Syzigium cumnii	2.00	0.50
Eucalyptus hybrid	2.06	0.48

The study concluded that:

- Eucalyptus hybrid consumed more water on per litre basis, but produced more biomass per unit volume of water
- *Pongamia pinnata* consumed the least water but produced least biomass per unit volume of water.
- Eucalyptus hybrid was the most efficient water user compared to the other species studied.

In another study in Central India where large-scale plantations of *Eucalyptus tereticornis* had been established, the level of water in wells declined until the plantations were 6 to 8 years (when trees have their maximum rate of growth) and thereafter, reverted to the earlier level. Similarly, adverse effects on hydrological cycle were not observed in older plantations of *E. globulus*. Cromer *et al*. (1993) on comparing the response of *E. grandis* under irrigation and fertility treatment found that the trees reacted favourably to additional fertility more than water. After three years, fertilizer treatment had significantly and substantially increased growth in mean height and basal area, but there was no response to irrigation and no interaction between fertilizer and irrigation.

The Overseas Development Administration of the UK supported a study to understand the impact of fast growing species on the environment by comparing water use in plantations of eucalypts, indigenous forest and annual agricultural crop (Calder, 1994). The main findings of the study were:

- In the dry zone, the water use of young Eucalyptus plantation was no greater than that of indigenous dry deciduous forest;
- The annual water use of Eucalyptus and indigenous forest was equal to annual rainfall;
- The annual water use of either indigenous or plantation forests was higher than that of agricultural crops; and
- There was no evidence of water abstraction from the water table by all species.

The general observations from these studies is that the effect of planted trees on ground water depends on the species, climatic conditions and type of soil.

15.3 Effects of Eucalyptus on soil fertility

Few studies have been done on soil nutrient status in Eucalyptus plantations in Kenya. In 1993, a study was carried out in Ethiopia to compare nutrient status in plantations of *E. globulus* at 40 years old, Cypress at 28 and 40 years old, and Cedar at 40 years (Teketay, 2003). The results showed that soils under *E. globulus* plantations had lower nutrient content than soils in cedar and natural forests. The soils under *E. globulus* and cypress also tended to have lower density of mycorrhiza fungi. In natural forest, the total annual litter fall was about twice as high as in plantations of *E. globulus*. However, nutrient release in *E. globulus* plantation was comparable to that in natural forest.

Laclau *et al*. (2003) studied dynamics of nutrients in short rotational clonal eucalypts and found that there are two growth periods. The first one is the juvenile phase up to canopy closure, during which the uptake of nutrient from the soil meet the requirements. The second phase involves intense nutrient recycling with internal translocation within trees supplying 30% of N and P from the second year onwards. At the end of the rotation the mineralization of organic matter from litter fall provided ample amounts of nutrients. Other studies recorded differences between the nutrient status of natural forest, savanna and that of cropped plantations, especially when grown on short rotations (Couto and Betters, 1995). In a natural forest with little disturbance nutrients are conserved and cycled between trees and soil. When a plantation is thinned or felled and the wood is extracted, the nutrient capital changes considerably because nutrients are removed from the site. Since Eucalyptus are fast growing and are used as a short rotation crop, nutrients are taken with the products within a short period of time. As the Eucalyptus coppice after clear felling, more nutrients are required to support the fast growth.

Research in Kenya has indicated that areas under Eucalyptus have high level of micronutrients when compared to those under old tea crops (Oballa and Langat, 2002). Long-term plantations of Eucalyptus have been reported to improve the soil fertility. This has been shown to take place within a period as short as 8 to 10 years (Couto and Betters, 1995; Sunder, 1995; Laclau *et al*, 2003). Comparative studies of soils under Eucalyptus and adjacent grasslands have shown no significant differences if the trees take longer than 10 years (Couto and Betters, 1995).

15.4 Allelopathy

One of the criticisms of Eucalyptus is its allelopathic effect on other plants (Sasikumar *et al*., 2001). This is to imply Eucalyptus produces foliar and root exudates that hinder the growth of other plants. An alternative argument has been that agricultural crops do not perform well for many years in land where Eucalyptus have been harvested. Florence (2004), in a review concluded that there is no scientific evidence that eucalypts competes directly with other plants through chemical exudes. The review also argues that it is appropriate to interpret any effects of eucalypt in terms of its capacity to compete for soil resources, i.e. nutrient and water in short supply. In an experiment in which soil from Eucalyptus plantation was used in a greenhouse to grow beans, no allelopathic effects were detected (Couto and Betters, 1995). In a trial on various clones of tea grown on sites that had been prepared after removal of tea, Eucalyptus and natural forest showed that tea yield was highest on land previously under Eucalyptus (Onsando, 2001).

At Muguga, the practice is to manage fuelwood plantations for four rotations that take a total of nearly 30 years (Dyson, 1974; Kaumi, 1983). Once the final harvest is done the fields are used for cultivation of agricultural crops for 1 to 2 years (Figure 7). The observation from such farms is that the yields of maize, beans or potatoes are usually higher than in the nearby cultivated farmlands, a confirmation that Eucalyptus return a good amount of nutrient to the soil and allelopathic effect is not a hindrance to crop production once the trees are clear felled. Furthermore, a rehabilitation plot of mixed indigenous tree species at Muguga, planted in a site after 60 years of Eucalyptus growing showed no growth inhibition as a result of allelopathic residue effects. The seedlings survival and tree growth was good and by 15 years the tree canopies had closed, with leading trees at 20 m and crown stratification beginning to form.

Allelopathic effects have mainly been confirmed in high concentrates of extracts from Eucalyptus tissues (Sasikumar *et al*., 2001) or immature compost of Eucalyptus litter (Teshome, 2009). However, given ample time, the leachetes of Eucalyptus and organic compost lead to soil enrichment. Planting of Eucalyptus with other species (mixed species trials) has been shown to hasten that decomposition of the litter and enrichment of soil.

Figure 7. Maize and beans planted on a site after clear felling of Eucalyptus (Photo by: P. Oballa)

15.5 Effects of Eucalyptus on biodiversity conservation

Several studies have been carried out to assess the effects of Eucalyptus plantations on biodiversity. At Muguga, plant diversity was assessed in two *E. saligna* plantations. There were about 7 times more plant species in the older plantation than in the younger one indicating that species richness increases with the age of the plantation (Figure 8). It is also evident that the lower the stocking, the higher the biodiversity of undergrowth plant species (Table 6).

Table 6. Number of indigenous plant species under plantations of Eucalyptus

Characteristic	Plantation 2H	Plantation 1C
Age in years	14	52
Number of rotations	1	4
Eucalyptus trees per ha	1550	920
Number of indigenous plant species per ha	50	370

Further studies showed that there were 26% and 68% of woody species in the younger and older plantations respectively. Observations in other parts of the country have also shown that at low stocking level or in high rainfall areas, regeneration of a wide range of indigenous plant species is found under plantations of eucalypts. Some valuable tree species that regenerate easily under eucalyptus plantations include; *Prunus africana*, *Polyscias fulva*, *Zanthoxylum gillettii*, *Juniperus procera*, *Croton macrostachyus*, *Carissa spinarum* (*Carissa edulis*) and *Olea* species, among many other lower plant species.

Senbeta *et al*. (1998) carried out a study in Ethiopia to assess the status of indigenous species diversity in plantations of *E. saligna* and *E. globulus*. The plantations were aged between 11 and 27 years. The results showed that while there were 3575 indigenous plant species per hectare in 11- year old plantation of *E. saligna*, the plantation at 27 years had a total of 18 650 indigenous plants. Under the 16-year old plantation of *E. globulus*, there were 2300 indigenous plants, while the 22-year-old plantation had 13 400 indigenous plants per ha. Studies in other countries have also given similar results. In Hawaii, it was reported that there were 42 indigenous species growing beneath *E. saligna* plantations at 26 to 32 years of age.

Binkley and Stape (2004) confirmed that large areas of Eucalyptus plantations have the potential to alter the diversity of plant and animal species but that varies based on the surrounding landscape, type of forest (savanna or natural forest), weather, agricultural status and the management regime. For example, plantation forests in Brazil as a rule must retain at least 20% of the land under indigenous forests to provide seed bank. The results further indicate that some trials with mixed species have shown increased benefits. Mixed stands that contain nitrogen-fixing tree species may increase stand growth depending on site conditions. Eucalyptus plantations with low stocking and open canopy create conditions favourable for regeneration of other plant species and therefore enhance biodiversity conservation (Figure 8). However, this is better enhanced in plantations close to indigenous forests where seed is easily dispersed by wind and animals into the Eucalyptus plantations.

Figure 8. Regeneration of undergrowth of indigenous plants in *Eucalyptus grandis* plantation (Photo by: P. Oballa)

16.0 Costs and Benefits of Growing Eucalypts

Farmers, private companies and the Government are increasingly growing eucalypts as investments for raising income. The cost of labour and inputs for growing Eucalyptus in Kenya varies with locality and season. The major costs of establishing Eucalyptus plantations include; site preparation (bush clearing, ploughing, harrowing, staking and pitting), procurement of seedlings, planting, weeding, protection, thinning and harvesting. The income from an on-farm Eucalyptus enterprise for poles production is from the sale of transmission poles, building poles and firewood.

Table 7 shows cost benefit analysis of a Eucalyptus plantation under management for transmission poles. Rotation age is 8 to 12 years (*E. grandis*/*E. saligna*/Eucalyptus clones), spacing between trees and rows at 2.75 m, mean annual rainfall more than 1000 mm and 85 % survival. Half of trees are each sold as a transmission pole (1 pole and some firewood) and the other half is sold as 2 poles each and some firewood.

Table 7. Cost benefit analysis for 1 ha of an on-farm Eucalyptus enterprise under management for transmission poles

No.	Item/Activity	Unit	Quantity	Unit Price	Amount, KES
	Inputs (costs)				
1	Seedlings	Number	1300	10	13,000
2	Fencing (Barbed wire + posts + nails + Labour)	Lump sum	-	-	50,400
3	Land Preparation	Lump sum (Tractor hire)	-	-	5,000
4	Stakes	Number	1,300	5	6,500
5	Staking out	Man days	4	250	1,000
6	Pitting	Man days	4	250	1,000
7	Transport of seedlings	Car hire	1	6,000	6,000
8	Planting	Man days	4	250	1,000
9	Complete Weeding (first 2 years)	Man days	40	250	10,000
10	Routine scouting for eventualities	Man days	40	250	10,000
	Total Cost				**103,900**
	Outputs (benefits)				
1	Transmission Poles	No.	533	1,200	639,600
2	Building poles	No.	1559	100	155,900
3	Firewood	Stacks	20	1,200	24,000
	Gross income				**819,500**
	Total Expenditure				**103,900**
	Profit				**715,600**

Some of the factors that are considered when evaluating Eucalyptus enterprises for profitability include net present value (NPV), equal annual equivalent (EAE) and land expectation value (LEV). NPV is the present value of all benefits (revenue) less the cost. EAE is an annual payment that will pay off the NPV of an asset during its lifetime and LEV is the capitalized value of the expected annual net income.

Results of a study in coast province estimated the compounded cost (at 10 % per year) of a 5 year old 1 ha of Eucalyptus clones plantation with the initial stocking of 2500 trees as Ksh. 294 000 over a period of 8 years. The total present value of the same plantation was calculated as Ksh. 666 000, resulting in a net profit of Ksh. 372 000, which is equivalent to an annual income of Ksh. 74 400. The results of the same study showed that it is more profitable to grow Eucalyptus for production of fuelwood and poles than maize in high potential agricultural areas like Kitale and Uasin Gishu. At Kericho, it was shown that it is slightly more profitable to grow tea than Eucalyptus for fuelwood but not for transmission poles (Figure 9). The estimated volume of wood that can be produced under various site conditions from ages 5 to 8 years for *E. grandis* varies from 75 to 360 m^3 ha^{-1}.

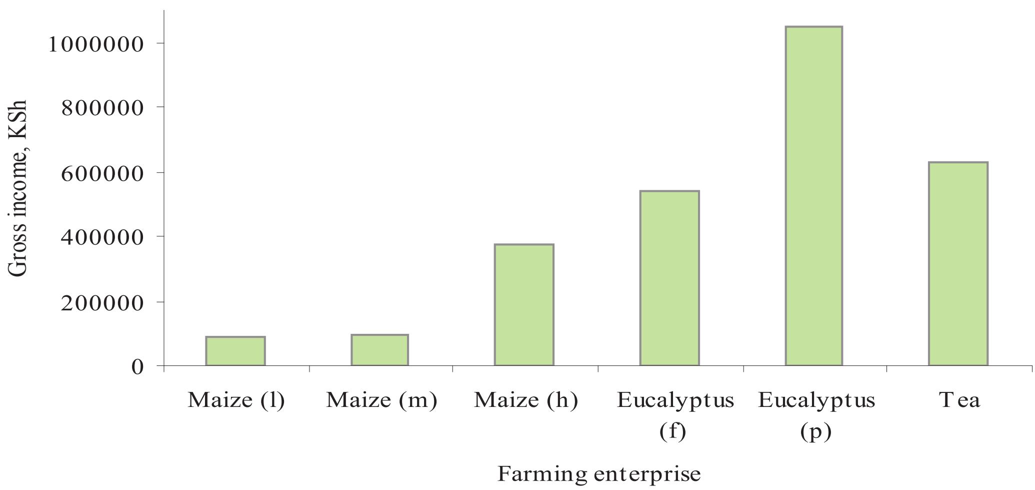

Figure 9. Net income of growing eucalyptus, maize and tea for 8 years (l = low potential, m = medium potential, h = high potential, f = fuelwood and p = pulp wood).

The above findings are similar to those by Cheboiwo and Maritim (2004), where growing trees gave positive returns for areas that yield more than 15 $m^3ha^{-1}yr^{-1}$ (VG1). It is therefore profitable to grow Eucalyptus in all areas suitable for agriculture.

17.0 Value of Eucalyptus in Kenya

The total area under eucalypts in Kenya is estimated as 100,000 ha, comprising: 15,000 ha in state forests, about 35,000 ha on private land owned by large companies, and 50,000 ha owned by farmers and local authorities in the form of woodlots, ornamentals, boundary planting, avenue planting and scattered trees on communal land. The total estimated standing volume of eucalypts round wood is about 27 million m^3. Thus a conservative potential monetary value of Eucalyptus trees in Kenya is 30 billion Kenya Shillings.

18.0 Promoting Eucalyptus in Kenya

To promote tree planting on farms, the government has provided favourable policies that give emphasis to farm forestry through the Economic Recovery Strategy for wealth and employment creation paper (2003), the Draft Forest Policy, 2005 and Forest Act, 2005. Among the key favourable actions include proposals to entrench forest products trade liberalization; tax incentives for trees grown on farms as reflected in the 2005-6 budget; leasehold and concessions to private sector in public forests; the creation of out-grower schemes through appropriate funding mechanisms and promotion of value addition in forest products. The policy on on-farm tree planting emphasizing that at least 10% of land holdings be put under tree cover is another important milestone in afforestation. More specifically to promotion of growing of eucalypts, the government is developing a policy on Eucalyptus and has caused the development of guidelines on hands-on growing of eucalypts by the Kenya Forest Service and a production of this technical publication detailing facts on Eucalyptus growing by the Kenya Forestry Research Institute.

19.0 Conclusions and Recommendations

Based on the facts on growing Eucalyptus in Kenya as presented in this document, the following conclusions are made:

- Eucalypts provide multiple benefits ranging from industrial wood, poles, timber, fuelwood, bee forage, essential oils and many environmental services such as windbreaks, erosion control, buffer to natural forests, flood control and climate change mitigation. Eucalyptus is also currently widely used in construction, joinery and furniture.
- There are specific Eucalyptus species adapted to various ecological zones in Kenya. Planting these eucalypts in the appropriate ecological sites is important to maximize on yields, while reducing negative environmental impacts.
- Farmers are expanding areas under Eucalyptus to meet increasing demand for forest products and to generate income. When planted on-farm, eucalypts should be restricted to sites where it will not adversely affect agricultural crops or neighbouring farms.

- Fast growth and high biomass yield of Eucalyptus require a high level of water consumption that must be balanced with other competing water uses such as agriculture and domestic needs. Planting of Eucalyptus species should therefore be restricted to sites recommended by the policy guidelines.
- When Eucalyptus is grown on short rotation, soil nutrient removal is high. Management systems should therefore include soil nutrient replenishment through application of fertilizers. For long rotations (12 years and above) nutrient recycling is similar to that of natural forest where decaying debris return minerals to enrich the soil.
- Mixing Eucalyptus with other tree species can enrich productivity in plantations, as these species hasten decomposition of litter, leading to soil enrichment. Biodiversity within Eucalyptus plantations is high in low-density plantations of over 15 years of age.
- There are still many issues on Eucalyptus relating to uses, physiological development and environmental influences that are characterized with uncertainty and need further research, some of which are site specific.

In implementing the above recommendations, there will be need to adhere to policy to guide planting of Eucalyptus to reduce negative environmental and socio-economic impacts. The policy is being developed within the framework of national forest policies, which are part of national economic and social development policies, especially those related to poverty alleviation, employment creation, reduction of pressures on natural forests and participatory natural resource management.

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Annex 1: Eucalyptus Species Grown in KEFRI Arboretum, Muguga

No.	Species	Planting years	Performance*
1	*E. grandis*	1954	Fast
2	*E. saligna*	1952, 1970	Fast
3	*E. globulus*	1955	Fast
4	*E. regnans*	1954, 1959	Fast
5	*E. camaldulensis***	1953, 1959, 1971	Moderate
6	*E. urophylla*	1970, 1983	Moderate
7	*E. paniculata*	1953	Moderate
8	*E. tereticornis*	1956, 1959, 1971,	Moderate
9	*E. citriodora*	1953	Moderate
10	*E. cloeziana*	1954, 1975	Moderate
11	*E. delegatensis*	1972	Moderate
12	*E. fastigata*	1954	Moderate
13	*E. gigantean (delegatensis)*	1957, 1970	Moderate
14	*E. maidenii*	1953	Moderate
15	*E. microcorys*	1954	Moderate
16	*E. nitens*	1959	Moderate
17	*E. rubida*	1959	Moderate
18	*E. zanzibar species(C)*	1955, 1971	Moderate
19	*E. baxteri*	1959	Slow
20	*E. cladocalyx (corynoxalyx)*	1954	Slow
21	*E. bicostata*	1957	Slow
22	*E. crebra*	1954, 1959	Slow
23	*E. cypeocarpa (E. goniocalyx)*	1959	Slow
24	*E. deglupta*	1959	Slow
25	*E. botryoides*	1953, 1959	Slow
26	*E. diversicolor*	1954	Slow
27	*E.dives*	1957, 1959	Slow
28	*E. drepanophylla*	1954	Slow
29	*E. dunii*	2003	Slow
30	*E. eugenioides*		Slow
31	*E. bosistoana*	1956, 1959	Slow
32	*E. ficifolia*		Slow
33	*E. bicolor*	1956	Slow
34	*E. globoidea*	1956, 1959	Slow
35	*E. acmenioides*	1954	Slow
36	*E. gomphocephala*	1956	Slow
37	*E. goniocalyx*		Slow
38	*E. alba*	1970	Slow
39	*E. gummifera*	1954	Slow
40	*E. longifolia*	1959	Slow
41	*E. macarthurii*	1953	Slow
42	*E. macrorhyncha*	1956	Slow
43	*E. cambageana*	1983	Slow
47	*E. marginata*	1955	Slow

No.	Species	Planting years	Performance*
48	*E. melanophloia*	1954	Slow
50	*E. melliodora*	1954, 1959	Slow
51	*E. bridgesiana (E. stuartiana)*	1954	Slow
52	*E. muelleriana*	1954, 1959	Slow
53	*E. nova-anglica*	1956	Slow
54	*E. nubilis (E. fibrosa var nubile)*	1955	Slow
55	*E. obliqua*	1957, 1959	Slow
56	*E. ovata*	1959	Slow
57	*E. pilularis*	1954	Slow
58	*E. punctata*	1953	Slow
59	*E. populnea*	1983, 1984, 1987	Slow
60	*E. baueriana*	1959	Slow
61	*E. resinifera*	1953	Slow
62	*E. robusta*	1954	Slow
63	*E. rostrata (E. camaldulensis)***	1959	Slow
64	*E. rummeryi*	1964	Slow
65	*E. amygdalina (E. salicifolia)*	1957, 1959	Slow
66	*E. salmonophloia*	1954	Slow
67	*E. scabra*	1959	Slow
68	*E. sideroxylon*	1953, 1959	Slow
69	*E. sieberi (E. sieberana)*	1959	Slow
70	*E. tesselaris*	1983	Slow
71	*E. viminalis*	1953, 1959	Slow

NOTE:

1. * Fast - mean annual height increment >2m for the first 8 years
   Moderate - mean annual height increment of 1-2 m for the first 8 years
   Slow - mean annual height increment <1 m for the first 8 years

2. **species 5 and 63 are the same but vary in origin

3. Apart from *Eucalyptus* species found in Muguga arboretum, various individuals and organizations have introduced other species.