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WATER USE AND ECOLOGICAL EFFECTS OF EUCALYPTUS TREES[1]

By
Joram Mbinga and Joshua Cheboiwo
Kenya Forestry Research Institute, Regional Research Centre, Londiani
Email: jmbinga@gmail.com

1.0 Introduction

The dramatic decline in forest cover in Kenya along with a growing population means that various products such as timber for construction, poles, and biomass fuels will increasingly become scarce. To overcome this shortage, Kenyans are increasingly turning to various Eucalyptus species that are fast growing with ability to yield multiple products within a relatively short time. The preference of Eucalyptus raises a number of issues particularly between environmentalists and foresters. The positive side of Eucalyptus is promoted by foresters when they highlight its ability to meet increasing wood demands for domestic and industrial use and evidence that it has become a species of choice for commercial purposes globally. On the other hand, some environmentalists are opposed to Eucalyptus due to perceived ecological hazard. They further argue that the species is ill equipped to serve the variety of diverse end uses demanded for tree species in Kenya.

This paper will examine available information to assess the validity of claims from both sides. In critically assessing the evidence for and against the species, Kenya stands to benefit from looking at how major eucalyptus growing countries like India, Ethiopia, South Africa and Brazil have coped with this dilemma. Also usefull is the scientific information from these countries and their perception of the best course of action to take. Initially, the paper gives the current place of Eucalyptus in Kenya relative to the rest of the world before delving into issues of water use and ecological effects.

2.0 Global situation with regard to Eucalyptus

Eucalypts are among the most widely cultivated trees in the world withabout 10 million ha of plantation globally (FAO, 1995). The genus *Eucalyptus* comprises more than 700 species and

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unknown number of hybrids and varieties which are planted in different ecological conditions. In Africa, Eucalyptus are planted in 35 countries. All countries with over 50, 000 ha of Eucalyptus plantations are listed in Table 1.

Table 1. Countries with large areas under Eucalyptus

Country	Area (ha) under Eucalyptus	%age of country's area
India	3,088,400	1.03
Brazil	2,717,300	0.3
China	662,600	0.07
South Africa	557,200	0.5
Vietnam	483,100	1.6
Ethiopia	477,000	0.4
Morocco	186,500	0.4
Madagascar	105,600	0.18
Rwanda	86,500	3.3
Kenya	70,000	0.12
Angola	67,000	0.05
Sudan	53,5000	0.02

2.1 Eucalyptus in Kenya

Eucalyptus were introduced to Kenya as early as 1902 from Australia. The aim of the initial introductions was to identify fast growing tree species to supply wood fuel for the Kenya - Uganda Railways. Since then Eucalyptus are popular species grown in many parts of the country. The most common species are *E. regnans* and *E. globulus* for high altitude areas, *E. grandis* and *E. saligna* for mid-high altitude areas, *E. urophylla* for lowlands, *E. camaldulensis* and *E. tereticonis* for ASAL areas and lately hybrids for marginal sites. The area under Eucalyptus in Kenya is not known but, given the recent increased interest in forestry by farmers and private sector, it is estimated to cover nearly 70,000 ha. The main reasons for the popularity of Eucalyptus are:

- Fast growth compared with other tree species thus give products within a short time.
- Able to re-grow (coppice) after cutting and this eliminates the cost of replanting.
- Yield a variety of products such as withies, firewood, charcoal, building materials, mining props, fencing posts, electricity transmission poles, railway slippers, pulp, paper, timber, plywood, oil, perfume and medicine.

3.0 Socio-economic contribution of Eucalyptus in national development

The Eucalyptus, alongside other tree resources are important national assets due to their economic, environmental, social and cultural values. It is estimated that short rotational trees that provide industrial firewood, pulpwood, sawn wood, transmission and construction pole wood have a value exceeding Kshs 1.6 billion annually where as the total contribution of forest products and services is indicated as Kshs 16.4 billion, equivalent to 1% of national GDP.

3.1 Provision of Firewood

The demand for domestic wood energy for the growing rural population is increasing. Currently, the country is experiencing wood deficit of about a million cubic meters per year. The deficit is expected to increase at about 0.5 million cubic meters annually. Planting fast growing species such as the eucalyptus, will check the increasing wood deficit with the resultant reduction in degradation of natural forests and woodlands leading to increased environmental protection and poverty alleviation.

3.2 Provision of Industrial Fuelwood

Textiles and food processing sectors are major consumers of industrial fuelwood. The tea industry, a major foreign exchange earner in Kenya, accounting for 20% of total exports and contributing 4% of GDP, relies on Eucalypts firewood in tea processing thereby saving approximately Kshs.2.2 billion annually. The Kenya Tea Development Authority (KTDA), which produces 60 percent of tea in the country, has embarked on a programme to establish Eucalyptus plantations to provide fuelwood for curing tea.

3.3 Supply of Pulpwood and Plywood

The Pan African Paper Mill requires about 60,000 m^3 of Eucalyptus pulpwood annually. The company is also switching from use of furnace oil to fuelwood to cut down costs of paper production. This will require about 250,000m^3 of Eucalyptus valued at Ksh.200 million annually. Raiply that also owns Timesales is the major plywood producer in the country. Annually, they process up to 250 000 m^3 part of which is derived from eucalypts.

3.4 Transmission Poles

Eucalyptus transmission poles are important in the country's development. Currently Kenya's demand for poles and posts is estimated at 1,500,000 m^3. For several years, the country has been importing electric poles resulting in loss of foreign exchange estimated at about Kshs.140 million annually. The shortage of poles has been attributed to the campaign against the planting of eucalypts in 1980s. The demand for poles is increasing because of the current Rural Electrification Programme. There are 8 transmission poles treatment plants in the country with capacity of 320,000 poles per year. Six more plants are under construction and when complete will bring total pole production to about 400,000 per year in the next two years.

3.5 Timber

The logging ban of 1999 has promoted the processing of Eucalyptus for timber. The timber from 12-25 year old Eucalyptus is currently popular in joinery and building industry and accounts for upto 60% of stocls in timber yards in Western Kenya (Cheboiwo, 2008).

4.0 The dilemma in growing of Eucalyptus in Kenya.

Eucalyptus have been grown for over 100 years and is still popular with farmers. Large tea estates, KTDA, tobacco companies, transmission pole treatment plants, and Homa Lime Ltd. are promoting Eucalyptus as the best-bet source of renewable raw material for processing of their produce. Industries such as Pan African Paper Mills and Raiply are using large volumes of Eucalyptus as industrial raw material and as firewood. Currently, there is enthusiasm in planting of eucalypts in areas outside state forests by farmers as the most reliable investment with good financial returns and as sources of products for domestic needs (Cheboiwo and Langat, 2009). These trees also cushion farmers when the markets for their agricultural produce fail or are low. Despite the enthusiasm with which Eucalyptus has been taken up, there is criticism from some environmentalists, social activists, some politicians and some NGO's. The negative concern has been that Eucalyptus use a lot of water, reduce soil fertility and are generally bad for biodiversity conservation. Despite Eucalyptus enormous potential for generating income, these negative concerns need to be addressed so that concerned parties come to a common understanding.

4.1 Water Use by Eucalyptus

The criticism is that Eucalyptus is water intensive user and reduces water available for other species, effectively out-competing them. In arid areas, the suppression of other plant life, coupled with high water demand, reduces soil moisture, preventing the recharge of groundwater and can reduce local water tables. This is exacerbated by a high transpiration rate indicative of the inefficient use of water by the trees.

Regarding this criticism, studies have been carried out in several countries on water use by various tree species including Pinus and Eucalyptus to see if it has a higher demand per unit of biomass fixed. At the Forest Research laboratory, Kampur, India (Lawbuary. Jo. 2000), Eucalyptus actually appears to be more efficient in water use than other native trees. The study showed that Eucalyptus consumed 0.48 litres of water to produce a gram of wood, compared to the average of 0.68 litres per gram of wood for local species. The reason why Eucalyptus was introduced was because of its rapid growth and productivity. In one year, total biomass produced is greater than many of the slower growing local species. In an eight year rotation, Improved E. grandis in Kenya yields between 50 to 75 m^3/ha/year compared to the average of 1-10m^3/ha/year for indigenous species (Oballa P, 2005). An overall high productivity therefore necessitates a greater overall water demand. On high rate of transpiration and possible contribution to water shortage in arid areas, it should be noted that transpiration of Eucalyptus is high under conditions of high soil moisture , termed 'luxury consumption' and under conditions of water stress, stomatal closure occurs, which restricts water loss from the plant. In cases where reduction of water table is reported, this may be due to many factors among them over extraction of ground water, aggravated by factors such as deforestation and other land uses.

Studies have also been conducted to assess the effects of land use change from grassland or indigenous forests to plantations of fast growing species of Pinus and Eucalyptus. The results from some of the studies are given below.

4.2.1 Kenya

In 1956, studies were conducted in Kenya to assess the effects of land use change on streamflow when indigenous forests in catchment areas are converted to:

i) Grassland and pine plantation (in Kimakia Forest Reserve, South Kinangop in an area with annual rainfall of 2070 mm);
ii) Tea plantation in Kericho which has annual rainfall of 2400 mm

The results showed that replacement of indigenous forest with either pine plantations or tea plantations did not result in any long-term reduction in water from the catchments. The following conclusions were made from these studies:

- Water use by *Pinus patula* plantation, tea plantations and grassland was similar to that of indigenous forest;
- Soil surface infiltration, rainfall frequency and storage characteristics of the catchment are critical factors which influence streamflow.

4.2.2 India

The controversy on water use by Eucalyptus started in India, a country that leads in the planting of Eucalyptus in the world. Many studies on water use by Eucalyptus have therefore been undertaken. However, the results have not been consistent as discussed below.

One study was carried out in 1982 in Kanpur to compare water requirements and biomass production of selected tree species. Among the species studied were *Pongamia pinnata (*slow growing), *Syzgium cuminnii (*Mzambarau) with moderate growth and Eucalyptus hybrid (fast growing). The results showed that *Pongamia pinnata* consumd 679 litres of water to produce 520 gram of biomass while Mzambarau consumed 1460 litres of water and produced 2386 gm of biomass. Eucalyptus hybrid consumed 2662 litres and produced 5209 gm of biomass. The average consumption of water per gram of biomass produced for *P. pinnata,* Mzambarau, and Eucalyptus hybrid were 1.30, 0.61 and 0.51 respectively. The study concluded that:
Eucalyptus consumed more water on per seedling basis, but produced more biomass per unit volume of water. *Pongamia pinnata* consumed the least water but produced the least biomass per unit volume of water. *Eucalyptus* hybrid was the most efficient water user compared with 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 in large-scale plantations of *Eucalyptus tereticornis* declined until the plantations were 6- 8 years (the years when the trees have their maximum rate of growth) and thereafter, reverted to the earlier level.

Observations in older plantations of *E. globulus*, in Nilgris showed no adverse effects were noticed in hydrological cycle.

In mid-1990, 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 Eucalyptus, indigenous forest and annual agricultural crop. The main findings of the study are:

- 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.

4.2.3 Ethiopian Experience

Ethiopia has 477,000 ha of Eucalyptus which plays an important role in meeting economic needs. In its humid zones where Eucalyptus is a key source of poles and firewood, the trees are reported to play a beneficial role in generating incomes comes without any apparent adverse ecological effect. However, long-term effects of Eucalyptus afforestation have yet to be assessed (WAC 2006).

4.2.4 South African experience

Relatively drier South Africa with 557,200 ha has had quite a different experience (WAC, 2006). Much of the land is greatly dependant on catchment of rainfall in the mountains to supply the rivers and streams. When natural forests and grasslands were converted into Eucalyptus plantations, stream flow reduced in much of the country. To counter this, South Africa has set up a licensing system that evaluates the possible consequences any possible afforestation scheme is likely to have on water resources. The country is also removing those plantations from riparian zones, thus encouraging the natural forests and grasses, which use less water to regenerate. It has destroyed alien tree species and encouraged the cultivation of new drought-resistant species that use water efficiently. Of great benefit to Kenya is South

Africa's long history of catchment hydrology, as the two share similar characteristics of water resources and environment.

4.2.5 Brazil

Although Brazil is one of the countries with the largest plantations of Eucalyptus in the world, few studies have been carried out on water use by Eucalypts. In 2002 and 2003, Aracruiz Company reported that in one watershed-scale experiment, the results showed that Eucalyptus plantations used similar (or slightly lower) amounts of water as native forests.

To briefly summarize the discussion regarding Eucalyptus and water; Contrary to common criticism, Eucalyptus is efficient in its water use as demonstrated by the biomass produced per unit volume of water consumed. Though transpiration rates are high, and may modify local level hydrology. The claim that plantations may lead to desertification is not substantiated,

4.3 Effects of Eucalyptus on Soil Fertility

Few studies have been done on soil nutrients status in Eucalyptus plantations. In 1993, a study was carried out in Ethiopia to compare nutrient status in plantations of *E. globulus* (40 years old), Cypress (28 and 40 years old) and Cedar (40 years). The results showed that *E. globulus* plantations had low nutrient contents 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 in plantations of *E. globulus*. However, nutrient release in plantation of *E. globulus* was comparable to that in natural forest.

When grown at shorter rotations, other studies elsewhere, recorded differences between the nutrient status of natural forest and that of cropped plantations, especially when grown on short rotations. 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 short rotation-crops, nutrients are taken with the products within a short period of time. As the Eucalyptus stumps coppice after clear felling, more nutrients are required to support the fast coppice growth.

Research has indicated that areas under Eucalyptus have high level of micronutrients when compared to those under old tea crops. 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 8-10 years. Comparative studies of soils under Eucalyptus and adjacent grasslands have found no significant differences if the trees take longer than 10 years.

In summery, the rapid depletion of the reserve of nutrients in the soil due to cropping of Eucalyptus on short rotation is expected and is a direct consequence of their rapid growth.

4.4 Effects of Eucalyptus on Biodiversity Conservation

Several studies have been carried out to assess the effects of Eucalyptus plantations on biodiversity. Results from these studies have been consistent and they are given below.

At Muguga, plant diversity assessed under *Eucalyptus saligna* plantations gave the result given in Table 3.

Table 2. 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 /ha	1550	920
Number of indigenous plant species/ha	50	370

The table shows there were about seven times more plant species in the older plantation than in the younger one indicating that species richness increases with the age of the plantation. There were 26 percent and 68 percent of woody species in the younger and older plantation 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 trees species that regenerate easily under eucalyptus plantations include *Prunus africana, Polycias fulva, Zathoxylum gelletii, Junipersons procera, Croton macrostachyus, Carisa edulis, Olea* species, etc.

In 1998, a study was carried out 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 3,575 indigenous plant species per hectare in 11- year old plantation of E. *saligna*, the plantation of 27 years had 18,650 indigenous plants. Under the 16-year old plantation of *E. globulus*, there were 2,300 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, studies by Harrington and Ewel (1997), showed that in plantations of *E. saligna* that varied from 26 to 32 years in age, there were 42 indigenous species growing beneath them.

In conclusion, Eucalyptus plantations seem to create conditions favourable for regeneration of indigenous plant species and therefore enhance biodiversity conservation. However, this may only happen in areas in close vicinity to indigenous forest where seed can easily be dispersed by animals or by wind to neighbouring Eucalyptus plantations. And finally, most of the criticism on Eucalyptus is based on generalizations and incomplete information without considering the whole picture. A few of the perceived negative effects can be mitigated by planting the species in the right sites and applying correct management practices. Rational use of Eucalyptus in Kenya should hinge on the successful South African experience. The country should avoid expanding Eucalyptus plantations into water catchment, and riparian areas. National Environmental Authority (NEMA) has provided guidelines on how far from rivers, streams and other water bodies Eucalyptus should be planted. There is need to critically assess the trade-off between the income Eucalyptus generates and the water it consumes

5. Conclusions

i) Eucalyptus will continue to be the most popular and widely planted species in the world and Kenya is no exception.

ii) The area under Eucalyptus species in Kenya is relatively low compared with other countries.

iii) All species of trees wether indigenous or exotic use more water than grass. However, a well managed forest with good under-growth enhances infiltration leading to increased soil moisture recharge.

iv) Studies undertaken to determine the effects of Eucalyptus and other fast growing species on streamflow have not given consistent results. This is probably because there are many factors that affect streamflow. These include annual rainfall and distribution, soil conditions particularly infiltration characteristics, tree density and age, presence of undergrowth, forest management practices, characteristics of the surrounding landscape, etc.

v) It appears planting Eucalyptus and other fast growing species is unlikely to reduce water flows in high rainfall areas of Kenya as evidenced by the results from the Kimakia experiment.

vi) Like other short rotation monocultural crop, Eucalyptus species utilize soil nutrients which must be replenished to restore fertility

vii) Under low plant density and as the Eucalyptus trees grow older, they provide favourable conditions for regeneration of indigenous species and therefore enhance biodiversity conservation.

viii) There is need for both small-scale and large-scale land users to be provided with adequate information, guidelines and maps on where best to plant which type of Eucalyptus and under what management regime.

ix) The benefits of growing Eucalypts appear to outweigh any negative effects. The rapidly growing human population in the country is increasing demand for wood especially woodfuel resulting in overexploitation of forests and woodlands. This is likely to continue for along time. In order to ease the pressure on natural forests and woodlands, it is necessary to continue the policy of promoting planting of fast growing species such as Eucalypts.

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