Report

TW
AGR
005

# National Woekshop
# On
# "The Eucalyptus Dilemma"

CCRDA

**Organizer:**

**Ethiopian Environmental NGO**
**In collaboration with Pact-Ethiopia**
**Addis Ababa – Ethiopia**
**November 15, 2000**

**ACKNOWLEGEMET**

A number of organizations working on environment, professionals in forestry and individuals have contributed a lot to make "The Eucalyptus Dilemma" National workshop conducted on November 15, 2000, a success.

The steering committee made up of Addis Ababa Agricultural Development Bureau, Agri-Service Ethiopia, Lem Ethiopia, Pact Ethiopia and Ethiopian Environmental NGO played significant role to conduct the workshop.

The resources persons presented all necessary information regarding socio-economic aspects, the ecological effects and ecological impact of eucalyptus. The participants of the workshop gave comments and contributed ideas to enrich the presentation. The facilitator took active initiative to gear the discussion to common understanding and the reporters did a commendable job of putting the ideas together.

Pact Ethiopia played an important part of initiating the eucalyptus issue and financing the workshop.
The workshop organizer, EENGO, did a good job of getting the concerned bodies together to convene on the eucalyptus dilemma that enabled the professionals to conclude the case to be an issue instead of dilemma.

We acknowledge the contribution made by all partners.

CCRDA

## Table of Content


| Content | Page |
|---|---|
| **Part I Overview** | **1-7** |
| 1. Introduction | 1-2 |
| 2. Welcoming Ceremony | 2-7 |
| 2.1 Welcoming Address | 2-4 |
| 2.2 Opening Speech | 4-7 |
| **Part II Summary of Presentations and Discussion** | **7-17** |
| 1. Summary of Presentations | 7-15 |
| 2. General Discussion | 15-17 |
| **Part III Conclusion and Recommendations** | **17-18** |
| 1. Conclusion | 17 |
| 2. Recommendations | 17-18 |
| **Part IV Full Text of Papers Presented** | |
| **Part V Annex** | |
| Annex 1 List of Participants | |


CCRDA

## Acronyms

| | |
|---|---|
| EARO | Ethiopian Agricultural Research Organization |
| EENGO | Ethiopian Environmental Non-Governmental Organization |
| ENDA | Environmental Development Action |
| GO | Governmental Organization |
| NGO | Non-Governmental Organization |
| SNNPR | Southern Nations, Nationalities and Peoples' Region |
| UNSO | United Nations Sahelian Organization |
| USAID | United States Agency for International Development |

CCRDA

## Part I Overview of the Workshop

### 1. Introduction

A one day National Workshop on November 15th 2000, where policy makers, researchers, academicians and development practitioners from Gos and NGOs who has come from 4 regions; Addis Ababa, Amhara, Oromia and SNNPR assembled at Ghion Hotel-Saba Hall to discuss on the 'Eucalyptus Dilemma'. Alemaya Agricultural University, Wondo Genet Forestry College, Addis Ababa University, EARO and NGOs (local & international) were among the workshop attendants. All in all there have been 70 participants among whom 3 participants were female. See Annex 1 for list of participants and institutions.

***Eucalyptus Dilemma*** has been the main theme of the workshop. And this National Workshop is an outcome of another workshop held at the end of 1999 in Nazareth (Adama) in Oromia region.

Everybody agrees on the historical concern about the introduction of eucalyptus was to overcome fuel wood shortage during the reign of Menelik II. In due course the demand for eucalyptus become beyond fuel wood, it is considered like the most common cash crops. In spite of its remarkable expansion than any other tree species in Ethiopia, there have been publicly three different opinions concerning eucalyptus. The first opinion says eucalyptus tree species exclusively have negative ecological impacts, the second says eucalyptus tree species exclusively have no negative impacts on the ecology and the third says these species can have negative impacts which can be avoided through appropriate management.

These have been realized in a number of fora, which ended without any concrete solution. The reason might be lack of strong evidence to convince each other or to reach into a consensus. Previously organized fora did not dealt in depth and consider the diversified climate of Ethiopia, specifically the soil type, the water condition, altitude and the different characteristics of eucalyptus species. In fact this is not something unique to Ethiopia but there are similar experiences the magnitude of the issue vary, in Kenya & Tanzania. With all these conflicting ideas about eucalyptus, end users stand for eucalyptus plantation.

In a similar manner there was a hot debate on eucalyptus plantation impacts during the training on conservation and management of natural resources held in December 1999 in Nazareth, organized by Pact Ethiopia. The then training participants reached into a consensus and demanded to call a national seminar to

CCRDA

overcome the **eucalyptus dilemma**. At the same time EENGO as a hosting organization, Lem Ethiopia, ENDA Ethiopia and Addis Ababa Agricultural Development Bureau as co-partners decided to carry out the task while Pact Ethiopia promised to provide the required fund.

Under the chairmanship of the hosting organization, EENGO a committee consisting of GO (Addis Ababa Agricultural Development Bureau) and NGOs (Agri-service Ethiopia, EENGO, Lem Ethiopia & Pact Ethiopia) was established in January 2000 and started in reviewing past and present efforts made to conduct researches on eucalyptus and looking through all other possible means to overcome the dilemma.

A project proposal with the main objective being to seek the reality on the eucalyptus dilemma so that ultimately the clear vision created shall help planners and decision-maker for a careful decision on eucalyptus. Then a considerable effort was made to bring this endeavor into reality. During the organization process due attention was given to the selection of relevant topics, identification appropriate resource persons and participant organizations/institutions which are mainly involved in natural resources conservation and management/environment. As much as possible the organizers have tried to have a wider coverage of institutions and regional representations.

Based on the brief presentations of qualified researchers and academicians and the hot discussion made among participants the ***eucalyptus dilemma has been disclosed*** by this national workshop participants who are the cream of the issue in accordance with their position and responsibility. The participants concluded that today onwards there is no eucalyptus dilemma; the issue is rather eucalyptus management. The recommendations focused on the need to improve its management and appropriate species selection as there are a number of eucalyptus species as a priority and networking and dissemination of the right information to all stakeholders and strengthening further research at different ecological zonation in future strategies. Appropriate site selection and other conservation management. With regard to the outcome it can be said that without hesitation, the workshop has attained its objective even beyond expectations.

CCRDA

## 2. Opening Ceremony

Ato Bekele Hambissa, executive director of EENGO, has given short briefing about the workshop and mentioned that his organization is involved in natural resources conservation, capacity building of farmers, potable water development to rural communities and in improving rural women living condition. After a brief statement Ato Bekele invited Ato Tsegaye Cherinet, Co-director of Pact Ethiopia to welcome participants.

### 2.1 Welcoming Address

By Tsegay Cherinet, Co-director, Pact Ethiopia

It gives me a great pleasure and a feeling of honor to welcome you all for this oneday workshop on 'Eucalyptus Dilemma'. I would like to say something for those of you who do not know what Pact is. Pact is:

- USA based NGO working in close partnership with the USAID mission here in Ethiopia,
- involving in the institutional capacity of 82 NGOs
- its area of interventions are education, health, street children, orphans and agriculture and food security.

Among its partners close to 20 NGOs are involved in agriculture and food security. The services for those NGOs include;

- training & mentoring in some technical and general capacity building,
- provision of grant (fund) to implement some innovative projects and
- facilitate information, experience and idea exchange through exposure visit to best practices

How did we come to support this workshop?

Participants of the training on 'conservation and management of natural resources' discussed and wanted to have more discussion at a national level. Then Pact offered to sponsor the workshop. It is Pact's conviction that, the cause has greater relevance/meaning to all concerned about the socio-economic development of the country.

CCRDA

Purpose of the workshop

Not to reach at an agreement as at end of this session. But to come up with valid ideas, exchange information, research outcomes that would help or facilitate to future action or policies to be mapped out in this regard.

So, we believe that such an effort would contribute to the effort that the government is making towards conserving and managing natural resources effectively.

Furthermore, there will be a panel discussion on the same issue as a follow-up of this session, which will be aired through Radio and TV with the view to reach a larger audience.

Gratitude to all who worked hard to materialize the workshop, especially of EENGO.

After Ato Tsegaye's welcoming address, Dr. Paulos, director of soil and water research, EARO was invited to make an opening speech.

## 2.2 Opening Speech

By Dr. Paulos Dubale, Director-Soil and Water Research-EARO

Mr. Chairman,
Dear Participants
Ladies & Gentlemen

The current population of Ethiopia is estimated at 62 million. With an estimated rate of growth of 3.4% per annum and the population of this country is expected to reach to 100.8 million by the year 2010.

The pressure of increasing population on land resources particularly on vegetation, soil and water has been very significant. Over 85% of the population being farmers and living in rural parts of the country, they have based all their livelihoods on the natural resources that are at their domain. The size of farm plots owned by a household is diminishing probably indicating the increasing number of farm population than is presently assumed. Hence, farmers are forced to cultivate marginal lands and lands having slopes over 40%. The dwindling natural forests,

CCRDA

woodlands and plantation forests of the community are being squeezed for more croplands.

Desperation in the rural population has forced them to convert some grazing lands to crop cultivation. The cultivated land itself has been exploited to the maximum capacity that has led to nutrient depletion. The Acrisols and Nitosols in most of the western half of the country from north to south are acidic and need amendment to make them more productive. Soils of the rift valley and the eastern half of the country are exposed to drought and have neutral to alkaline reaction, which also requires careful management.

The relief of Ethiopia and the nature of climate (particularly the heavy torrential rains concentrated within a short period of time in the highlands), soil characteristics and the predominance of subsistence agriculture put the soils at a great risk of degradation and yet soil is the primary life support system for a pre-industrial Ethiopia.

Soil erosion is a major problem of Ethiopia. Studies on soil loss under major agro-ecology for cultivated lands, on the average, is estimated at 42 t/ha per year. In terms of only nitrogen and phosphorous nutrients that are lost per ha per year by erosion and equivalent to the blanket recommendation of 46 kg N and 46 kg $P_2O_5$/ha is about 184%. Soil erosion is by far the largest threat to soil productivity in that water infiltration rate, soil organic matter content, soil depth, content of other nutrients are highly reduced. The annual national loss in terms of money is more than Birr 400 million. In a study on soil loss due to erosion in northern part of the country predicts that crop production may cease in about 50 years time unless proper soil conservation and management measures are not taken from now onwards.

Mr. Chairman,
Ladies and Gentlemen,

The focus of this workshop is on *The Dilemma of Planting Eucalyptus Trees* as far as Ethiopia is concerned. Have *eucalyptus* trees locally known as *Bahir Zaf* been a blessing or a curse to the Ethiopian people? The answer to this question may vary significantly. To the rural people in the short term it may be a blessing. To people like us in this hall we may need empirical data before we decide whether it is a blessing or a curse. However, in the Ethiopian context we may not have ample data on the role and impact of eucalyptus trees on the economic life of the Ethiopian population and on the environment. From the pint of soil erosion

CCRDA

control, however, eucalyptus plantations may have done a good service. Look at the hills and mountains around Addis Ababa, Ghimbi, Debre Sinna and many other towns that you know of eucalyptus plantation cover them. The service eucalyptus rendered to these towns or cities is not only providing fuel wood and construction materials but it has controlled soil erosion.

Many writers do agree that eucalyptus was introduced to Ethiopia about 1895. It is also stated that the introduction was to solve the shortage of fuel wood shortage when the capital, Addis Ababa was established. Eucalyptus trees are known for best growth and high biomass stock and regeneration after stumping. The tree is also known to perform equally well when planted on degraded soils or wastelands.

Eucalyptus has also significant socio-economic importance that every Ethiopian understands. It is a source of fuel wood, construction materials, and cash for rural people. The Forestry Research Center has developed beautiful furniture that is made of Eucalypti timber.

Afforestation and reforestation programs have been stepped up during the Derg era in state and community owned forests with the objectives of self-reliance in production and supply of non-industrial wood products and probably for soil erosion control. Eucalyptus species probably made about 50% of these populations. In fact the UNSO, African Development Bank and the World Bank have supported the programs. Right after the fall of the Derg regime destruction of these forests were observed all over the country but many farmers have again taken up replanting mainly eucalyptus on their own small private plots. Planning of eucalyptus as curse of fuel wood and construction material has an advantage in relieving cow dung and crop residues as a source of fuel or construction materials in many parts of the country.

Although there is not sufficient empirical evidence yet on the ecological disturbance by eucalyptus trees most farmers planning eucalyptus do share the opinion that the tree has negative effect on soil fertility and soil water reservoir. Many farmers admit that they plant it because they have no other options. Crops grown close to eucalyptus trees exhibit poor performance. It is also known that the leaves of eucalyptus have an allelopathic effect on the growth and germination of other plants that grow under the tree and this has been proved empirically.

In addition to soil nutrient depletion and allelopathic effects, competition for soil moisture to the detriment of neighboring plant species or crops has been widely observed. It also drains the soil of its water table. In Ethiopia the farmers plant

CCRDA

eucalyptus on wetlands when they wish to drain the swamp. I am sure there are more advantages and disadvantages that can be listed to the farmers planting eucalyptus on their own farms and to the public at large. Eucalyptus are the most important economic trees for Ethiopia. However, today many parts of agricultural lands in Ethiopia are facing moisture stress. Hence, can the farmers keep on planting eucalyptus indiscriminately all over the country especially close to the farmstead? Considering the points raised above, the trade-off between potential socio-economic benefits and the environmental risks associated with planting eucalyptus need to be carefully evaluated and planned. Currently, I am afraid we do not have better alternatives to substitute eucalyptus. But I believe, the main objective of this workshop is to open a discussion forum among all the stakeholders, i.e. scientists, development officers and policy makers on the socio-economic and ecological effects of eucalyptus plantations that this country may eventually face if expansion continues at the present rate. Hence, some recommendations are expected from this workshop to the policy makers, development institutions, researchers and farmers on the ecological damage that may arise from eucalyptus plantation. Finally I want to thank the Ethiopian Environmental NGO and Pact Ethiopia for taking the initiative to organize this workshop and sponsoring it. With these remarks and wishing you fruitful deliberations and outcomes I now declare the workshop is officially open.

Thank you.

## Part II Summary of Presentations and General Discussion

Three papers under the theme of the National Workshop 'Eucalyptus Dilemma', which have focused on impacts of eucalyptus plantations on the ecology were presented by known researchers and academicians. The presenters have been Ato Kinfe Abebe-private consultants, Dr. Demel Teketay-Director of Forestry Research-EARO and Dr. Lisanework Nigatu- Lecturer at Alemaya University of Agriculture. The presentations have been based more on scientific and research findings. There were ample of empirical evidences to the findings. The three topics the papers have dealt with respectively were,

1. Historical/Socio-economic Aspects of Eucalyptus
2. The Ecological Effects of Eucalyptus
3. Ecological impacts of Eucalyptus plantations in Ethiopia

CCRDA

The papers were interrelated and supplement each other. Therefore, it is appropriate to merge the summary of the papers instead of summarizing them independently to avoid redendency.

## A. Ecological Impacts of Eucalyptus Plantations in Ethiopia

### 1. Introduction

Eucalyptus was brought to Ethiopia during the reign of Emperor Menelik II by an Australian named Monsieur Antonio in the year 1895 in order to overcome the fuel wood and construction shortage which previously necessitated the Emperor to settle in four different places in search of fuel wood.

Emperor Menelik himself has practiced the first seedling production in the compound of his palace. Later on, the Emperor ordered all the feudal lords to plant at least five eucalyptus tree seedlings each.

After Emperor Menelik died, his successor Lij Eyasu took over the power for a while, Lij Eyasus advisors informed him that Eucalyptus induces erosion, is not friendly with agricultural crops, does not support undergrowth and contributes to the drying up of the springs of the country. Then Lij Eyusu accepted his advisor's opinion and issued an order to uproot 2/3 of the eucalyptus tree seedlings. This implies that conflicting ideas on eucalyptus plantation started since earliest time. Eucalyptus are being alleged of depleting the soil nutrient elements, excessive water use and depression of food crops grown near by; and suppression of ground vegetation and resulting in unsuitability for soil erosion control.

Despite this, the practice of planting eucalyptus has rather expanded tremendously. Some of the reasons being: its fast growth, coppicing power and multidimensional uses has made eucalyptus to widely expand throughout the country. Eucalyptus species are the first exotic to be developed in plantation forestry of Ethiopia. More than 10 species are widely practiced in plantation mainly for the supply of wood product. But about 55 species of eucalyptus are found in Ethiopia according to research reports. These days eucalyptus plantation is practiced in more than 100 countries in the world.

As noted in one of the presentations, eucalyptus species have a number of economic and social values. Among the common uses are firewood, pole/posts, timber bee forage, windbreak, and as medicine, exhaustion of bad smell etc. These species are usually managed on coppice rotation of 7-10 years cycle.

CGRDA

According to the preliminary survey conducted in specific urban & rural areas by one of the presenters, the response given proved that eucalyptus is useful, eucalyptus is part of the respondents' life, if not for eucalyptus the country has been completely devastated, no substitute for it, and it is expanding at an equal rate to other agricultural practices.

The reasons behind this are the following;

- availability and easy propagation of seeds,
- relative ease of plantation establishment,
- tolerance to wide environmental conditions
- fast growing
- efficient conversion of solar energy,
- wood of high specific gravity and calorific value
- high coppicing ability,
- exceptional hardiness and good quality of timber,
- good economic return and
- relative tolerance to diseases and pests, etc.

With the existing situation of eucalyptus plantation in the country, current fuel wood situation is in a deficit of 32.5 million $m^3$ where the need being 45 million $m^3$ and the incremental yield 12.5 million $m^3$. If the situation continues unchanged, the demand would reach about 84.2 million $m^3$, by the year 2014. Thus, six million ha of land should be planted to bring equilibrium with demand and supply.

CERDA

## 2. Eucalypt Taxonomy and Genetics

- Early introduction of eucalypt to Ethiopia has been obscure and systematic documentation on the species began very recently.
- Its seeds are usually obtained through purchase or locally collected which resulted in inferior genetic quality. Along with this hybridization is a common feature of eucalyptus.
- This unintended effect can be minimized through the use of provenance of the right species.

## 3. The Eucalyptus Dilemma

- Despite the apparent benefits eucalyptus have some adverse public reactions against its plantation
- According to Davison (1989), a lot the criticisms are unfair, biased, nationalistic or emotional. The criticisms would equally apply to other exotic trees planted in many countries, not just eucalyptus.
- Eucalyptus has often been heralded as wonder species that will bring immediate solutions to local wood and erosion problems.
- When planting which fail follows it, because they have frequently been of the wrong species, site or management, local people may be left with vegetation, which is little if at all better than what was there before.
- The blame then falls on the Eucalyptus rather than on the real culprit, which is bad forestry practice.
- Had it not been for the introduction of eucalyptus to Ethiopia, the forest in the south and southwestern parts of the country would have disappeared long time ago.

**The various concern voiced about eucalyptus include;**

- removal of too much water from streams or underground water supplies
- adverse effects of their litter on soil humus, nutrient supply or prevention of erosion
- inhibition of the growth of other vegetation under their canopy
- no provision of food supplies or adequate habitat for wildlife, etc.
- as there are over 500 species of eucalypts with widely varying properties, the ecological effects of the same species may vary greatly in moist or arid sites or on different soils or topographies.
- the dilemma is general and real, but solutions and judgments must be specific to each case and based on accurate appraisal of biological, physical and human factors.

## 4. Eucalyptus and Water Consumption/Supply

- In determining water use of eucalyptus, it is necessary to consider "the water efficiency" of eucalyptus.
- Extensive plantation of fast growing tree species, including eucalyptus, will reduce water yield.

CCRDA

- All closed forests take up more water than scrub or grass. Eucalyptus utilize less water than pine, but probably more than other broad-leaved trees. Use of water is proportional to the amount of biomass produced.
- In suitable conditions eucalyptus help to control runoff, but their effect varies according to the slope, the growing condition and the presence of other ground cover.
- Studying details of the site should carefully assess cost and benefit of planting eucalyptus.
- Local need for forest products must be balanced against the effect on water supplies that may be essential to the people of the area. This being the most difficulty problem associated with growing eucalyptus.
- Catchments under eucalyptus forest have a lower water yield than grasslands, but they may maintain seasonal flow of water better, depending on the nature of the ground cover.
- Management of catchments under eucalyptus forest should aim at setting priorities particularly priorities, which will be given wood production and water yield.

## 5. Eucalyptus and Climate

- The effects of eucalyptus on a microclimate are in general similar to those of other evergreen plantations though some eucalyptus cast less shade than other broad-leaved trees because their leaves are held vertically on the twigs and their crowns are narrow.
- Tree collect moisture from drifting mist as it passes through upper leaves and branches.
- Considerable amount of water trapped by the crown and drip through the forest canopy to the ground, providing valuable addition to the annual rainfall that is not received in treeless areas.

## 6. Eucalyptus & Soil Erosion

- Erosion depends on such factors as intensity of rainfall, soil condition, slope and live vegetation and litter cover.
- Clear weeding practiced in young eucalyptus plantations may make soil susceptible to erosion.
- Plantations on steep slopes can provide effective erosion control, if careful techniques such as contour planting are used.
- Tree monocultures of any kind may not be the best solutions to soil erosion control, particularly sheet erosion.

CCRDA

- ⇨ On slopes from 40% to 100%, the stands are best developed into uneven ones by selective cutting over a period of years.
- ⇨ Use of mixed stands, better silvi-culture and management are required for effective soil conservation.
- ⇨ Eucalyptus rapidly develops good roots even in dry sandy soils, which makes them useful to control wind erosion.

## 7. Eucalyptus and Soil Nutrients

- ▼ Eucalyptus were found to have a beneficial effect on soil structure and compared favorably with pine and sal (shorea robuta). On treeless sites eucalyptus improved soil fertility through decayed leaves and litter.
- ▼ There is great difference between nutrient status of natural forests and harvested plantations (grown on short rotation).
- ▼ Soil fertility under eucalyptus plantains can be decreased through excessive removal of litter fall. In intact or little disturbed natural forest, nutrients are conserved and cycled between trees and soil.
- ▼ When a plantation is thinned or felled and the wood extracted, the nutrient capital changes considerably.
- ▼ Nutrients in the products are removed within a comparatively short period of time since eucalyptus is chosen for their fast growth.
- ▼ Harvesting younger trees reduces nutrients faster.
- ▼ Nutrients in the soil are affected by part of trees removed, type of management needed to obtain it, and harvesting method used; all have 'nutrient cost'.

## 8. Eucalypt and Wildlife

- A change in the vegetation/habitat affects most of the organisms and their food chain is disturbed until a modified food chain appropriate to the new habitat development.
- If suitably managed, eucalyptus can be grown in multi purpose plantations to provide fuel and timber at the same time be a habitat that will attract certain species of wildlife.
- Animals depend on natural vegetation for their food and shelter. Hence, they are affected when exotics replace their natural habitat.

CCRDA

## 9. Effects of Eucalyptus on Biological Condition of the Soil

- Impacts of eucalyptus on the ground vegetation depend very much upon the climate and edaphic factors.
- In drier climate, undergrowth vegetation composition and cover is often poor, due to combined effects of allelopathy and direct competition for water and nutrients.
- In wetter, high altitude climates, plantations of eucalyptus had higher species richness, biomass and cover of frobs and graminoids of the undergrowth vegetation when compared to conifer and pine plantations.
- Indigenous species have been found to regenerate and better perform under the canopies of eucalyptus plantations established in highland Ethiopia.
- With careful site-species matching and proper management option aimed at encouraging undergrowth species development eucalyptus plantation may serve as foster ecosystem in degraded highlands of Ethiopia.
- According to studies made at the Entoto hills in Addis Ababa, it was concluded that despite the potential "allelopathic effects" of the eucalyptus trees and nutrient deficient soils, the juniper has grown effectively on the eroded areas competing well with eucalypt trees.
- The studies made at the Munessa-Shashmane forest protected area revealed that, provided there is a seed source in the vicinity, establishment of forest plantations can help to:

    - forest regeneration of native woody species
    - enhance biodiversity
    - provide wood for various purposes
    - rehabilitate degraded lands and
    - conserve soil and water

On the other hand, potential allelopathic effect of eucalyptus on seed germination, radicule and seedling growth was investigated with chickpea, maize, pea and *teff*.

## 10. Eucalyptus as a Windbreaker and Shelter Belts

- Probably the most important effects that eucalypts have on other vegetation.

CCRDA

- Eucalyptus make good shelter belts, and E. camaldulensis has been recommended for this because even in low rainfall areas it rapidly develops an efficient root systems and sheltering crown.
- A well chosen mixture of species will not only shelter crops from wind but will also yield fruit, fodder and fuel wood
- Eucalyptus are useful trees for starting shelter belts because they are hardy and establish themselves quickly and farm animals do not eat them.

## 11. Eucalyptus and People

- Eucalyptus plantations have become a subject for argument in some countries and, on the other hand, they are making a useful contribution to the needs of the community because advantages outweigh disadvantages.
- Eucalyptus can play an important part of developing the objectives of social forestry.
- It is critical for communities and governments to support land use that is technically sound which can be continued for many years and which meets the practical needs of the community.
- Although eucalyptus don't provide fodder or add nitrogen to the soil, there are many instances where they make an important contribution to improved rural living

## 12. Conclusion

Despite the growing concern against planting eucalyptus, most of the reports available on eucalyptus in Ethiopia (and elsewhere) are in favor of planting them as different authors acknowledge that;

- Negative impacts can be minimized provided that the choice of species and sites as well as the management of the stands are appropriate,
- Benefit derived can offset losses that can occur from such plantations,
- No other species, be it indigenous or exotic, can replace them in the near seeable future to bridge the ever-widening gab between demand and supply of wood, and
- The profit derived from eucalyptus plantations is considerably higher than cultivating crops

CCRDA

Therefore, it has been strongly emphasized that careful selection of appropriate species and matching of species with appropriate sites must be taken as prerequisites on the right management practices should be employed. In conclusion high rates of wood production cannot be achieved without high rate of water use and the probable eucalyptus water use efficiency need to be compromised with increased biomass production.

## B. General Discussion

A number of issues have been raised during the discussion session in which the facilitator raised a lead question 'what are the major issues under the workshop title the Eucalyptus Dilemma?' Then the facilitator provoked participants by raising another question 'where is the dilemma? Because dilemma means there is difficulty to choose between the two options. But here there are no alternatives to choose; we are not dealing with option. If we really have understood the issue the most important thing is that what can we do in the future?'. Though the questions raised by the facilitator were challenging, after a while participants have realized that the issue is not dilemma. Then suggestions, supplements, questions, and objections started to flow. The main issues raised were the following.

- Lack of feasible/realistic option or alternative to eucalyptus,
- Eucalyptus is useful but if problem appear it is only a problem of management. Therefore, it is not a dilemma and the issue is eucalyptus management,
- How to manage it is an issue to be discussed,
- The problem is monoculture and if not appropriately treated it will go on by being dilemma.
- Eucalyptus is not sufficiently researched in our context i.e., in the Ethiopian context,
- The papers have not touched the utilization aspect E.g. timber, pulp, sawmill etc. Is eucalyptus used merely for pole, construction and fuel wood?
- The papers do not discuss much on the experiences of other countries,

CCRDA

- eucalyptus should be considered in future similar workshops or research,

- Lack of commitment to natural resources management including eucalyptus at the political/policy level is an issue,

- Lack of networking or communication among stakeholders, implementers, researchers, universities etc, is the source for the dilemma,

- In some regions there are directives, which discourage plantation of eucalyptus. There is a big information gap. Why food security is considered only along with crop production? Why not along with trees? Without evidence mentioning pros & cones of eucalyptus may create confusion even in learning institutions, leave alone experts at lower level and communities,

- As there is moisture stress in the northern part of Ethiopia, it might be the reason to discourage eucalyptus plantation. Without considering land use classification and the species type it might cause negative ecological impact,

- Prior to this workshop the issue of eucalyptus has been debatable in a number of workshops and training organized on natural resources conservation. Similarly two weeks a go there was a debate on newspaper. Where are those opinions? Does it mean the issue is sufficiently discussed or does it mean those individuals/opinions are not represented here?

- It is true that in some places eucalyptus plantations are dying out. It might be due to pathogenic effect or moisture stress and this may be the reason to pose directives that discourage eucalyptus,

- Eucalyptus plantation in rural areas is mainly demand driven and recognized as a cash crop,

- All the three paper presenters are from forestry discipline, thus it does not mean that these papers are exhaustive i.e., it would have been good if there were papers from the hydrology, economics or botany sectors. It is essential to consider the indigenous knowledge, economic and social problems related to eucalyptus too,

CCRDA

- There is under representation of professionals of forestry in a number of similar meetings on natural resources management and even lack of trained manpower in a number of institutions is observed and its impact is related to this issue.

## Part III Conclusion & Recommendations

### 1. Conclusion

After a thorough discussion among different outlooks on issues of eucalyptus participants compromising the facts and the existing situation, reached into a consensus 'eucalyptus is useful with appropriate management practices'. But participants have realized that without appropriate management eucalyptus can create a problem. Knowing the problem and its cause is something, but the most important thing is finding a means or a solution that can help to overcome the problem. Thus, '***What must be done then?***' is a valid question and the important part of this national workshop. The issue on 'The Eucalyptus Dilemma' has been discussed very well and at the end of the workshop most of the participants have understood about the issue and come into agreement that the issue of eucalyptus is an issue of management without reservation. By saying this no participant has denied to the need for further researches being area specific and species for the effective exploitation of eucalyptus. It can be said that this workshop has been the first in finding remedial solution rather than treating the symptom of the problem. The national workshop concluded its deliberations by passing important recommendations.

CERDA

### 2. Recommendations

1. Development is an outcome of a number of factors. Among these, are policies, regulatory laws and directives, institutions and the necessary manpower that promote and create conducive environment for development. With this regard, land use policy, forestry policy, agricultural policy, etc. should be considered as one of the essential elements to conserve and develop our fragile ecosystem. Participants appeal for the emplacement of these important policies.

2. Along with the emplacement of the policies (cross-ministerial) it is essential to set up efficient and adequate institutions/institutional capacity (research & educational), which should be supported by strategy, master plan and regulatory framework respectively.

3. It is essential to strengthening existing or establishing new information fora to provide/avail appropriate information to policy & development implementers and end users of eucalyptus at all levels.

4. To provide the governments with the right information and to avoid confusion among the public, it is essential to have a discussion forum through media.

5. Community and all other concerned parties should be involved/participate during policy/development strategy designing for the effective implementations of policies and development strategies and maximum attainment.

6. Strong networking among the different actors represented here and others not represented including the community to improve past mistakes and to avoid unintended mal effects.

7. The extension service should give more emphasis than before for the forestry sector including to eucalyptus plantations by providing with the necessary trained manpower. This will help in facilitating the environment for policy decisions.

8. Eucalyptus plantations must be continued with effective and improved management that can decide where to plant and which species to be planted in accordance with the communities need.

9. Instead of monoculture the management should focus on mixed plantation.

10. For the effective implementation of the knowledge and experience gained from presentations and other sessions of this workshop, it is important to translate the document in local languages that can be used at Woreda and grass-roots level.

CCRDA

**Part III Full Text of Papers Presented**

**Table of Content**


1. The Socio-economic aspects of eucalyptus. By Ato Kinfe Abebe, Private Consultant page 1-11.

2. The Ecological Effects of Eucalyptus: Ground for Making Wise and Informed Decision By Demel Teketay (PhD), Director of Forestry Research-EARO page 1-45.

3. Ecological Impacts of Eucalyptus Plantation in Ethiopia. By Lisanework Nigatu (PhD)-Lecturer at Alemaya Agricultural University page 1-22.


CCRDA

Annex 1 List of Participants

| S.No. | Name of the Participant | | Sex | Organization |
|---|---|---|---|---|
| 1 | Mengistu | Ayele | M | Eletawi Addis |
| 2 | Tibebu | Hailu | " | Ethiopian Telecommunication corporation |
| 3 | Birhanu | Wolde | " | Addis Ababa Agricultural Development Bureau |
| 4 | Tawit | Bekele | " | Addis Ababa University |
| 5 | Zerihun | Wolde | " | " " " |
| 6 | Kebede | Seifu | " | Alemaya University |
| 7 | Yadessa | Gire | " | CRDA |
| 8 | Negash | Mamo | " | Forestry Research Center (EARO) |
| 9 | Dechasa | Jiru | " | Board Chairman-EENGO |
| 10 | Amare | Mugoro | " | SOS Sahil |
| 11 | Dawid | Mussa | " | Oromiya Region North Shoa DPPD |
| 12 | Sorsa | Debela | " | Hundee (Oromo grass roots organization) |
| 13 | Seifu | Legesse | " | Addis Ababa Environmental Protection Bureau |
| 14 | Feyera | Sembeta | " | Wendo Genet Forestry College |
| 15 | Aman | Wabe | " | ADAA |
| 16 | Adugna | Mekonnen | " | Oromiya-North Shoa Department of Agriculture |
| 17 | Ensermu | Kelbessa | " | Addis Ababa University |
| 18 | Swen-gunnar | Larsson | " | PM-SLU/Wendo Genet Forestry College |
| 19 | Lisanework | Nigatu | " | Paper presenter-Alemay University |
| 20 | Aklu | Girgre | " | Facilitator-Development Studies Association |
| 21 | Azene | Bekele | " | Closing speaker-Ethio-forest |
| 22 | Tesfaye | Hunde | " | Forestry Research Center (EARO) |
| 23 | Beyene | Bezabih | " | Addis Ababa Agricultural Development Bureau |
| 24 | Biresaw | Mahtot | " | Amhara-Agricultural Development Bureau |
| 25 | Eyasu | Chiroka | " | EREDPC (MME) |
| 26 | Desta | Beyera | " | West Shoa Zone Agricultural Development Department |
| 27 | Melaku | Tadesse | M | Ministry of Agriculture |
| 28 | Korme | Lemmi | " | West Shoa Zone Agricultural Development Department |
| 29 | Zeleke | Tesfaye | " | ERSHA |
| 30 | Sisay | Biru | " | EENGO |
| 31 | Mebrate | Mihreta | " | Forestry Research Center (EARO) |
| 32 | Dawit | Berhanu | " | ENA (Ethiopian News Agency) |
| 33 | Shiferaw | Degefa | " | " " " " |
| 34 | Fuffa | Tesso | " | West Shoa Zone -DPPD |
| 35 | Hussien | Ambo | " | CDI |

CCRDA

Annex 1 List of Participants (cont...)

| S.No. | Name of the Participant | | Sex | Organization |
|---|---|---|---|---|
| 36 | Teshome | Tadesse | " | Bureau of Planning & Economic Dev. SNNPR |
| 37 | Mogues | Worku | " | Lem Ethiopia |
| 38 | Oli | Jira | " | Finfine Forest Dev. & Marketing Enterprise |
| 39 | Abdissa | Soboka | " | En. Pr.A.O. |
| 40 | Fikru | Deksissa | " | Oromiya Agricultural Development Bureau |
| 41 | Walelign | Mengiste | " | ORDA-Bahir Dar |
| 42 | Kidane | Mentistu | " | Ministry of Agriculture |
| 43 | Tekahun | Basha | " | Ministry of Economic Development & Cooperation |
| 44 | Dabie | Qonshie | " | SEDA- |
| 45 | Yeyesuswork | Bekile | F | Committee member-Lem Ethiopia |
| 46 | Tadelech | Tadesse | " | Addis Ababa University |
| 47 | Getachew | Abdi | M | Ministry of Water Resources |
| 48 | Getu | Alemu | " | OSRA |
| 49 | W/Yohannes | Fantu | " | Forestry Research Center (EARO) |
| 50 | Yeraswork | Admassie | " | Addis Ababa University |
| 51 | Adugna | Jebessa | " | Ministry of Water Resources |
| 52 | Begashaw | Wukaw | " | Proceeding-Oromiya Regional Council |
| 53 | Mersha | Alemayehu | M | Bureau of Agriculture - SNNPR |
| 54 | Mesfin | Tefera | " | Committee member-Agri-service Ethiopia |
| 55 | Kidane | Wolku | " | A.A Fuelwood project |
| 56 | Mulugeta | Asechenki | " | DKT/Ethiopia |
| 57 | Gebere | Markos W/S | " | Consulting firm |
| 58 | Tsegaye | Bekele | " | Wondo Genet Forestry College |
| 59 | P.L. Bark | Lund | " | Wondo Genet Forestry College |
| 60 | Seyoum | Kelemework | " | Forester Research Center (EARO) |
| 61 | Gari | Sima | " | Board member-EENGO |
| 62 | Beltu | Mengistu | F | EENGO-Board Member |
| 63 | Kiflu | Segu | M | Woody Biomass |
| 64 | Tekele | Legesse | " | ECA FCO S.C |
| 65 | Ababu | Anage | " | EPA |
| 66 | Ayele | Bekele | " | EENGO |
| 67 | Deribe | Gurmu | " | EARO |
| 68 | Paulos | Dubale | " | Guest of honor- EARO |
| 69 | Woges | Gobena | " | Committee member-EENGO |
| 70 | Desalegn | Eyob | " | Environmental Journalists Association |
| 71 | Debebe | Ero | " | Committee member-Pact Ethiopia |
| | | | | |

ORDA

# THE EUCALYPTUS DILEMMA

*The socio - economic aspects of eucalyptus*

CCRDA

*By*
*Kinfe Abebe*

November 6, 2000
Addis Ababa

## Historical Background

Since the time Emperor Menelik II fled to Ankober, has realized an acute shortage of fuelwood. This had been a reason to shift the capital from one place to another and first from Ankober to Eneware in North shoa. The same thing happened in Eneware as well. In a short while, the followers of Menelik consumed the forest around Eneware. Menelik was worried as to how to handle the situation and an immediate step towards the solution, again he had to change the capital from Eneware to Ada Girge where he thought that a better forest condition exists. In few years, the forest in Ada Girge was also finished. Finally, Menelik shifted the capital to Entoto hills in 1873 EC. The natural high forest in and around Entoto hills was also over used and finished and another shift of the capital from Entoto to Menagesha hills was planned. However, the fact that the forest in the low lying Finfine area was a source of fuel for that particular moment, the idea to shift the capital to Menagesha hills was changed to Finfine in 1879.

The fuelwood problem was not resolved after even shifting the capital to Adis Ababa. Out of a keen concern, historical documents revealed that Emperor Menelik II discussed the issue with his cabinet repeatedly and was advised that the issue be raised with Monsieur Mondel Videlio, who was a French train engineer staying in Addis Ababa. After understanding the problem, Mondel promised to the Emperor that he would make an effort to import a fast growing fulwood species to Ethiopia.

In 1897 November, Emperor Menelik called an urgent meeting of all important Feudal Lords, numbering some 32 to discuss on the issue of wood shortage and among the Feudals there was an Australian called Monsieur Antoni who was considered as one of the important people in Ethiopia. He briefied the participants that he knows a tree species called Eculaypt (Kulufto) fast growing found natually in Australia and expressed his readiness to go and bring the seeds to Ethiopia. Finally, the participants endorsed the idea and Monsieur Antoni was sent to Australia to bring the seeds of Eucalypts in 1899E.C.

The seeds of eucalypt were first raised in the Emperor's palace near the spring in a special place called Ebir Gabriel. The responsibility of raising the seedlings was voluntarily taken by the

CCRDA

Emperor. A documented historical evidence reveals that Menelik with his servants used to fetch water from the spring to water the seedlings. Surprisingly, it is documented that the first seedling of the Eucalyptus was planted by Emperor Menelik II in a pit prepared by his own hands in the compound of the Emperor's palace. Subsequently, the Emperor ordered all his highlevel followers to plant five eucalyptus sedlings each and it was serously instructed that those who failed to achieve 100% survival would be sentenced for a strong penality. In the third year of seedling raising and distribution from the Keranio nurssery the name of the tree species was changed from "Lalibo" to "Bahrzaf" by Menelik himself.

The protection of the planted seedlings was also taken serious concern of and few forest guards were employed to guard the plantations around Addis Ababa.

CCRDA

## Origin of the Eucalyptus Controversy

Emperor Menelik II died in 1906 E.C. and his successor Lig Eyasu also had the same concern on the fuelwood shortage of the country. He used to have advisors (Foreigners) and he was informed that eucalypt:-

- induces erosion
- is not friendly with agricultural crops
- dosnot support under growth
- and contributes to the drying up of lthe springs of the country.

Then, the King, Leg Eyasu issued an order that of those eucalyptus plantations established 2/3 should be uprooted and replaced by mulberry species for silk production. Since then, the controversy on eucalyptus was started.. This issue was taken more seriously when the Egyptian Minister of works who visited Ethiopia in 1913 E.C. spoke of the cause for the drying up of the springs in Ethiopia, to be the eucalyptus intoduction.

Then it was introduced, eucalyptus gained popularity and despite the negative advocacy and order by Leg Iyasu, planting eucalyptus was expanded.

### *The current Fuelwood situation of the country*

History reveals that eucalypt was introduced to solve the then fuel and construction material shortage in the country. The fast growth, its coppicing power and the multi dimensional uses, eucalyptus can be put into, have been some of the main resons for the wide expansion of eucalyptus to date. Individual landlords, farmers, even people owning land at the outskirts of big and small town have been planting eucalyptus in the country.

CCRDA

The Derg regime discouraged individual efforts and gave way to communally owned plantation development in the form of woodlots. Towards the end of th Derg regime, it is documentaed that about 35,000 ha. of fuelwood plantation was established and managed by govrnment.

The current situation in plantion development is not that encouraging. Especially when it comes to planting eucalyptus it is becoming controvertial. In most cases to encourage the planting of indigenous species discouraging plating eucalytus is taken as a strategy.

What does the reality in fuelwood situation of the country depict?

Not much seems to have been done on current fuel wood situation, after the Ethiopian Forestry Action Programme (EFAP) was completed in 1994.

The following information gives idea on the fuelwood demand and supply situation of the country in 1987 and the projection to date.

- of all energy consumption, household accounts for 88% of the total consumption with rural community taking 93% share.
- cooking accoutns for 86% of the total use, and lighting accounts for 13% of the total use.
- percapeta consumption for all households (rural and urban) 1.16m3s or 241 kg of oil equivalent.
- In 1992, the total demand for household energy is estimated at 68.1 million $m^3$ of wood equivalent, fuelwood taking the share of 45 million $m^3$s of which 41.6 million $m^3$s of the total demand comes from rural and 3.4 million $m^3$s from urban households.
- The incremental yield from the forests is 12.5 million $m^3$s.
- The difference between 45 and 12.5 million $m^3$s which is 32.5 million $m^3$s is fulfilled "illegally" from the differnt sources.
- To rescue the situation by 1992 2.1 million ha. of plantation is required. If the situation continues unchanged 6 million ha of area should be planted by 2014 to bring equilibrium with demand and supply.

CCRDA

*The economic uses of Eucalyptus*

| | | |
|---|---|---|
| 1. | Euc.camaldulensis | Firewood, charcoal poles and posts, timiber (construction), bee forage, ornamental wind break, |
| 2. | Euc. citroidora | Fire wood, charcoal, poles, timber beeforage, medicine (leaves) wind break |
| 3. | Eucalyptus globulus | Firewood, charcoal poles, posts, timber construction, veneer ply wood, medicine bee forage, pulp, boxes flooring, structural work, furniture tool handle, cheapboard, light/heavy construction, building, shade, ornamental. |
| 4. | Eucalyptus grandis | Firewood, charcoal, poles, posts, timer (construction), furniture building, transmission, flooring, honey production shade, amenity, etc. |
| 5. | Eucalyptus saligna | Firewood, charcoal poles, timber, furniture veneer, ply-wood, construction, medicine, beforage, shade, wind break, flooring packing case mining timber, pulp, fibre board |
| 6. | Eucalyptus viminalis | Firewood, poles timber (construction) boxes, veneer plywood, building flooring beeforage, ornamental wind break, paper, pulp. |

CCRDA

| No | Use type | Eucalyptus camaldulenses | Eucalyptus citrordora | Eucalyptus globulus | Eucalyptus grandis | Eucalyptus saligna | Eucalyptus viminales |
|---|---|---|---|---|---|---|---|
| 1 | Fire wood | X | X | X | X | X | X |
| 2 | Charcoal | X | X | X | X | X | - |
| 3 | Ploes/Posts | X | X | X | X | X | X |
| 4 | Timber | X | X | X | X | X | - |
| 5 | Beeforage | X | X | X | - | X | X |
| 6 | Orinamental | X | - | X | - | - | X |
| 7 | Wind break | X | X | - | - | X | X |
| 8 | Medicine | - | X | X | - | X | - |
| 9 | Veneer | - | - | X | - | X | X |
| 10 | Plywood | - | - | X | - | - | X |
| 11 | Furniture | - | - | X | X | - | X |
| 12 | Boxes | - | - | - | X | - | X |
| 13 | Pulp | - | - | - | X | X | X |
| 14 | Shade | - | - | X | X | X | - |
| 15 | Flooring | - | - | X | X | - | X |
| 16 | Tool handle | | | X | | | |
| 17 | | | | | | X | |

N.B Please note that all types of eucalyptus are good for fuel and construction purposes.

CORDA

## *The social values of eucalyptus as a species*

Eucalyptus was a highly recognized tree species since its introduction.

The introduction of Eucalyptus has made a number of contributions in the social system of the Ethiopian Society.

The following make some of the social services covered by the existence of Eucalytpus.

- Eucalyptus, especially E. globulus is used as traditional medicine for flue by boiling the leaves and allowing the water vapor into an open month.
- During a holy day called Timket celebrated each year by the christaian Ethiopians, the eucalyptus stick (billet) is used by each male individual for the special dancing and group celebration. The young trees of eucalyptus are excessively harvested to celebrate the day. Without it, Timket wouldn't have any color.
- Eucalyptus is also used during the other christian festival called Christimas. Knoted short eucalypt billet is used for the special tournament called "Gena" especially by the young rual people.
- Eucalyptus stick is usually used by old people as a support rode. Shepherds in the rural Ethiopia make use of eucalyptus stick to guide and control their animals.
- The good smell eucalypt has is usually used to control exusion of bad smell. This being the built ground, eucalypt is used to sprinkle water on the dead body of human beings to clean the corpse before burial.
- Eucalyptus citroidora has a special attractive Odour and is used in the making of perfum. Traditionally, some people chew and throw away euclyptus globulus leaves to control bad smell from the mouth.

CCRDA

*An example on the openion of the Rural population.*

The openion of the rural prople on Eucalyptus is, in general, positive. There is not any particular case study conducted to measure the openion of the rural people. However, through any contacts with rural people, one could feel the positive attitude they have for Eucalyptus.

My personal experience very recently at North Shoa around Debre Berhan could be taken as a classical example on the openion of farmers for eucalyptus.

In a discussion made to get the comparative advantage of indigenous species over euculyptus and other fast growing intoduced species; it was clearly shown that the people have high consideration for eucalyptus than for indigenous species. The reasons they gave include the following.

- Eucalyptus is fast growing
- Eucalyptus is economic speceis
- Eucalyptus has a coppicing power.

More and above this, they mentioned that this time, their farm plots are not giving them enough yield to sustain their life. The only alternative they have is to strength planting eucalyptus on the marginal plots they have.

In fact, they mentioned that they are not allowed by the Agriculture Bureau experts to change the land use from agriculture to tree culture for they have already understood that even the small number of trees they kept in their compound have been constant sources of income for their day in and day out incidentals and the Bureau is aware that the moment they are given the freedom they would do it.

In general, the openion of the farming community on eucalyptus, for the above mentioned reasons is positive.

CCRDA

## The survey on people openion about Eucalyptus in Addis Ababa

Places of the survey:-

- Kara
- Agoza
- Shola
- Kolfe /Atana Tera
- French Embassy area

Target groups

| | |
|---|---|
| Brush wood and leaf collectors | 24 |
| Engera bakers | 2 |
| Eucalyptus pole dealers | 8 |
| Fuelwood dealers | 12 |
| Stump removers | 5 |
| Users of eucalypt as fuel | 2 |
| wood spliters | 2 |
| | **81** |

*Survey Method*

*Questionnaire based interview*

*Summary of the results*

1. Almost all replied that Eucalyptus is useful.
2. For the question asked to know if there is any reservation on growing of eucalyptus, or if there is any one having a point against eucalyptus, the answer was none.
3. Respondents enumerated the uses of eucalyptus as fuelwood, for baking engera construction, furniture, paper making, source of income for wood dealers, climate ameleoration
4. Respondents replied the following for the question asked as to what would happen if eucalyptus is totally cleared:-

CCRDA

* The poor remains without shelter.
* The country will be desert.
* Most people will be starved.
* Disease will be expanded.
* Climate will be changed and the country will be windy.
* Many people will be jobless.
* There will be no rain.
* Soil erosion will be intensified.
* We will not have clean air.
* No shelter for wild animals.
* The rural people and those who use eucalyptus in small and big towns will fall in a critical fuelwood shortage.

5. There was a question on whether planting eucalyptus should be strengthened or not. Every one asked has expressed his /her earnest feeling that it has to be expanded much more so that they will have easy access to eucalypts cheaply.

6. For the question asked if they have any other point to justify the expansion of eucalyptus, the following points were mentioned:

* It has to be expanded, because there is no replacement to it.
* It has to be expanded, because it is our source of income.
* It has to be expanded, because it is the only source of fuel and construction material for the country.
* It has to be expanded to maintain good air.
* Its expansion should go to the extent that if 50% food crop is cultivated an equal amount of land has to be put under eucalypt.
* It has to be expanded to manage the future fuelwood shortage, which will be much more aggravated.
* The question asked if they know any replacement for eucalyptus was replied by the majortity that it has no replacement. Few individuals mentioned Acacia, Cupressus, Cordia and podocarpus.

CCRDA

## Conclusion

1. People know that eucalyptus is useful.
2. People feel that eucalyptus is part of their life (fuelwood).
3. People have very great fear that absence of eucalyptus brings a total disaster to the country.
4. people know that there is no replacement so far for its use as source of fuel and construction material.
5. People feel that eucalyptus has to be expanded in an equal extent to angricultural expension.

CCRDA

# The Ecological Effects of Eucalypts:
## Ground for Making Wise and Informed Decision

*Paper presented at the workshop on*
***"The Eucalyptus Dilemma"***
**15 November 2000**
**Ghion Hotel**

CCRDA

**Compiled by**

**Demel Teketay, PhD**
**Director of Forestry Research**
**Ethiopian Agricultural Research Organization**
**P. O. Box 2003, Addis Abeba, Ethiopia**

# Summary

The dilemma over the use of eucalypts for social and industrial forestry has been mounting in Ethiopia and elsewhere in the world. There are two schools of thought: *for* and *against* using eucalypts in plantations. Although fast growing and relatively sure to survive, there is concern that eucalypts may not adequately supply forest benefits such as quality wood, watershed and soil conservation, wildlife habitat and even recreational or aesthetic values. Other controversies on eucalypts include removal of too much water from streams and underground water, adverse effect of their leaf litter on soil humus, nutrient supply or the prevention of erosion, inhibition of growth of other plants and inability to provide food supplies or adequate habitat for wildlife. Those arguing *for* planting eucalypts emphasize that the criticisms on eucalypts are *unfair, biased, nationalistic* or *emotional*. The dilemma is general and real, but also equally applicable to other exotic trees planted in many countries, not just eucalypts. Therefore, solutions and judgements must be specific to each case and based on accurate appraisal of biological, physical and human factors. In countries like Ethiopia, where there are huge gaps between demand and supply of wood as a result of escalating deforestation/devegetation of forest and woodland vegetation resources, the use of fast growing plantation species such as eucalypts is inevitable. Eucalypts are preferred to other species, both exotic and indigenous, because of their peculiar features. Farmers in Ethiopia plant eucalypts, particularly *E. globulus*, on small areas of land and manage them to yield a variety of products including leaves and small branches for fuelwood, and poles and posts for house building and other farm uses. The use of eucalypt trees as a *living bank account*, i.e. to be harvested when there is a need for cash, is widespread. Many people in Ethiopia are absolutely dependent on eucalypts as a source of fuel and house building material. Therefore, before any decision is made *against* the use of eucalypts, these and other relevant factors have to be considered very carefully. Hence, the aim of this paper is to review the available information on eucalypts, which is particularly relevant to Ethiopia, and provide a strong ground for wise and informed decision on the use of eucalypts. The paper highlights: the evolutionary adaptive and special features of eucalypts that have contributed to their successful establishment in many parts of the globe; when, where, how and by whom eucalypts had been introduced to Ethiopia; habit and wood, special features, hazards from diseases, pests, fire, frost, wind and drought, experience in Ethiopia and uses of four of the widely planted eucalypts in Ethiopia; causes of the eucalyptus dilemma; various ecological effects of eucalypts with regard to the four key ecological questions, namely *water, erosion, soil nutrients* and *competition*; close association of eucalypts and people; the need to make the right decisions. Careful study of the ecological effects of eucalypts in the light of available evidences and consideration of the arguments, both *for* and *against*, lead to the conclusion that there does not seem to be any profound reason why eucalypt planting should not continue in Ethiopia until such time that alternative species are discovered. The establishment of eucalypt plantations could take different forms, e.g. huge number of small woodlots, groups, belts, lines and single trees scattered throughout the rural, but also urban areas. However, it has to be strongly emphasized that **careful selection of appropriate species and matching of species with appropriate sites must be taken as prerequisites and the right management practices should be employed**.

CCRDA

# 1. Introduction

*Eucalyptus* belongs to the family of flowering plants known as **Myrtaceae** (Friis, 1995). The term *Eucalyptus* has been derived from two Greek words, "**eu**" meaning "**well**" and "**kaluptos**" meaning "**covered**", a botanical reference to the trees, flowers and fruits (FAO, 1988). It is a genus of more than 500 (Friis, 1995; Turnbull, 1999) to 600 species (FAO, 1988), mostly in Australia, but extending to the Malaysian region and the Philippines. Some of the giant trees have a top height of 90 m, but in open scrub areas, which have a low annual rainfall, dwarf forms of eucalypts are quite common.

In their homeland, eucalypts dominate most of the natural forests, growing in diverse climates and soil types ranging in altitude from sea level to 1,850 m (Pohjonen, 1989). They play an important part in the closed forests of southern Australia, and typically they are trees up to 200 years forming a transition stage between older, fire damaged natural forest and the closed rainforest. Acacias are also often a component in this type of forest. The open forests, on the other hand, are dominated by eucalypts growing together with *Callitris, Casuarina, Melaleuca* and *Acacia* (FAO, 1988).

When planted outside their natural habitat, many species of *Eucalyptus* have shown a high degree of tolerance to extremes of latitude and longitude. This is in contrast to many plants, which cannot flourish when introduced to different latitudes and longitudes. Outside their natural habitat, eucalypts were probably first grown in Portugal 400 years ago, but the first major plantings were started in Brazil in 1904 where, today, the country has over one million ha (FAO, 1988; Turnbull, 1999). It is interesting to note in this connection that eucalypts were first introduced to Ethiopia in 1895 (von Breitenbach, 1961). With over 100 countries in the world growing eucalypts in plantations, it is said that no other trees have been so widely propagated.

A large number of eucalypts have been planted throughout the tropical zone but most overseas planting is of 10 species, namely *E. camaldulensis, E. globulus, E. grandis, E. maculata, E. paniculata, E. robusta, E. saligna, E. urophylla* and *E. viminalis* [Nomenclature follows that of Friis (1995)]. With the exception of *E. urophylla*, all of these plants have been introduced to Ethiopia. Initially, eucalypts were planted for curiosity in botanic gardens, arboreta, parks and for amenity. Later on, they were found to be useful for fuelwood, charcoal, paper pulp, shade and shelter, posts, poles, mine props, sawn timber, plywood, fiberboard, tannin, production of eucalyptus oil, ornamental purposes and as a source of nectar in honey production (Pohjonen, 1989; Friis, 1995; Turnbull).

As stated above *Eucalyptus* has become the most planted genus of trees in the world (Table 1). Reliable global estimates of areas of planted eucalypts are difficult to obtain, but published reports suggest that there are at least 12 million ha of eucalypt plantations all over the world (Turnbull, 1999). Over 90 % of these forests have been established since 1955, and about 50 % in the past decade. From about one million ha in 1962, planting has approximately doubled each decade until the end of 80s when the plantations covered about seven million ha, with variable annual planting rate estimated at about 175,000 to 200,000 ha. It is expected that the area covered by

CCRDA

eucalypts would increase to about 15-20 million ha by the year 2000 (Turnbull, 1999). In East Africa, over 100 species have been recorded from cultivation.

**Table 1. Area coverage of eucalypt plantations in different countries.**

| Country | Area Under Eucalypts (ha) |
|---|---|
| Brazil | 3,000,000 |
| India | 1,000,000 |
| China | 600,000 |
| Portugal | 550,000 |
| South Africa | 477,000 |
| Spain | 396,000 |
| **Ethiopia** | 250,000* |
| Morocco | 200,000 |
| Chile | 170,000 |
| Australia | 125,000 |
| Thailand | 100,000 |
| **Total** | 6,618,000 |

Sources: Turnbull (1999); * Tsegaye Bekele (1996): only *E. globulus* & *E. camaldulensis*

Different authors (von Breitenbach, 1961; Poore & Fries, 1985; FAO, 1988; Davidson, 1989; Pohjonen, 1989; Amanuel Mehari, 1996; Turnbull, 1999) have indicated the major reasons that contributed to the widespread cultivation of eucalypts in various parts of the earth. These include availability and easy propagation of seeds, relative ease of plantation establishment, tolerance to wide environmental conditions, fast growth, efficient conversion of solar energy, wood of high specific gravity and calorific value, high coppicing ability, exceptional hardiness and other fine qualities of their timber, good economic returns, unpalatability or tolerance of most species to browsing and grazing, relative tolerance to diseases and pests, etc.

To understand why eucalypts are so successful, one needs to look at the evolution of eucalypts and the natural history of the Australian Continent (Davidson, 1989). Australia became completely separate from Gondwanaland about 60 million years ago and developed independently in isolation. It was originally very humid, and covered with rainforests. About 10-15 million years ago, it became not only arid and semi-arid but also experienced several cycles of glaciations and decline of soil fertility.

Almost all of the angiosperm families now found in Australia are also found widely in other parts of the world. Australia has the widest array of primitive angiosperms in the world. However, below the family level, i.e. at the genera and species level, plants with special features have developed as a result of adaptations o evolutionary stresses of water scarcity, low nutrition, fine and high soil salinity. Among these unique plants are more than 500 species of eucalypts (all but two species indigenous to Australia) and more than 800 species of leafless and thornless acacias.

The evolutionary adaptive features of eucalypts (Davidson, 1989) include:

A. *Tolerance of severe periodic moisture stress*

- Xeromorphic leaves
- Stomata close when water potential deficit in the leaf is high
- Wax coating

CORDA

- Hairy juvenile leaves (some spp.)
- Volatile leaf oils
- Deciduous in dry season (few spp.)

B. *Tolerance of low soil fertility*

- Adapted to soils with low nitrogen and phosphorous contents
- Do not fix nitrogen but do have specialized nutrient uptake system of ecto- and endo-mycorrhizas that increase phosphorus uptake mainly, but also zinc, copper, molybdenum and in some cases ammonium

C. *Tolerance of fire / insect damage*

- Lignotubers (underground organs)
- Thick barks
- Dormant bud system indeterminate crown

About 1/3 of Australia lies in the tropics and it extends from 11 to 44° S with a variety of seasonal distribution types of rainfall. Its environment matches 70 % of the earth's surface. *In a large part of this, eucalypts would be better off than they would be at home because of higher rainfall and better soils.* The superior performance of eucalypts in relation to other exotic and native species has its origin in their greater ancestral diversity. There was a higher number of species in the ancestral moist forests in which the eucalypts evolved as environmental conditions changed severely in Australia. Flora of other continents do not have this genetic history. Because no two areas of the world are exactly similar, plants evolving in one place under fiercer competitive conditions involving a wider and better range of ancestors over a longer time must be at an advantage (Davidson, 1989).

CCRDA

## 2. Eucalypts in Ethiopia

Documentation on eucalypts in Ethiopia, particularly reports on results from studies on eucalypts are few. Of these, reports by von Breitenbach (1961, 1962a, b), von Breitenbach & Koukol (1962), Teferi Haile (1961), Wolde Michael Kelecha & von Breitenbach (1961), FAO (1979), Adugna Zerihun (1981), Mebrate Mihretu *et al.* (1983), FAO (1983), Örlander (1986a, b), Davidson (1989), Pohjonen (1989), Pohjonen & Pukkala (1988a, b, 1990a, b), Pukkala & Pohjonen (1988, 1989, 1990a, b), Mebrate Mihretu (1992, 1993), Azene Bekele *et al.* (1993), Lisanework Nigatu & Michelsen (1993, 1994), Michelsen *et al.* (1993), Fichtl & Admasu Adi (1994), Amare Getahun & Girma Balcha (1995), Friis (1995), Negash Mamo *et al.* (1995), Persson (1995), WUARC (1995), Michelsen *et al.* (1996), Friis & Michelsen (1996), Tsegaye Bekele (1996), Amanuel Mehari (1996), Gebrekidane Teklu (1997), Betre Alemu (1998), Daba Wirtu (1998), Feyera Senbeta (1998), Kidane Woldu (1998) and Mebetu Moges (1998) have been used for the present compilation. In addition several other publications, specifically those by Poore & Fries (1985), FAO (1988) and Turnbull (1999) have been very relevant to the topic at hand.

**Eucalypts** were introduced to Ethiopia during the reign of Emperor Menelik II (1868-1907) in 1895 (von Breitenbach, 1961; Teferi Haile, 1961). It has been

reported that when Emperor Menelik found out that his people did not have sufficient fuelwood and timber for construction, he decided to start afforestation. Discouraged by the performance of indigenous species, he requested Mondon-Vidaillet, a French Railway Engineer and Philologist (one of his expatriate advisers), to assist him in the introduction of exotic tree species. Mondon-Vidaillet ordered seeds of many eucalypts (*E. amygdalina, E. bicolor, E. camaldulensis, E. cladocalyx, E. cornuta, E. diversicolor, E. globulus, E. incrassata, E. leucoxylon, E. melliodora, E. patens, E. resinifera, E. rudis, E. salubris* and *E. tereticornis*) and acacias from Australia as well as pines from Portugal, Italy and Greece. After the seeds had arrived, he laid out a nursery in the Imperial Palace and raised seedlings, which were planted afterwards in Addis Abeba. Only a few of the eucalypts succeeded.

*E. globulus*, known locally as 'Nech-Baharzaf' or 'White Eucalypt', proved best by its distinguished vigour, fast and beautiful growth habit as well as high production of wood suitable both for fuel and construction. It conquered the surroundings of villages, towns and capitals on the cold highlands, and was replaced by *E. camaldulensis*, known locally as 'Key-Baharzaf' or 'Red Eucalypt' in the lowlands.

While the interest of the public was concentrated on the above two eucalypts, on account of their easy propagation and fast growth, the other introduced species remained more or less neglected. With the beginning of the modern development and industrialization, however, the necessity of favouring other eucalypts, which might yield better timber, particularly more suitable for building and industrial purposes, was recognized. Hence Australian eucalypts unknown in Ethiopia up to that time (*E. grandis, E. mucronata, E. rubida, E. saligna, E. sideroxylon* and *E. viminalis*) were introduced by E.H.F. Swain (Australian Forestry Adviser), H.L. Vernede (French Forestry Advisor), F. Mooney (British Forest Officer) and Wolde Michael Kelecha (Ethiopian Forester) (von Breitenbach, 1961). Since then, quite a number of other eucalypts have been introduced.

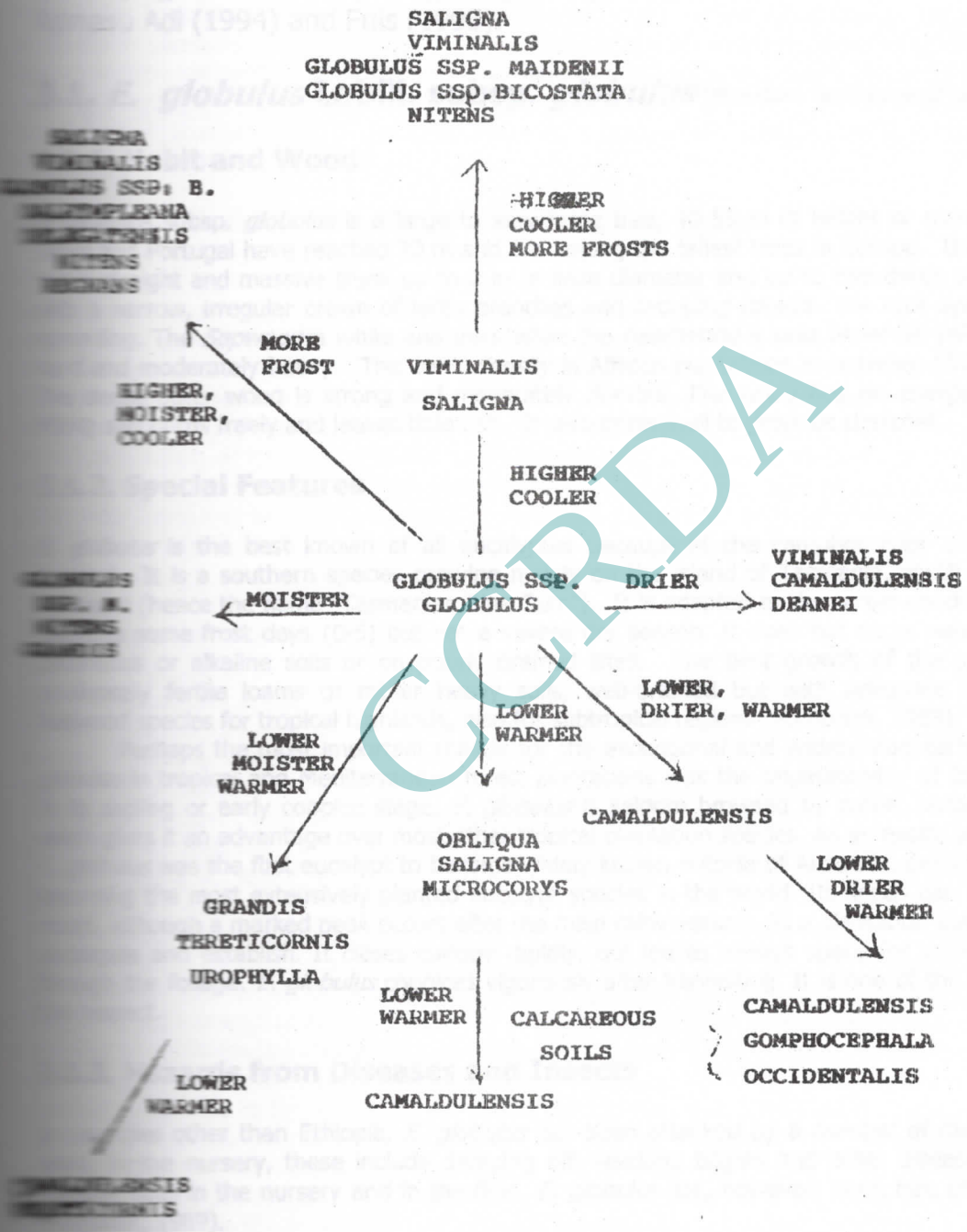
Currently, about 55 species of eucalypts have been reported from cultivation in Ethiopia, of which between five and ten are widely planted (Friis, 1995). Description of the genus, notes on some features of *Eucalyptus*, introduction to Ethiopia, keys for species identification, description of the species with line drawings of some plant parts, distribution within Ethiopia and elsewhere in the world and voucher specimens have been presented by Friis (1995).

In Ethiopia, the most widespread species include *E. camaldulensis, E. melliodora, E. globulus* subsp. *globulus, E. regnans, E. saligna* and *E. tereticornis* (Friis, 1995). These are chiefly grown for building-timber and fuelwood, both in large-scale plantations and in small woodlots, but also as shelterbelts in farmland and to form shady groves in and around villages, churches and other dwellings. They occur nearly everywhere in the country where the rainfall is above *ca.* 400 mm (Friis, 1995). Many other species have been planted as ornamentals, in arboreta, trial plots or in pilot plantations on a comparatively small scale. About 10 species of eucalypts are potentially able to cover a wide range of environments (Figure 1). They are generally superior to other exotic and native species in their field performance.

Before we move to discussions of "**The Eucalypt Dilemma**", let us now examine the habit and wood, special features, hazards from various agents, experience in Ethiopia and uses of a few of the widely planted eucalypts in Ethiopia.

CRDA

Figure 1. Performance and choice of eucalypt species using *E. globulus* subsp. *Globulus* as a benchmark (adopted from Davidson, 1989).




CCRDA

# 3. Some of the Widely Planted Eucalypts in Ethiopia

Among the widely planted eucalypts, *E. globulus, E. camaldulensis, E. saligna* and *E. grandis* are discussed below to elucidate their characteristics. The information was compiled based on mainly the works of Mebrate Mihretu *et al.* (1983), Örlander (1986a, b), von Maydell (1986), Pohjonen (1989), Azene Bekele *et al.* (1993), Fichtl & Admasu Adi (1994) and Friis (1995).

## 3.1. *E. globulus* Labill. subsp. *globulus* (Blue Gum; 'Nech-Baharzaf' or 'White Eucalypt')

### 3.1.1. Habit and Wood

*E. globulus* subsp. *globulus* is a large to very large tree, 40-55 m in height or more. Specimens in Spain and Portugal have reached 70 m and are among the tallest trees in Europe. Usually, *E. globulus* has a straight and massive trunk up to 2 m in base diameter and up to two-thirds of the total height with a narrow, irregular crown of large branches and drooping foliage. The root system is deep and spreading. The *Sapwood* is white and thick while the *heartwood* is pale brownish-yellow. The wood is hard and moderately heavy. The *basic density* in African plantations is between 550 and 640 kg/m$^3$. The dense outer wood is strong and moderately durable. The wood has an *energy content* of 20.7 MJ/kg and burns freely and leaves little ash. It carbonizes well to produce charcoal.

### 3.1.2. Special Features

*E. globulus* is the best known of all eucalyptus because of the camphor odor of its leaves when crushed. It is a southern species growing mainly on the island of Tasmania, south of the Australian continent (hence the name "Tasmanian Blue Gum"). It is adapted to the cooler conditions of Australia, tolerates some frost days (0-5) but not a severe dry season. It does not occur naturally on strongly calcareous or alkaline soils or on poorly drained sites. The best growth of the species occurs on moderately fertile loams or rather heavy soils, well-drained but with adequate moisture. It is a fuelwood species for tropical highlands, also for subtropical regions (Pohjonen, 1989).

Perhaps the most important reason for the exceptional and widespread early popularity of *E. globulus* in tropical and Mediterranean forest plantations was the unpalatability of its juvenile leaves. In its sapling or early coppice stage, *E. globulus* is seldom browsed by cattle, sheep or even goats, which gives it an advantage over most other tropical plantation species. As an exotic plantation species, *E. globulus* was the first eucalypt to become widely known outside of Australia. Early success led to its becoming the most extensively planted eucalypt species in the world. Its seeds can be collected year round, although a marked peak occurs after the main rainy season. As a plantation species, it is easy to propagate and establish. It closes canopy rapidly, but leaves always space for sunlight to penetrate through the foliage. *E. globulus* coppices vigorously after harvesting. It is one of the best eucalypts in this respect.

### 3.1.3. Hazards from Diseases and Insects

In countries other than Ethiopia, *E. globulus* has been attacked by a number of diseases and insect pests. In the nursery, these include damping off, seedling blights and other diseases. In Ethiopian forestry, both in the nursery and in the field, *E. globulus* has, however, been free of serious diseases (Pohjonen, 1989).

More dangerous than the attack of disease to *E. globulus* are insect pests. In Africa, the most serious of these is a defoliator, the *Eucalyptus* snout beetle (*Gonipterus scutellatus*). It was imported accidentally from Australia to Africa, and is now found damaging plantations in Kenya, Zimbabwe, Uganda and in countries to the south. In the southern African countries the snout beetle attack has been so total that planting of *E. globulus*, once a dominating species in the highlands, has been stopped completely. So far, the snout beetle has not been reported in Ethiopia. Outside Africa some

CCRDA

other serious pest attacks have been reported. In New Zealand, an insect pest (*Eriococcus coriaceus*), followed by a number of other pests, killed mature trees over a wide area in the early 1900s. This attack was so severe that *E. globulus* had to be replaced by other pest resistant species. In Ethiopian plantations, aphids regularly eat the youngest juvenile leaves and buds surrounded by them. Although aphids are numerous, they do not seem to harm the saplings, even if some growth reduction is suspected. When the juvenile leaves turn into adult leaves, the aphids disappear.

In the light of the serious insect pest problems found in other countries with large *E. globulus* plantations, Ethiopia has been surprisingly lucky (Pohjonen, 1989). This is even more surprising since for decades large monocultures have grown in the area surrounding Addis Ababa. The excellent health in Ethiopian plantations may be due, partly, to the chilly and windy highland conditions that do not favor a sudden outburst of pests. For the *Eucalyptus* snout beetle, the desert barrier of Northern Kenya may have saved the Ethiopian plantations from invasion. In any case, numerous diseases and insect pests do exist worldwide for *E. globulus.* They are a continuous, potential danger that we should be aware of at all times.

### 3.1.4. Hazards from Fire, Frost, Wind and Drought

Young trees are easily damaged by fire, but rarely killed. This is because growth starts mostly from lignotubers. Larger trees survive severe fires, and new shoots flush from epicormick buds. A succession of severe fires, however, may be fatal. Since the species is relatively frost tolerant, it has been widely grown in the highlands of Ethiopia, even in frost-prone areas. *E. globulus* is firm in the wind. Even when the strong dry-season winds, which come continuously from one direction, blow over plantations, the young plants can resist them by concentrating the branch growth on the sheltered side of the stem. Later, as the canopy closes, the branch growth continues as normal. It does not withstand severe drought, especially on shallow soils. It grows best in areas with annual rainfall of more than 1,000 mm. There are, however, examples of successful plantations in areas of North Africa that have a mean annual rainfall of only 525 mm. Drought-resistant genotypes of *E. globulus* are known in Spain and Portugal.

### 3.1.5. Experience in Ethiopia

Of all the *Eucalyptus* species introduced in Ethiopia, 105 years ago, *E. globulus* has been found to be the most satisfactory, particularly in the highlands (von Breitenbach, 1961, Teferi Haile, 1961, Örlander, 1986a, b; Pohjonen, 1989; Pohjonen & Pukala, 1988, 1990; Pukkala & Pohjonen, 1990a, b; Persson, 1995; Tsegaye Bekele, 1966; Amanuel Mehari, 1996). For instance, twelve different species, *E. globulus* amongst them, were planted at Holetta Agricultural Research Center, 50 km west of Addis Ababa in 1956. This trial confirmed the superior growth of *E. globulus* over non-eucalypt species such as *Pinus radiata, P. patula, Cupressus lusitanica, Acacia decurrens* and *Juniperus procera* (Örlander, 1986a, b).

An important set of species elimination trials was established by the Forestry Research Center in 1975 (Mebrate Mihratu *et al.*, 1983). Large-scale trials with a number of different eucalypts, other exotic species and some potentially promising indigenous species, were established at 3 sites: Menagesha (20 km west of Addis Ababa), Hamulo (250 km south of Addis Ababa) and Bellete (300 km southwest of Addis Ababa). These sites are part of the central plateau, and they represent the original highland coniferous-forest types in Ethiopia. The Menagesha-Hamulo-Bellete species trials have been measured twice: first at the age of 5 years (Mebrate Mihratu *et al.* 1983), then at the age of 10 years (Örlander, 1986). The first measurement of the Menagesha trial deserves a special attention since it was used - together with the older Holetta trial - as the main background for selecting *E. globulus* as the main species for large scale fuelwood plantation establishment in the Ethiopian highlands (Pohjonen, 1989). As far as volume and biomass growth were concerned, eucalypts were superior to other exotic species and to potential indigenous species, *E. globulus* being the most productive (Table 1). The early growth of indigenous species was rather slow. The best of them was *Erythrina brucei,* the volume growth of which was about 20 % of the growth of *E. globulus* (Pohjonen, 1989).

The latter inventory (at the age of 10 years), confirmed the results besides in Menagesha, especially also in Hamulo and Bellete. As an overall result from all three sites, it can be calculated that the average growth over 10 years of the least four eucalypts is designated 100 %, the corresponding

CRDA

figure for the four best exotic conifers (*Cupressus* sp., *Pinus* sp.) is 55 %, and 18 % for the best indigenous species *(J. procera).* In the typical central highland zone (Menagesha and Hamulo), *E. globulus* did best while in the moister western site of Bellete, it was outgrown by *E. saligna, E. grandis* and *E. viminalis* (Pohjonen, 1989).

**Table 2. Growth of the best exotic and indigenous tree species up to age of 5.25 years in the Menagesha species elimination trial.**

| Species | Tree height (m) | DBH (cm) | Stem Volume ($dm^3$) | Relative Stem volume |
|---|---|---|---|---|
| ***Eucalyptus globulus*** | 18 | 12.3 | 89.1 | 100 |
| *Eucalyptus obliqua* | 19 | 10.9 | 75.0 | 84 |
| *Eucalyptus resinifera* | 12 | 11.7 | 54.1 | 61 |
| *Eucalyptus viminalis* | 15 | 10.4 | 53.6 | 60 |
| *Eucalyptus pilularis* | 12 | 11.4 | 51.2 | 58 |
| *Acacia mearnsii* | 13 | 10.9 | 50.9 | 57 |
| *Eucalyptus saligna* | 14 | 10.2 | 48.0 | 54 |
| *Eucalyptus camaldulensis* | 13 | 9.5 | 38.4 | 43 |
| *Eucalyptus maculata* | 11 | 9.5 | 32.8 | 37 |
| *Cupressus lusitanica* | 8 | 9.1 | 21.9 | 25 |
| *Acacia melanoxylon* | 9 | 8.5 | 21.3 | 24 |
| *Cupressus torulosa* | 8 | 8.6 | 19.5 | 22 |
| *Pinus radiata* | 8 | 8.3 | 18.1 | 20 |
| ***Erythrina brucei*** | 7 | 8.8 | 19.5 | 20 |
| ***Hagenia abyssinica*** | 8 | 6.6 | 11.5 | 13 |
| *Casuarina stricta* | 9 | 5.7 | 9.7 | 11 |
| *Grevillea robusta* | 8 | 5.8 | 8.8 | 10 |
| *Casuarina cunninghamiana* | 6 | 6.5 | 8.4 | 9.4 |
| *Pinus patula* | 6 | 5.6 | 6.2 | 7.0 |
| ***Cordia africana*** | 5 | 3.1 | 1.6 | 1.8 |
| ***Juniperus procera*** | 4 | 3.0 | 1.2 | 1.3 |
| ***Olea europaea*** | 3 | 2.0 | 0.4 | 0.5 |

**Sources:** Mebrate Mihratu *et al.* (1983); Pohjonen (1989); DBH = Diameter at Breast Height

### 3.1.6. Uses

*E. globulus*, with its moderately straight stem form (varying with provenance), is useful for poles, telegraph masts and in building construction. It has an oil content that makes it resistant to termites. The wood has also been used as lumber for home framing, flooring and siding, as well as for decorative interior paneling and furniture. It is also suitable for plywood, veneer, railroad crossties and tool handles. It is one of the best eucalypts for paper pulp and very suitable for fuel, especially the leaves for baking 'injera', and mature wood for charcoal making. Young branches are commonly used for house construction (Pohjonen, 1989; Fichtl & Admasu Adi, 1994).

The species is the most important source of eucalypt honey in the country. It produces abundant nectar and pollen every year with a flowering peak every four to five years. The sugar concentration of the nectar is medium and the protein-rich pollen is pale yellow to creamy white. Honeybees work all day round on the flowers. Colonies near this eucalypt develop very fast with a tendency to frequent swarming. The honey has a distinctive flavour and is light amber in colour. The granulation is medium to slow and fine. Because of its attributes, the species is recommended for planting to increase honey production (Fichtl & Admasu Adi, 1994).

Eucalyptopol, commercially important eucalypt oil distilled from this species, is used as medicine. The medicinal use of *E. globulus* leaves, against flu and fever, is a local tradition in Ethiopia; the steam from boiled leaves is inhaled to relieve the common cold and other bronchial problems. *E. globulus* has also been planted for land reclamation, including the drying up of swamps. It has a

CCRDA

widespread, dense and deep root system, an asset for binding soil against erosion. With its large, dark green glossy adult leaves, glaucous and bluish juvenile leaves and stems, and its showy flowers and fruits, *E. globulus* can also be regarded as attractive ornamental trees for parks, windbreaks and shelterbelts.

## 3.2. *E. camaldulensis* Dehnh. (Murray Red Gum; Red River Gum; 'Kay-Baharzaf' or '*Red Eucalypt*')

### 3.2.1. Habit and Wood

*E. camaldulensis* is a large evergreen tree, 20 to 40 m high (up to 50 m in Australia). It has a stout trunk that is often short and crooked, 0.6 to 1.0 m in base diameter. The crown is irregular, open and widely spreading. The root system is deep and spreading. Exceptional to eucalypts, the trunk can form air roots. The *sapwood* is thick and pale red in color, the *heartwood* is from reddish to dark red. The wood is strong, hard and heavy. The *basic density* in African plantations is between 710 and 890 kg/m$^3$. The wood is durable and resistant to termites. It is not difficult to saw and takes a fine finish, but tends to warp in drying. As fuelwood, *E. camaldulensis* has few equals and is outstanding when fully dry. It is highly valued in its homeland of Australia as fuel. The wood has *energy content* of 19.8 MJ/kg, burns quickly and makes good charcoal. The steel industry of Argentina relies on its charcoal. The only limitation on its use in open fireplaces is that the wood smokes heavily (Pohjonen, 1989).

### 3.2.2. Special Features

*E. camaldulensis is the most widespread eucalypt in Australia and is found in all states except* Tasmania. In its natural range, *E. camaldulensis* is mainly a riverine species. As a plantation species, it has been successfully planted over a wide ecological range, from the semi-arid zones of the Mediterranean to the humid zones of Hawaii. It has been planted from sea level to the highlands. It is more tolerant of drought, frost (0-50 days) and alkali soils than *E. globulus,* but grows slower. Even if *E. camaldulensis* is naturally widespread in Australia, it has only been planted occasionally in its home continent. The main experience of *E. camaldulensis* as a plantation species comes from outside of its natural habitat. The main characteristics that have been responsible for its success as an exotic are rapid growth on poor sites with low rainfall, ability to coppice readily, tolerate periodic water-logging and some salinity in the soil. *E. camaldulensis* was one of the first eucalypts introduced outside of Australia. In Italy it was already planted in 1803. Currently, it is the dominant eucalypt in the Mediterranean. Contrary to *E. globulus,* the leaves of *E. camaldulensis,* even in the juvenile stage, are palatable to livestock. Plantations need careful guarding when young.

Similar to *E. globulus,* the early introductions of *E. camaldulensis* were successful, and they led to the rapid establishment of plantations on a practical scale. The largest plantations are in Spain and Morocco, while it is also important in Israel, Turkey, Pakistan, Uruguay and Argentina, as well as in California. Due to the wide natural occurrence of *E. camaldulensis,* there is great deal of different provenances adapted to special climates such as tropical or arid and to high altitudes. For successful afforestation, it is important to select seed from a climatic zone comparable to that of the planting area. Mother trees produce a healthy seed crop every year or two. Seed germination is high, and they are long-lived when stored in a sealed container in a dry, cold place. Most provenances of the species coppice vigorously.

### 3.2.3. Hazards from Diseases and Pests

*E. camaldulensis* has not encountered calamities similar to *E. globulus,* neither in nurseries nor in plantations. Like most eucalypts, *E. camaldulensis* is susceptible to termite damage during its early years (only the mature timber is termite resistant).

CORDA

### 3.2.4. Hazards from Fire, Frost, Wind and Drought

*E. camaldulensis* is considered fairly fire resistant in a number of countries, particularly Spain and Turkey. Younger trees are most susceptible, but older trees usually recover after a fire. Even severely damaged trees, if felled immediately, will coppice successfully. *E. camaldulensis* is not regarded as a species for frost susceptible areas, but, rather, as one suitable for hotter lowland areas. However, in a highland experiment at Debre Berhan, *E. camaldulensis* showed itself as frost resistant as *E. globulus* (Pohjonen, 1989). The wind resistance of *E. camaldulensis* is comparable to that of *E. globulus*. Even strong, desiccating winds do not harm it. Out of the ten most common plantation eucalypts, *E. camaldulensis* is the most drought resistant. It can endure dry seasons of up to 8 months.

### 3.2.5. Experience from Ethiopia

Following their introduction into Ethiopia in 1895, *E. camaldulensis* was one of 15 eucalypts that survived. Similar to *E. globulus,* it has been extensively planted, but at somewhat lower altitudes (at or under 2,000 m). It has been planted around towns in the Rift Valley, and also in the moister areas of the southwest. Although *E. camaldulensis* has been widely planted in Ethiopia, the growth data available from dryland species elimination trials are few. Several trials were established in Wollo and Tigray between 1977 and 1980, but the success was poor. Often, the survival rate after two or three years was too low for reliable species evaluation. The species has shown no remarkable growth performance in dry, lowland zones (Örlander, 1986).

The best growth data for *E. camaldulensis* are available from the central highlands, from the Menagesha-Hamulo-Bellete species trials. As far as biomass growth of *E. camaldulensis* is concerned, these trials have been somewhat disappointing (Pohjonen, 1989). The mean annual increment after 10 years has been less than half of *E. globulus.* One reason for the modest growth of *E. camaldulensis* in these Ethiopian trials could be the original species and provenance selection (Pohjonen, 1989). Of the original seedlots sent to Ethiopia, there was no guarantee that selection for high quality was made. Furthermore, there have been morphological indications in the older Ethiopian stands that trees marked under the name *E. camaldulensis* are not of a pure species but hybrids with other eucalypts (such as *E. tereticornis*). In newer trials established by United Nation Sudano-Sahelian Office (UNSO) fuelwood projects with certified Australian seeds, *E. camaldulensis* has been surprisingly good. However, the diameter growth was rather slow. When *E. globulus* grew on average 1.3 cm/annum, *E. camaldulensis* grew only 0.5 cm/annum.

At the Nazret fuelwood project, on vertisol, *E. camaldulensis* has shown relatively promising initial growth. There are indications also elsewhere in Ethiopia that *E. camaldulensis* thrives better than other eucalypts on soils susceptible to waterlogging. In the light of Ethiopian growth data, the dominance of *E. camaldulensis,* however, as a fuelwood species next to *E. globulus* is somewhat contradictory (Pohjonen, 1989). The dominance is not supported by performance from long-term species trials. Rather, it is the result of general, conventional recommendations from similar ecological conditions elsewhere.

### 3.2.6. Uses

In Australia, *E. camaldulensis* is the most important inland hardwood. It is used extensively for structural timbers where strength and durability are required. It is also used for interior finish, flooring, furniture, fence posts and sometimes, for pulp. The dense red wood is valuable and termite resistant. In Ethiopia, it is primarily planted for fuelwood and charcoal production. The timber is used as fence posts and poles for house construction.

This is one of the heaviest nectar yielder species of eucalypts. It is a major source of pollen and produces abundant nectar, which gives heavy yields of honey. Honeybees collect both nectar and pollen. The sugar concentration is high and pollen value is good. The colour of the honey is clear amber and the granulation is medium with fine-grained crystals. The flavour is mild and the aroma characteristic. As a result, it has been recommended to increase honey production (Fichtl & Admasu (ed.) 1994). Other uses are medicinal, rayon and tannin from the bark. The trees are also planted for shade and ornament along roadsides, shelterbelts and windbreaks.

CORDA

## 3.3. *E. saligna* Smith (Sydney Blue Gum; 'Saligna Baharzaf')

### 3.3.1. Habit and Wood

*E. saligna* is a tall evergreen tree, 40 to 50 m high, sometimes up to 71 m (in Hawaii). Its trunk may be 1.2 to 1.8 m in diameter and is usually straight. The crown is open, spreading and irregular. It has clear lignotubers. The wood is light to reddish brown, moderately hard and moderately heavy. The *basic density* in African plantations is between 640 and 890 kg/m$^3$. The wood is coarse-textured with straight or sometimes wavy grain, strong, stiff, tough and moderately durable. It is easy to work, finish and takes a good polish.

### 3.3.2. Special Features

In its natural habitat it usually grows mixed with other eucalypts, but occasionally in pure stands. Its typical environments are moister slopes and cooler mountains. Generally, it is more suitable to moist, warm lowlands. It is a fuelwood species adaptable to the highlands and the humid tropics. *E. saligna* coppices well, but less than *E. globulus.* It is easy to raise in the nursery and to establish in plantations. It has a moderate ability to compete with weeds, but grass and herbaceous weeds can severely limit its growth. Mechanical site preparation is essential for rapid growth. The leaves of *E. saligna* are palatable to cattle, and plantations need guarding during the establishment phase.

### 3.3.3. Hazards from Diseases and Pests

Most exotic plantations of both *E. saligna* are free of any serious pests or diseases. *E. saligna* is susceptible to a serious canker (*Cryptonechria cubensis*), and whenever canker-like disease breaks out in its stands, this serious disease should be suspected.

### 3.3.4. Hazards from Fire, Frost, Wind and Drought

*E. saligna* develops clear lignotubers, which help it recover from fires. In western Australia, the sensitivity of *E. saligna* to fire is rated as low to medium. It is somewhat more frost resistant than *E. globulus.* It can tolerate short dry periods although its best growth is achieved on sites with high rainfall that is well distributed throughout the year.

### 3.3.5. Experience from Ethiopia

*E. saligna* was probably introduced into Ethiopia among the group of 15 eucalypts that were brought in the end of 1800s. However, no trees of that age appear to have survived. The first reported trial plantation was in 1956 at the Holetta Agricultural Research Center. Although the trial had only one plot of *E. saligna* and that this unfortunately has been subject to uncontrolled cutting, the growth rate is comparable to that of *E. globulus.* It has also done well in the Menagesha-Hamulo-Bellete species elimination trials. In the medium-rainfall sites of Menagesha and Hamulo, its growth has been comparable to *E. viminalis,* but slower than *E. globulus* and *E. grandis* (Pohjonen, 1989). In the western, high-rainfall site of Bellete, *E. saligna* has grown comparatively well with *E. grandis* and has been done better than *E. globulus.* In Bellete, a remarkable mean annual increment (MAI) of approximately 50 m$^3$/ha/annum at the age of 10 years was recorded both for *E. saligna* and *E. grandis* (Chaniler 1986). Based on promising research results, *E. saligna* has been planted in practical scale in the Munessa forest.

CCRDA

### 3.3.6. Uses

In addition to fuelwood and transmission poles, *E. saligna* is used for construction, shipbuilding, railroad crossties, furniture, cabinet making, turnery and veneers. In Australia, it is favored for flooring and making steps because it is not greasy. Because of extremely good form, there is a high demand for its straight stems in transmission line construction. It is also grown as an ornamental and shade tree. It is a good honey plant.

## 3.4. *E. grandis* Maiden (Flooded Gum; Rose Gum; 'Kay Baharzaf')

### 3.4.1. Habit and Wood

*E. grandis* is a large evergreen tree, 45 to 55 m high, with a tall, white and straight trunk which is 1 m, sometimes 2 m in base diameter and self-pruned for up to two-thirds of its total height. The crown is spreading and sparse when the tree grows in open, but small and compressed in closed plantations. It lacks lignotubers. The wood is pink to light reddish brown, moderately hard but lightweight (when fresh, *E. grandis* floats in water). The basic density in African plantations is between 510 and 560 kg/m$^3$. The wood is coarse-textured and straight-grained, of moderate strength and durability. During seasoning it is subject to warping, splitting and other defects. It is regarded as excellent firewood and has also served as locomotive fuel for trains.

### 3.4.2. Special Features

*E. grandis* occurs in pure or almost pure stands in its natural habitat. It is a fuelwood species for highland areas and the humid tropics. Its optimal growing sites are somewhat warmer than those of *E. saligna*. Field identification between *E. grandis* and *E. saligna* is somewhat difficult. Provided the choice of species has already been limited to these two, the existence of lignotuber is the first sign of identification. If lignotuber exists, then the species is *E. saligna*. However, at times the lignotuber of *E. saligna* is not clear, therefore, non-existence of lignotuber does not necessarily determine the species as *E. grandis*. The second means of identification is to study the seed capsules, especially the valves. *E. grandis* has more valves (predominantly 5), and their tips are blunt and turned inward. On the other hand, *E. saligna* has fewer valves (predominantly 3 to 4), and their tips are sharp and straight or spreading.

*E. grandis* coppices vigorously when young, but trees over the age of 10 have been noticed to be less vigorous. The renewal of young stands by coppicing after clear-felling is enough for practical silviculture. The expected number of vigorous coppice crops is from two to five. When optimal site conditions are selected, there is probably no eucalypt, probably no other tree species either, that will produce more in wood volume than *E. grandis*. Compartment-scale growth figures of more than 100 m$^3$/ha/annum on seven years rotation have been recorded in Brazil. But to achieve such results, management must be intensive including thorough site preparation, selected clonal planting stock, fertilization and complete weeding. By 2 years of age, early flowering may be observed in solitary *E. grandis* trees; however, proper seed crops cannot be expected before the age of four years. Commonly, there is a good seed crop each year. A fully mature, vigorous tree can produce 2 kg of seed annually. Similar to *E. saligna*, plantations of *E. grandis* are easy to establish. The weeding requirements for maximum timber growth are similarly high.

### 3.4.3. Hazards from Diseases and Pests

Most exotic plantations of both *E. grandis* are free of any serious pests or diseases. In Brazil, a serious canker (*Cryptonechria cubensis*) has attacked *E. grandis* provenances that have been ecologically unsuitable to the site. Susceptibility to this disease has been solved through clonal selection. This canker has also been identified on the African continent, at least in Cameroon. *E. grandis* is susceptible to it, and whenever canker-like disease breaks out in its stands, this serious disease should be suspected.

CIRDA

### 3.4.4. Hazards from Fire, Frost and Drought

Since *E. grandis* does not develop lignotubers, it is sensitive to fire. It is moderately sensitive to frost. It can tolerate only light frosts down to - 5° C. If the weather is cool, seedlings of *E. grandis* can withstand drought, but there is a high mortality rate under hot conditions. Areas with a mean annual rainfall of at least 800 mm are preferred.

### 3.4.5. Experience from Ethiopia

The experience of *E. grandis* in Ethiopia is similar to that of *E. saligna.* The first and so far most comprehensive research results come from the species elimination trial of Menagesha-Hamulo-Bellete. In Menagesha and Hamulo, *E. grandis* has grown slightly better than *Eucalyptus saligna.* In Bellete, it has done comparatively well. The best growth data for *E. grandis,* as well as for three other eucalypts, comes from a well planned and scientifically sound experiment at Wondo Genet where *E. grandis* clearly overgrew the other three species (Pohjonen, 1989).

### 3.4.6. Uses

*E. grandis* has been used for utility poles although, since it is lightweight and less durable, it is not suitable for transmission lines. It is also used in home construction, boxes, veneer and mine props. The species has a great potential for pulp milling, and it is one of the main species used for that purpose in the large pulp industry of Brazil. *E. grandis* is also an ornamental and shade tree, as well as a good honey plant.

## 4. The Eucalypt Dilemma

Despite the apparent benefits discussed above, there have been some adverse public reactions against planting of eucalypts. The criticisms are based on a range of technical, ecological and socio-economic arguments (FAO, 1988). According to Davidson (1989), a lot of the criticisms are unfair, biased, nationalistic or emotional. He noted that the criticisms would apply equally to other exotic trees planted in many countries, not just eucalypts.

It has been pointed out (Poore & Fries, 1985) that there is a double standard that seems to be used in passing judgment on forestry crops compared with many agricultural crops. No one is surprised that the latter are often introduced species. Indeed, most crops in many parts of the world are of foreign origin (wheat, maize, rice, potatoes, etc.). No one is surprised either that the soil under agricultural crops becomes depleted if these are continuously cropped without adding fertilizers. But both of these features are considered grounds for criticism in forestry.

Some of the criticisms have been caused by disappointed expectations rather than by ecological effects. Eucalypts have often been heralded as wonder species that will bring immediate solutions to local wood and erosion problems. When it is followed by planting which fail, because they have frequently been of the wrong species, site or management, local people may be left with vegetation which is little if at all better than what was there before. THE BLAME THEN FALLS ON THE EUCALYPTS RATHER THAN ON THE REAL CULPRIT, WHICH IS **BAD FORESTRY PRACTICE** (Poore & Fries, 1985).

One of the principal reasons for planting eucalypts is because they grow more rapidly than other species on the same site. This increased growth is necessarily

CCRDA

associated with greater consumption of water. The question then arises: which is more important in the circumstances of the case, wood or water?

Development programs often must strike a real balance between agriculture, forestry and other land uses to meet peoples' needs (FAO, 1988). Forests and trees can supply a variety of benefits that are often crucial to the well-being of people. When environmental quality and/or material production potential have **deteriorated**, remedial actions are usually needed as quickly as possible. *In many situations,* ***exotic trees*** *have proved to be faster growing than native and have been utilized for quick results.* ***In the tropics and sub-tropics, eucalypts are often judged to be faster growing than other species and the most likely to survive on difficult sites*** (FAO, 1988).

To lay a foundation for the discussion at hand, it is wise to put our situation in perspective and think deeply about the past and present scenarios with regard to our natural resources in general and the forest and woodland resources in particular. As stated above, the major reason for the introduction of eucalypts into Ethiopia during the reign of Emperor Menelik was the critical shortage of wood both for fuel and construction. Had it not been for these introductions, the forests in the south and southwestern parts of the country would have disappeared long time ago. In fact, the history of Ethiopia is characterized by, among many others, what have been referred to as "wandering capitals" by some writers (Horvath, 1969; Assefa Kuru, 1990; Persson, 1995; Gebre Markos, 1998). One of the main reasons for southward movement of capitals had been connected with exhaustion of fuelwood associated with deforestation/devegetation. If the introduction of eucalypts had not solved the prevailing problem of wood shortage at that time, Emperor Menelik would have been forced to move the capital to *Alemgena* and Addis Abeba would not have been founded.

As far as wood is concerned, the country is, probably, in a more desperate situation than it had been during the time of Emperor Menelik. It has been under severe deficit of wood, and the gap between supply and demand of wood for fuel, construction and industry is widening enormously (Table 3).

The figures in Table 3 indicate that a large deficit has occurred since 1992 (33 million $m^3$s), and fuelwood deficit amounted to 32.5 million $m^3$s. This deficit is the main cause for the "mining" (the volume of wood harvested in a given period exceeding the sustainable rate / incremental yield) of forest resource base of the country. This leads to reduction in the woody biomass growth stock and future incremental yields. This has already led to the use of dung and agricultural residues for fuel instead of natural fertilizers and environmental degradation reflected in the form of soil erosion, loss of soil fertility and biodiversity as well as degradation of water bodies. The cumulative effects of these phenomena had been and continue to be decline of productivity and production in the agricultural sector, the backbone of our economy, ultimately causing adverse negative impact on the welfare of plants, animals, microorganisms and people. The projection of supply and demand of wood is even more frightening (Table 3).

CCRDA

**Table 3. Incremental yield from forest and woodland resources, projected demand and deficit of wood products.**

| Year | Incremental Yield* (million $m^3$s) | Demand (million $m^3$s) | | | | Deficit (million $m^3$s) |
|---|---|---|---|---|---|---|
| | | Industrial Wood | Construction Wood | Fuelwood | Total | |
| 1992 | 14.4 | 0.4 | 2.1 | 44.9 | 47.4 | 33.0 |
| 2000 | | 0.7 | 2.7 | 58.4 | 61.8 | |
| 2005 | | 0.9 | 3.2 | 68.4 | 72.5 | |
| 2010 | | 1.3 | 3.8 | 79.5 | 84.6 | |
| 2014 | 10.6[a] | 1.6 | 4.3 | 88.9 | 94.8 | 84.2 |
| | 30.2[b] | | | | | 64.6 |

Source: EFAP (1994); * = incremental yield from natural forests, woodlands, bushlands, industrial forest plantations, peri-urban plantations, community woodlots, catchment and protection forests and farm forestry; a = without intervention; b = with intervention; "intervention" refers to the implementation of programs developed by EFAP (1994); s = solid over bark.

Although fast growing and relatively sure to survive, concern exists that eucalypts may not adequately supply forest benefits such as *quality wood, watershed* and *soil conservation, wildlife habitat* and even *recreational* or *aesthetic values* (FAO, 1988). The various concern voiced about eucalypts include:

- removal of too much water from streams or underground water supplies
- adverse effects of their leaf litter on soil humus, nutrient supply or prevention of erosion
- inhibition of the growth of other vegetation under their canopy
- no provision of food supplies or adequate habitat for wildlife, etc.

Judgment about the relative merits and disadvantage of eucalypts should be made by *qualified objective personnel* in each specific instance (FAO, 1988). There are over 500 species of *Eucalyptus* with widely varying properties, although only a few comprise the most popular plantation species. The ecological effects of the same species may vary greatly in moist or arid sites or on different soils or topographies. Finally, the array of needs of various communities can vary as widely as types of species and the ecological nature of sites. The dilemma is general and real, but solutions and judgments must be specific to each case and based on accurate appraisal of biological, physical and human factors (FAO, 1988).

Let us now examine the actual ecological effects of eucalyptus with regard to the four key ecological questions, namely **water, erosion, soil nutrients** and **competition**. The review is based mainly on the works of Poore & Fries (1985), also summarized in a booklet by FAO (1988) and other relevant published reports (Davidson, 1989; Pohjonen, 1989; Turnbull, 1999).

SCRDA

# 5. Ecological Effects of Eucalypts

In the following section the discussion will focus on the effects of eucalypts on the water cycle, climate, soil erosion, plant nutrients, wildlife, other plants and as windbreaks and shelterbelts.

## 5.1. Eucalypts and the Water Cycle

As indicated above, it has been argued that eucalypts take up a great amount of water from the soil, and when grown in plantations they lower the ground-water level more than other tree crops. To study these questions, it is necessary to consider how trees use water, and also how they obtain it.

Trees need food to grow. They get their food from the soil in the form of nutrients dissolved in water, and they use the water to pump these nutrients through the roots and branches to all the living parts – wood, leaves, flowers, fruits, etc. After doing this most of the water evaporates through the leaves by a process known as transpiration, leaving the nutrients to feed the tree. To produce one unit of woody matter young trees require between 300 and 500 units of water, but as they get older their efficiency decreases and more water per unit of wood is needed.

### 5.1.1. The Water Cycle

The water cycle is crucial to plant growth and human welfare. Annual crop planting is usually timed to take advantage of seasonal rainfall and warm temperatures. Tree crops, however, are often able to live through dry periods because they have roots at deeper levels in the soil, and can withstand drought.

When rain falls, most of the rainwater drips through the tree canopy to the ground (*throughfall*), but the sun and wind cause some of the water to evaporate back to the air above (*interception*). Some runs down the tree trunk (*stemflow*). When rainfall reaches the ground some may flow over the surface, some evaporates, and the remainder sinks down into the soil. Part of the water in the soil is absorbed by the roots and travels inside the tree to the branches and leaves. Some of it is used by the tree to form new growth, but most the water passes through the leaves into the surrounding air (*transpiration*), and in eucalypts the rate can reach between 20 and 40 liters per tree each day, depending on the size of the tree and the surface area of the leaves.

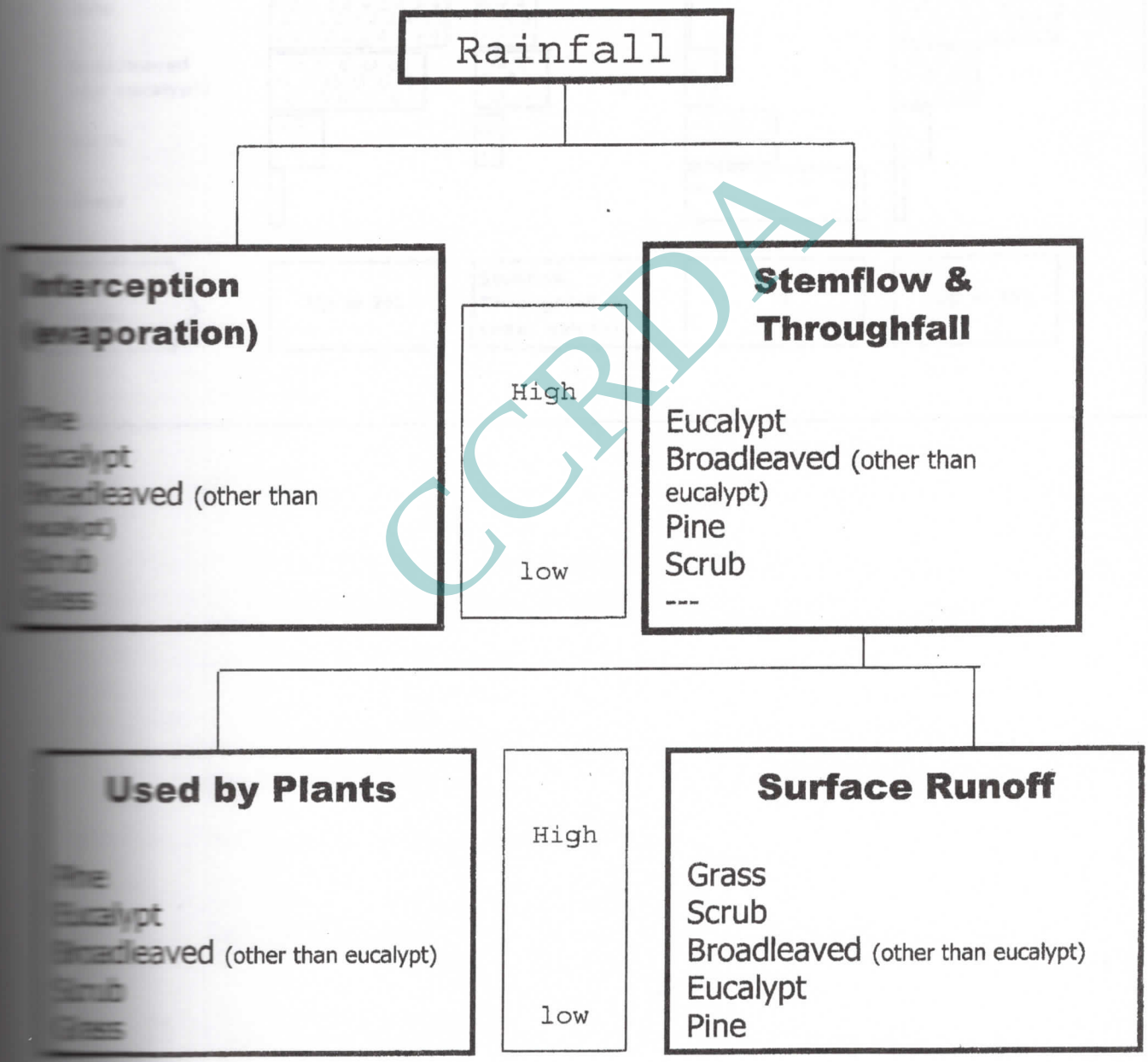
The relative amounts of water that flow through each part of the cycle depend on factors such as the ground cover, soil type, and most important of all, the temperature, humidity, solar rays and wind-force. The quantity of rainfall and how it is distributed during the year is especially important. A plant's efficiency in retaining water depends on its physical characteristics and behaviour. Most plants are able to close their leaf pores to control water loss, and in arid climates many have leaves that are coated with wax to protect them from drying out.

CCRDA

### 5.1.2. Comparison Between Eucalypts and Other Vegetation

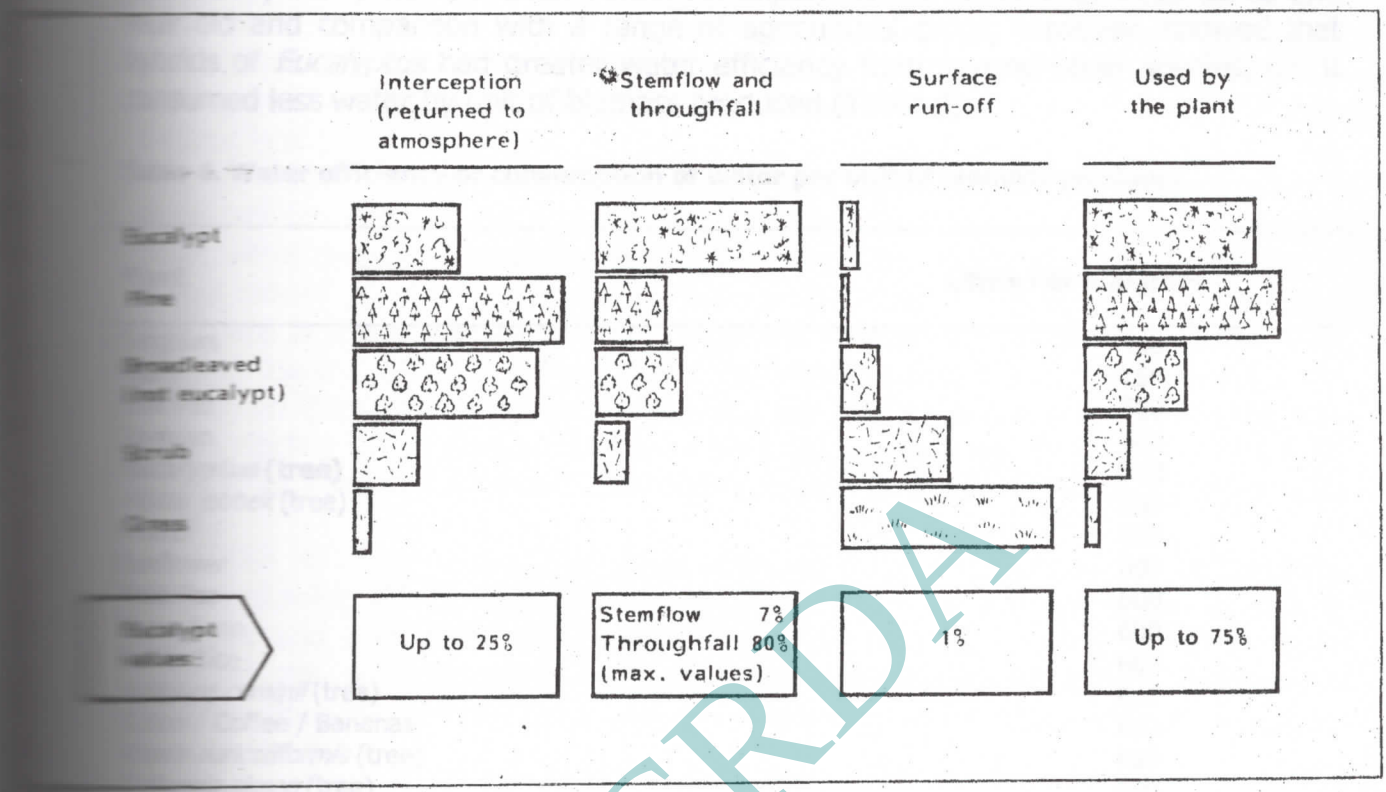
The amounts of rainwater used by different types of plants have been studied in a wide range of conditions. The results vary according to the site and its climate, and in the case of forests, the age and size of the trees. There are general trends in the observations made and these are broadly summarized in the example given in Figure 2. The vegetation is listed in decreasing order of amounts used by plants. It is difficult to measure the amount of water in the different flows, but Figure 3 compares the combined results from experiments and gives estimated values for eucalypts.

**Figure 2. Comparison of rainwater use by vegetation (adopted from FAO, 1988).**




CCRDA

**Figure 3. Comparison of amount of rainwater disposed by different vegetation (adopted from FAO, 1988).**




CCRDA

Research results indicate that eucalypts have a high water usage per unit time, and this is consistent with their high rate of growth. The factors affecting water consumption by trees under natural conditions are difficult to measure, and no satisfactory study has yet been made. An experiment in India with trees up to one year old and comparison with a range of agricultural crops, however, showed that hybrids of *Eucalyptus* had greater water efficiency than several other species, i.e. it consumed less water by unit of biomass produced (Table 4).

**Table 4. Water efficiency or consumption of water per unit of biomass produced.**

| Plant | Liters Per Kilogram |
|---|---|
| Sorghum | 250 |
| Maize | 250 |
| Cow Pea | 500 |
| Soybean | 500 |
| ***Eucalyptus* (tree)** | **510** |
| *Albizia lebbek* (tree) | 580 |
| Potato | 600 |
| Sunflower | 600 |
| Field Pea | 600 |
| Horse Bean | 600 |
| Paddy Rice | 600 |
| *Syzigium cuminii* (tree) | 610 |
| Cotton / Coffee / Bananas | 800 |
| *Acacia auriculiformis* (tree) | 860 |
| *Dalbergia sissoo* (tree) | 890 |
| Conifers | 1000 |
| *Pongamia pinnata* (tree) | 1300 |

Source: FAO (1988), Davidson (1989)

Rainfall partitioning at *E. saligna* or *E. grandis* stands at Nekemt has been exercised and reported by Davidson (1989) as follows:

Annual Rainfall: 2158 mm
Evaporation: 216 mm
Throughfall: 1942 mm
Runoff: 194 mm
Uptake: 1748 mm

Production of above ground, stem-wood biomass:

50 $m^3$/ha/year: 1875 mm (- 127 mm)
45 $m^3$/ha/year: 1687 mm ( + 61 mm)
40 $m^3$/ha/year: 1500 mm (+ 248 mm)

*Note: 1 mm rain = $10^4$ liters of water/ha*

Similar exercise had also been made for eucalypts, another broadleaved non-eucalypt, a conifer and an acacia at annual rainfalls of 2158 mm, 1550 mm, 1000 mm and 500 mm (Davidson, 1989). Results are summarized in Figures 4 and 5. From the

CCRDA

graphs, it can be understood that in all cases eucalypts are much more efficient users of water for the amount of biomass produced. If one considers a "leakproff hectare", i.e. no movement of water over or under the surface into or out of the hectare, at Nekemt, eucalypts could potentially produce 46.6 $m^3$/ha/year without drawing on water reserves (rainfall only). The equivalent values for the conifer, acacia and broadleaved species are 16.4, 16 and 12.4 $m^3$/ha/year respectively (Figure 4). The ranking remains the same for decreasing annual rainfalls, but relative differences become less (Figure 5).

Unfortunately, the real situation is more complicated than consideration of single isolated hectares. Davidson (1989) tried to show how the water balance might result within three adjacent one-hectare blocks running up and down a slope under an annual rainfall of 1550 mm / year at Bellete Forest Area (Figure 6). It can be seen that there is a net surplus of both runoff and groundwater from the upper block, allowing the eucalypts to grow at 40 $m^3$/ha/year, causing a deficit in their block but drawing on the surplus from above. There is still enough water in the system to grow a high yielding maize crop on the lower block and leave a net discharge of 378 x $10^4$ liters/ha for human and animal consumption and for stream run-off to supply other areas.

This example shows that quite high eucalypt production can be achieved without drawing down regional water reserves. Problems are only likely to arise in semi-arid and arid areas with annual rainfall of less than 400 mm where some eucalypts are so competitive in obtaining eventually all what little moisture is available, thus starving any other vegetation either under or adjacent to the eucalypts (Davidson, 1989)

### 5.1.3. Water Supply at Lower Depths

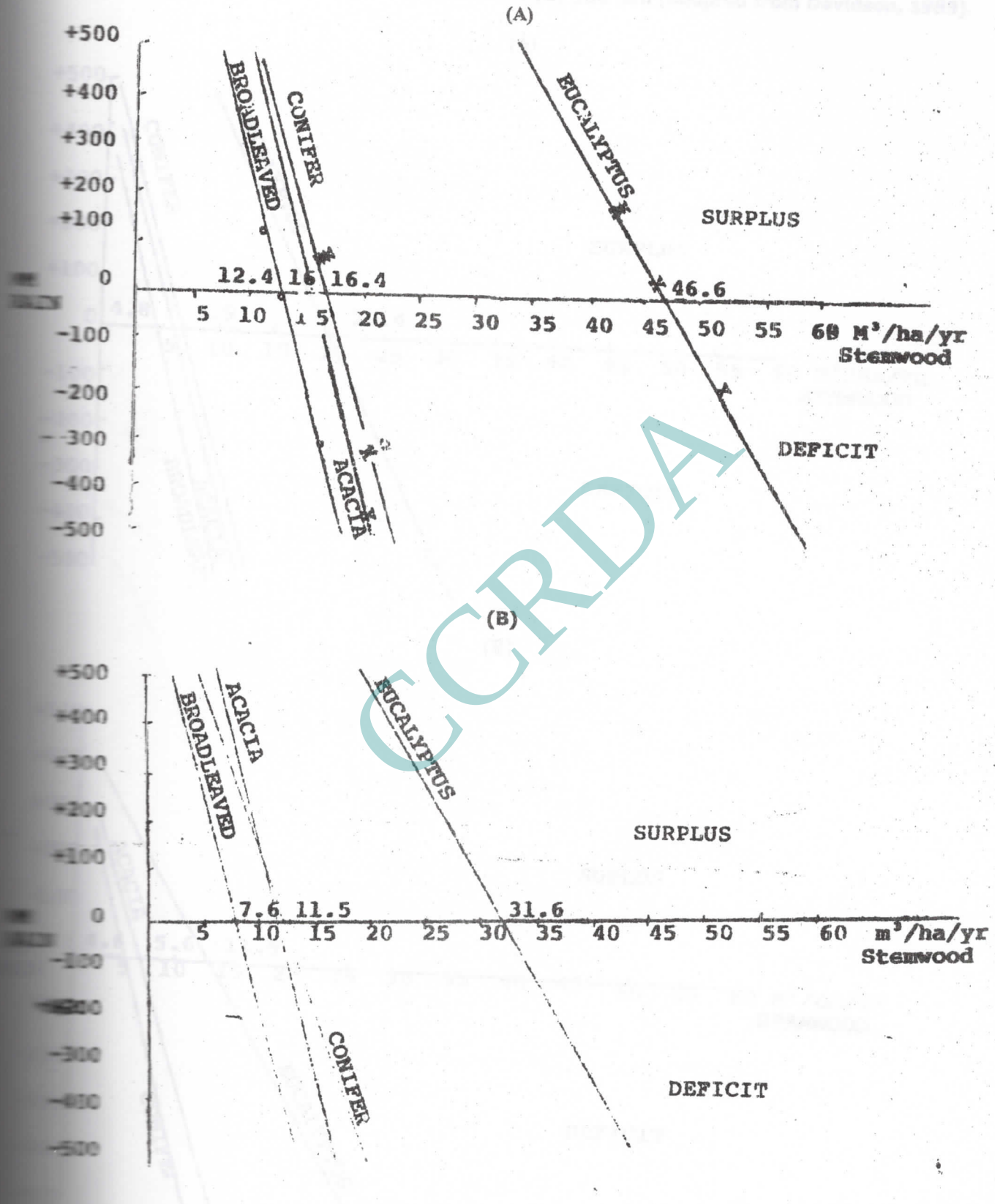
In most soils, which are not very shallow, the surplus rainwater drains down to a level at which no more water can be held, and where the soil is totally saturated. This ground-water level rises and falls seasonally, and the overall water balance of the region also locally affects the levels.

In swampy areas, the ground-water level is near or at the surface, and some species of eucalypt have been used to drain the water away by drawing it up through the tree roots. Mosquito breeding areas can sometimes be controlled in this way, but if the work is not well planned it may cause adverse effects in adjacent land by reducing domestic water and irrigation supplies.

The opposite effect may occur when existing trees are removed from areas where the ground-water supply is not far from the surface, and too much water is left in the soil. In Australia major changes in land use resulted in eucalypt trees being cleared which in turn caused a rising of ground-water levels and an increase of soil salinity which was harmful to local farming. The State has now restricted the removal of trees from some water catchment areas to help regulate and protect important water supplies. There is not much information on consumption of water by eucalypts when it is plentiful, and no comparisons between eucalypts and other trees have been made.

CCRDA

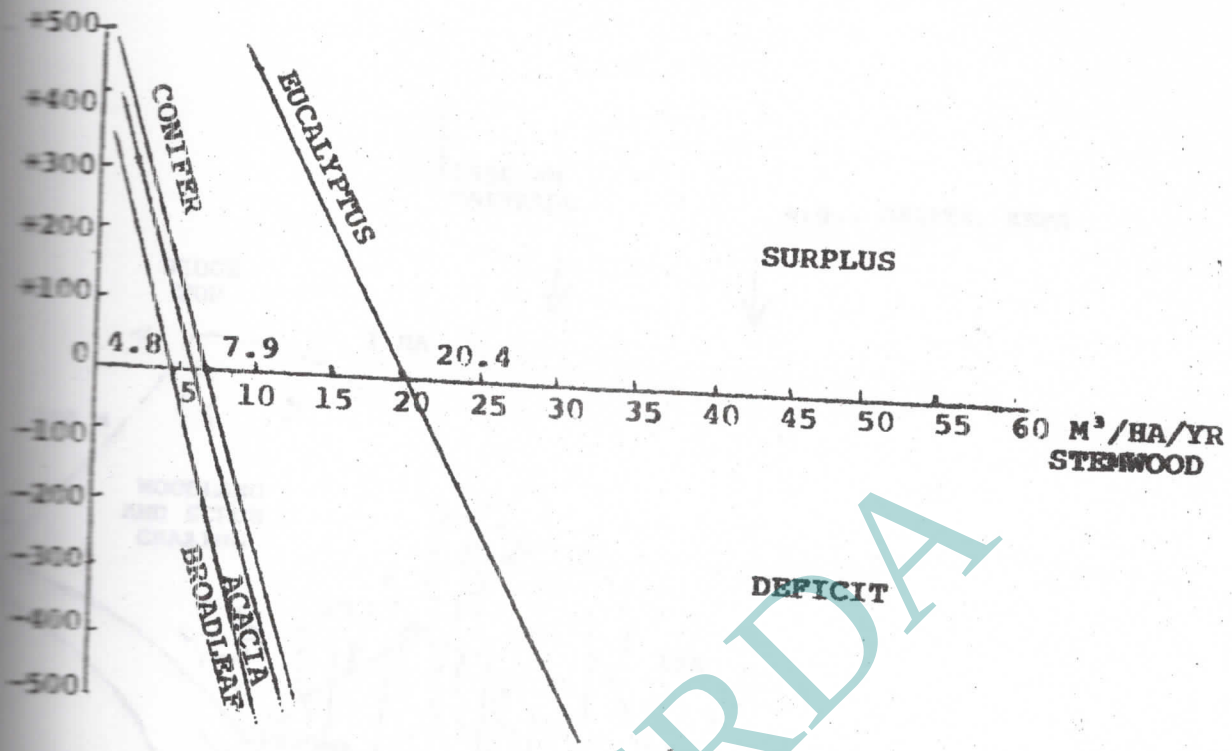
**Figure 4. Comparison of consumption of water per unit biomass (stem wood) produced per year among eucalypts, a conifer, an acacia and non-eucalypt broad-leaved species at (A) annual rainfall of 2158 mm (Nekemt) and (B) 1550 mm (Bellete Forest Area) (adopted from Davidson, 1989).**



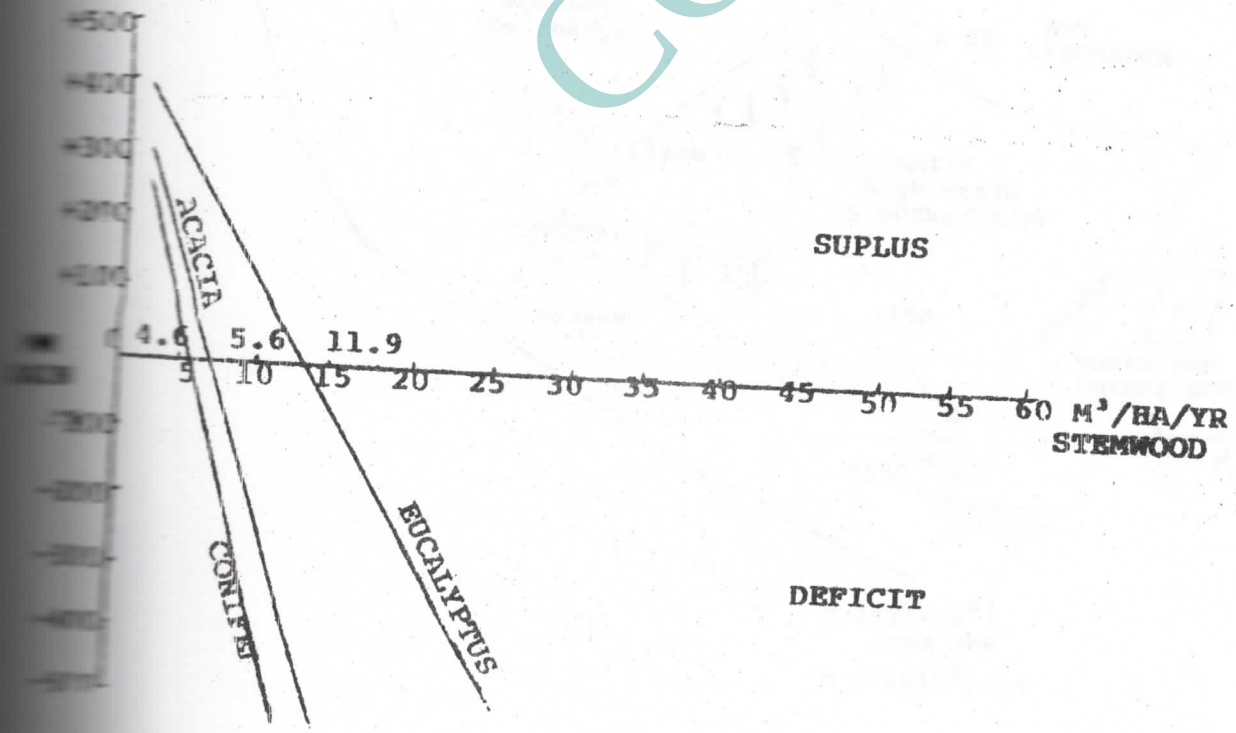

CCRDA

**Figure 5. Comparison of consumption of water per unit biomass (stem wood) produced per year among eucalypts, a conifer, an acacia and non-eucalypt broad-leaved species at (A) annual rainfall of 1000 mm (Addis Abeba) and (B) 550 mm (adopted from Davidson, 1989).**

(A)

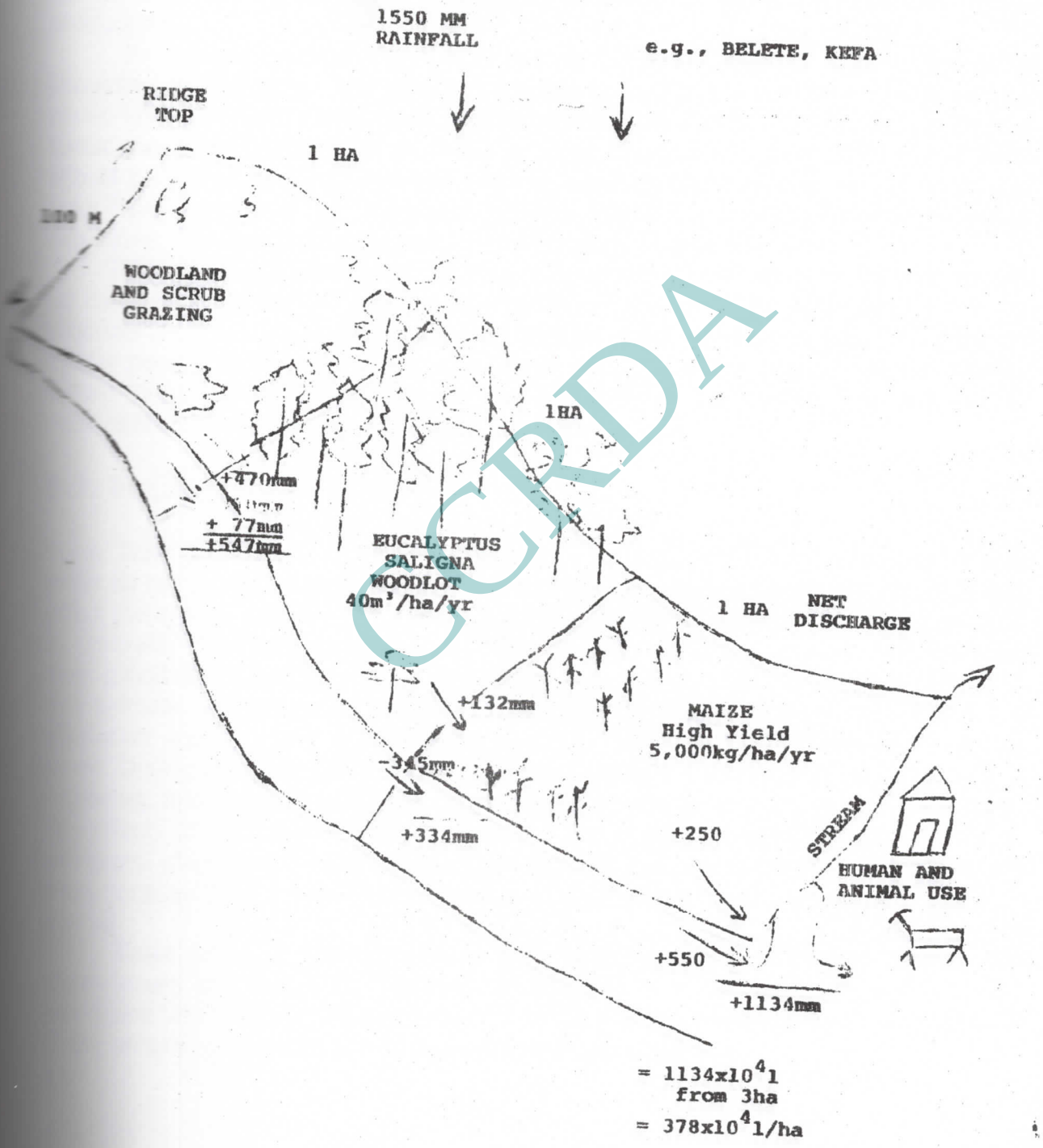



(B)



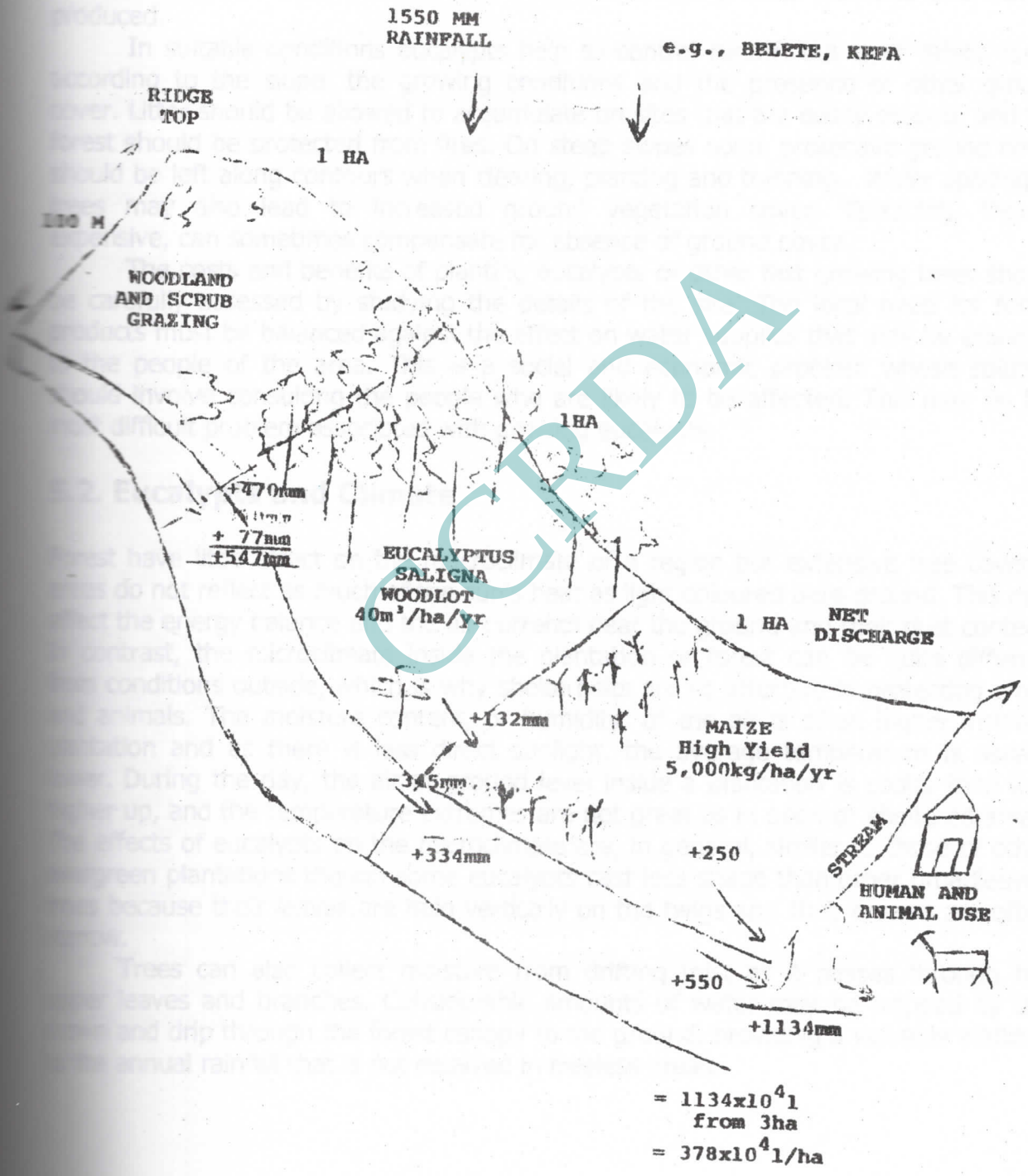

CCRDA

**Figure 6. Water balance within three adjacent one-hectare blocks of land running up and down a slope under an annual rainfall of 1550 mm at Bellete Forest Area (adopted from Davidson, 1989).**




CCRDA

**Figure 6. Water balance within three adjacent one-hectare blocks of land running up and down a slope under an annual rainfall of 1550 mm at Bellete Forest Area (adopted from Davidson, 1989).**




CCRDA

### 5.1.4. Summing up the Effects of Eucalypts on the Water Supply

Extensive plantations of fast growing tree species, including eucalypts, will reduce the water yield in a region. Forests utilize more water than other land uses but may increase useful water yield by increasing dry season stream-flow and reducing reservoir sedimentation. Clearing the plantations will increase the water yield and, by raising the ground-water level to the surface, may in some cases cause problems with flooding and salinity. Eucalypts utilize less water than pine, but probably more than other broad-leaved trees. All closed forests take up more water than scrub or grass. Use of water is proportional to the amount of biomass (wood, branches and leaves) produced.

In suitable conditions eucalypts help to control runoff, but their effect varies according to the slope, the growing conditions and the presence of other ground cover. Litter should be allowed to accumulate on sites that are easily eroded, and the forest should be protected from fires. On steep slopes some protective ground cover should be left along contours when clearing, planting and thinning. Wider spacing of trees may also lead to increased ground vegetation cover. Terracing, though expensive, can sometimes compensate for absence of ground cover.

The costs and benefits of planting eucalypts or other fast growing trees should be carefully assessed by studying the details of the site. The local need for forest products must be balanced against the effect on water supplies that may be essential to the people of the area. This is a social and economic problem whose solution should involve consulting the people who are likely to be affected. This may be the most difficult problem associated with growing eucalypts.

## 5.2. Eucalypts and Climate

Forest have little effect on the macroclimate of a region but extensive tree covered areas do not reflect as much of the sun's heat as light coloured bare ground. This may affect the energy balance and the air currents near the ground and their dust content. In contrast, the microclimate inside the plantation or forest can be quite different from conditions outside, which is why shelterbelts are so effective in protecting crops and animals. The moisture content, or humidity, of the air is often higher inside a plantation and as there is less direct sunlight, the average temperature is usually lower. During the day, the air at ground level inside a plantation is cooler than it is higher up, and the temperature extremes are not great as in open or sheltered areas. The effects of eucalypts on the microclimate are, in general, similar to those of other evergreen plantations though some eucalypts cast less shade than other broadleaved trees because their leaves are held vertically on the twigs and their crowns are often narrow.

Trees can also collect moisture from drifting mist as it passes through the upper leaves and branches. Considerable amounts of water may be trapped by the crown and drip through the forest canopy to the ground, providing a valuable addition to the annual rainfall that is not received in treeless areas.

CCRDA

## 5.3. Eucalypts and Soil Erosion

When the land is not properly managed, excessive surface runoff after heavy rains cause soil erosion. Erosion depends on such factors as intensity of rainfall, soil condition, slope and live vegetation and litter cover. Conditions should favor the penetration of water into the soil, rather than its flowing across the surface. Clear weeding such as may be practiced in young eucalypt plantations may make soil susceptible to erosion. If the growing conditions are good, young trees can provide complete ground cover within a year of planting. Plantations on steep slopes can provide effective erosion control if careful techniques such as contour planting are used.

This method has been successful in Nigeria where a humid climate favoured rapid site coverage and production of large volumes of wood from *E. hemiphloia* and *E. occidentalis* have been recommended for control of erosion in these conditions. The litter which gathers under most eucalypt plantations can help to form a protective barrier against erosion, but in many places the litter is collected as fuel or removed to reduce fire hazard. A realistic assessment of each area to be planted is needed to decide whether erosion will be a serious problem, and if so, whether it can be controlled. Some places may not be suitable for plantation establishment.

Tree monocultures of any kind may not be the best solutions to soil erosion, particularly sheet and surface erosion (Davidson, 1989). *E. globulus* has a generally good reputation for catchment protection. It has been widely planted for this purpose in countries other than Ethiopia. It has good lateral root system in addition to a strong taproot. The problem in Ethiopia, e.g. around Addis Abeba, is the degree of human and animal disturbance. People take away all the litter and donkeys and foot traffic compact the soil. Stands become patchy and the ground is left bare under the trees offering little protection against erosion.

Farmers seem to know better when it comes to planting eucalypts in Ethiopia. They plant dense stands and periodically coppice only part of the stand at a time so that there is a multi-layered canopy and they allow grass to grow beneath. In state forests, often clear felling is carried out on steep slopes, when it should be either selected stems or strips cut on the contour (Davidson, 1989). Eucalypt forest established for catchment protection should not be harvested at all on slopes over 100 %. On slopes from 40 to 100 %, the stands are best developed into uneven ones by selective cutting over a period of years. Even more suitable may be mixed stands, particularly of eucalypts and acacias. Whatever the tactics adopted, better quality planting material, species-site matching, establishment and aftercare, in short *better Silviculture and Management*, are required (Davidson, 1989).

Wind erosion occurs on light soils when there are few tree roots or other vegetation to hold the topsoil. Trees reduce the force of the wind as well as dropping litter on the soil surface, but the species used is not important in controlling wind erosion. Eucalypts rapidly develop good roots even in dry sandy soils, so they are useful for starting wind barriers (FAO, 1988).

CCRDA

## 5.4. Eucalypts and Soil Nutrients

Plants obtain the food or nutrients they need for living and growing from the soil around their roots. The nutrients are dissolved in water or, as in the case of nitrogen, can be absorbed in gas form. The main mineral elements required for plant growth are phosphorus, potassium, calcium and sulphur, all of which behave in roughly the same way unlike nitrogen, which moves more freely. Certain other elements are also required for healthy growth and these are called trace elements because plants use only very small amounts.

Nutrients come mainly from the weathering of rocks underneath the soil, and also from the air as chemicals dissolved in rainwater, or as dust. Trees are very effective in collecting solid particles carried by the wind and these are washed off the leaves into the soil. Nutrients are removed, or leached, from the soil in water that the plants do not use, and they are also carried away in surface runoff and by wind erosion. The plants eaten by animals, birds and insects contain nutrients that have come from the soil. Living creatures circulate these nutrients by returning them to the soil in their droppings and dead bodies. In undisturbed natural conditions, dead branches of trees break off and fall to the ground. Whole trees also fall and decompose, returning the nutrients to the soil or directly to the trees through roots and associated fungi.

Soil fertility in agricultural lands may be restored by having a forest fallow period of seven to 10 years after two successive rotations, using species that add nitrogen to the soil. Forests utilize soil nutrients for growth but they may also restore soil fertility through mobilizing recycling and storing nutrients. These processes are complex, difficult and expensive to measure and imperfectly understood, especially in the tropics.

The nutrients circulated between the plants and soils include nitrogen. But this element also exists as a gas so that the nutrient system can gain or lose nutrient nitrogen. When decayed plant material is exposed to high temperatures and bright light, nitrogen is lost to the atmosphere, and this also happens when plant material is burnt. On the other hand, the roots of some plants in symbiosis with bacteria and fungi can convert nitrogen from the air in a form, which is then available for plant use, e.g. species of *Acacia*.

The effects of uncropped eucalypts on soil quality have been compared with other species and with treeless areas. The studies were mostly from India and the Mediterranean and are fairly recent. *Eucalypts were found to have a beneficial effect on soil structure and compared favourably with pine and sal (Shorea robusta).* ***On treeless sites eucalypts improved soil fertility through decayed leaves and litter.***

Very few comparative studies have been made in Ethiopia on soil nutrients among plantations of different species, including eucalypts, and the adjacent natural forests (Michelsen *et al.*, 1993; Lisanework Nigatu & Michelsen, 1994; Michelsen *et al.*, 1996; Betre Alemu, 1998).

In the first study, soil fertility, growth, nutrient utilization and mycorrhizal colonization were compared among plantations of *E. globulus* (40 years old stand coppiced 2-6 years before the study), *Cupressus lusitanica* (28 years old), *Juniperus*

CCRDA

*procera* (40 years old) and the adjacent natural forest at Menagesha state forest, about 50 km west of Addis Abeba (Michelsen *et al.*, 1993). The results revealed that soil of both *C. lusitanica* and *E. globulus* plantations had lower nutrient contents than soils of both *J. procera* plantation and the natural forest. The pool size of all nutrient elements in herbaceous plants was also much lower in the *C. lusitanica* site than other three sites. Soils of the *C. lusitanica* and *E. globulus* sites tended to have lower density of vesicular-arbuscular mycorrhizal fungi.

In the second study, nutrient cycling in the above-mentioned plantations and in natural forest was compared at the same forest (Lisanework Nigatu & Michelsen, 1994). The results indicated that the total annual litterfall was about twice as high in the natural forest as in the plantations, with the lowest litterfall in the *C. lusitanica* plantation, and slightly higher figures in the *E. globulus* and *J. procera* plantations. The four sites differed with respect to the rate of nutrient release from decomposing litter. The *E. globulus* plantation had comparable nutrient release with the natural forest after one year.

The third study focused on large-scale comparative studies of understorey vegetation and soil fertility in plantations and adjacent natural forests (Michelsen *et al.*, 1996) in 11 areas with a total of 83 plantations in central and southern Ethiopia. The results showed that the natural forest soil had a higher content of total nitrogen, available phosphorus and exchangeable calcium. This has been attributed to a combination of loss of organic matter during conversion of natural forest to plantations, increased leaching in young plantations and low nutrient demand by natural forest tress compared with fast-growing exotics.

Similarly, in the fourth study, where soil nutrient status was studied after conversion of natural forest to plantation and secondary forest at Munessa forest (Betre Alemu, 1998), the plantation stands (*E. globulus, E. grandis, E. saligna, Pinus patula* and *C. lusitanica*) had significantly lower pH, total nitrogen, organic matter, exchangeable calcium and magnesium than the adjacent natural forest in the topsoil.

CORDA

### 5.4.1. Eucalypt Utilization and Soil Nutrients

There is an important difference between the nutrient status of a natural forest and that of cropped plantations, especially when these are 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. The type of wood produced from eucalypt plantations depends on local or other market requirements and can be fuelwood, poles, timber or fiber. The nutrients in the products are removed within a comparatively short period of time, because eucalypts are usually chosen for their fast growth. Cropping younger trees reduces the nutrient status of the soil faster than mature crop felling.

The three main aspects of plantation cropping that affect the nutrients in the soil are parts of the trees removed, the type of management needed to obtain it and the harvesting method used. All have a 'nutrient cost', or amount of nutrient loss resulting from each process. The total parts of a tree are its roots, stem, bark, branches, twigs, leaves, flowers, and fruits, all of which are included in the term 'biomass'. Nutrients are found in every part of the tree in differing proportions, and

biomass may therefore be used to measure the amounts of nutrients removed in cropping.

### 5.4.2. Nutrient Content of Eucalypt Trees

Studies of the biomass of four-year *E. saligna* trees in Brazil included investigations into some of the elements essential for tree growth (nitrogen, phosphorus, potassium, calcium and magnesium). These nutrients are stored in the soil as well as in the tree. Figure 7 compares the amounts of nutrients in various tree components.

### 5.4.3. Uptake of Nutrients in Different Trees

A comparison was made between the amount of nutrients removed from an average native Australian eucalypt forest, where two cubic meters of timber per hectare was harvested each year, and an eucalypt plantation with short rotation total tree utilization (leaves and branches where removed as well as wood). The nutrient content of a cereal crop was also included in the comparison. These results show that the amount of nitrogen taken in by the cereal crop is two and half times more than the amount taken by the eucalypt plantation, and 15 times more in the case of phosphorus. The nutrients removed in the native forest are 20 times less than in the short rotation eucalypt plantation (Figure 8).

The reason for these differences is that only the timber was taken from the native forest - the leaves, branches and bark were left on the site. In the eucalypt plantation most of the nutrients were removed because the total tree above ground was taken or harvested every 10 years, and in the cereal crop, everything was taken each year. The reason for the larger amount of phosphorus being removed in the eucalypt plantation is that the sapwood contains 33 times more of this nutrient than heartwood, and in eucalypts the heartwood does not start to form until the tree is more than 15 years old.

CCRDA

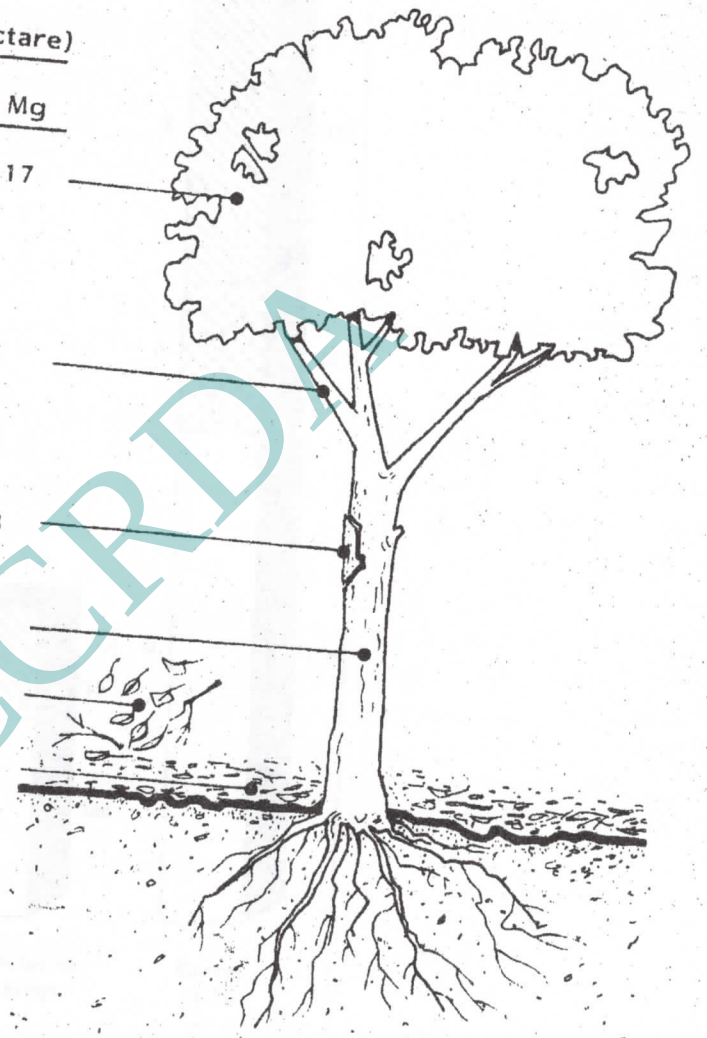
## 5.5. Eucalypts and Wildlife

Animals, birds and insects that live in the wild depend on natural vegetation for their food and shelter. Therefore, when a plantation of exotic species replaces their natural habitat, they are affected. Birds and browsing animals may find this vegetation less palatable, and although some remain in their established feeding areas others move away to search for new territory. Usually, the population is reduced rather than totally eliminated in an area.

There is a complex relationship between living creatures (including man) and the various organisms they need for their survival. Figure 9a is a simplified example of an animal consumer process showing how each stage is linked to the next. Figure 9b is an example of a similar cycle or chain involving different creatures. These two food chains are interwoven with each other because different forms of wildlife share the same territory. A change in the vegetation, or habitat, affects most of the creatures in one way or another, and their food chain is disrupted for a period until an equal or modified animal food chain appropriate to the new habitat develops.

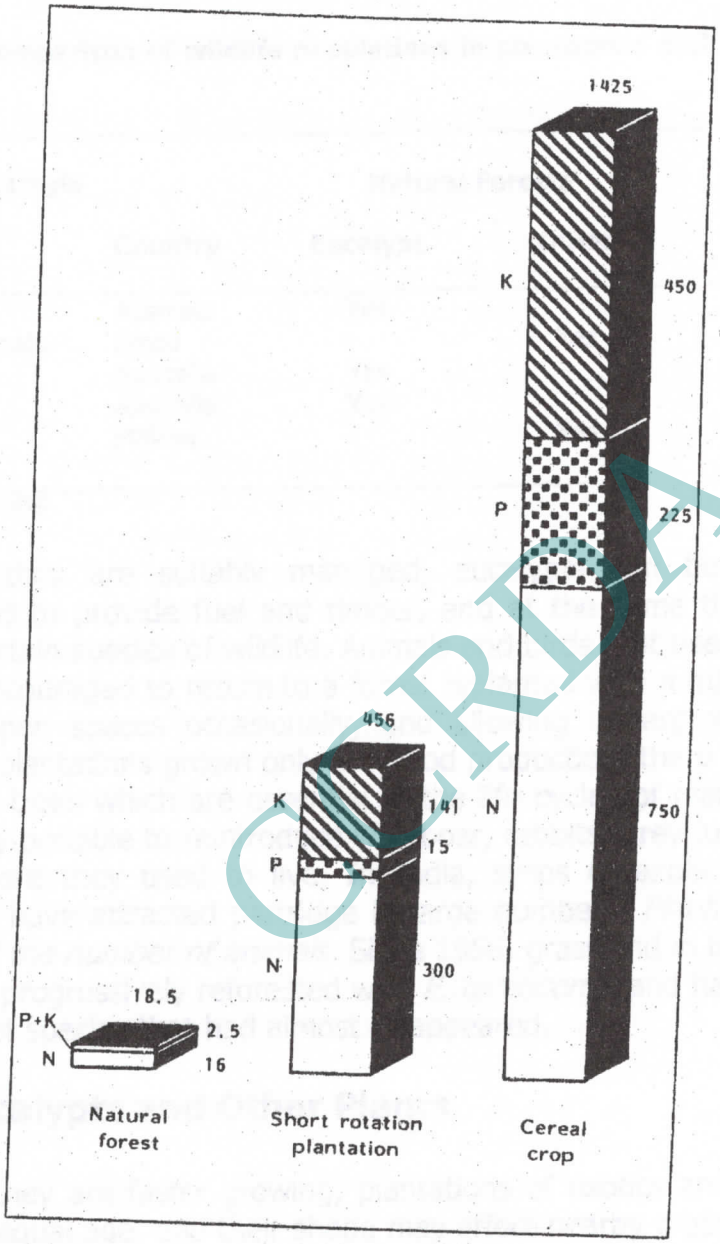
**Figure 7. Nutrient content in the various parts of four-year-old trees of *E. saligna* (adopted from FAO, 1988).**

| Component | Element (kg per hectare) | | | | |
|---|---|---|---|---|---|
| | N | P | K | Ca | Mg |
| Leaves | 108 | 7 | 61 | 64 | 17 |
| Branches | 30 | 3 | 45 | 69 | 7 |
| Bark | 13 | 2 | 26 | 57 | 13 |
| Wood | 21 | 12 | 42 | 17 | 6 |
| Litter fall/year | 42 | 24 | 41 | 44 | 12 |
| Litter | 63 | 3 | 20 | 100 | 15 |



CCRDA

**Figure 8. Nutrient [nitrogen (N), phosphorus (P) and potassium (K)] removed through harvest over ten-year period (kg/ha) (adopted from FAO, 1988).**




CERDA

The effects of exotics, including eucalypts, on certain species of animals, birds and insects have been studied in Africa, Brazil, Puerto Rico and India. Although these studies provide information relevant only to their own locality some of them illustrate how wildlife populations can respond to special conservation measures. Table 5 compares the wildlife populations, which occur in some natural eucalypt forests with those found in non-eucalypt forests, e.g. tropical rain forest. It also gives a similar comparison for eucalypts and pine grown in plantations.

**Table 5. Comparison of wildlife populations in plantations and natural forests in different countries.**

| Wildlife and Origin | | Natural Forests | | Plantations | |
|---|---|---|---|---|---|
| **Group** | **Country** | **Eucalypt** | **Other** | **Eucalypt** | **Pine** |
| Mammals | Australia | Yes | | Yes | |
| Small mammals | Brazil | | Yes | Yes | No |
| Birds | Australia | Yes | | Yes | |
| Beetles | Australia | Yes | | No | Yes |
| Spiders | Malawi | | Yes | Yes | |

Source: FAO (1988)

If they are suitably managed, eucalypts can be grown in multipurpose plantations to provide fuel and timber, and at the same time be a habitat that will attract certain species of wildlife. Animals and birds that used to live in natural forests can be encouraged to return to a forest replanted with a mixture of exotic species by leaving open spaces occasionally, and allowing undergrowth to remain here and there. In plantations grown only for wood production, there are very few over-mature and dead trees which are essential in the life cycles of many insects and birds. It is technically possible to reintroduce wild boar, rabbits, grey jungle fowl and partridge in areas where they used to live. In India, strips of exotic trees planted along the roadsides have attracted partridge in large numbers. *Planting eucalypts in India has increased the number of animals.* Since 1958, grassland in the 119 $km^2$ game reserve has been progressively reforested with *E. tereticornis* and has resulted in a population increase of species that had almost disappeared.

## 5.6. Eucalypts and Other Plants

Because they are faster growing, plantations of exotics are usually taller than other plants of equal age, and their shade may affect nearby crops by reducing the sunlight needed for growth. In semi-arid regions, water is limited and plants with deep spreading roots take most water while plants with shallow roots may be stunted or unable to survive. Some species of eucalypt such as *E. tereticornis* are able to grow in very dry climates and may take most of the available water in the soil.

The effects that tree plantations can have on other plants, i.e. shading and competition for water, may be seen in several ways. Inside the plantation, the [illegible] often consists of sparse patchy grass, herbs and creepers all of which

are unsuitable for grazing by farm animals. Just outside the plantations, the yields from agricultural crops close to the trees are sometimes not as good as they are further away from the edge. This situation can be improved by digging narrow trenches along the edges of the plantation to stop the tree roots growing out sideways towards the crops. The trees along the edges of plantations usually have large side branches, and the trees develop well-grown, strong roots to withstand the force of the wind and draw water from a wider area.

### 5.6.1. Interactions of Eucalypts with Other Plants in Different Countries

In India, farmers are now planting eucalypts along farm boundaries. This is because the elongated crowns and vertical roots of eucalypts do not noticeably reduce crop yields, and also because the farmers can use or sell the produce from the trees. In Colombia, single trees of *E. camaldulensis* are grown along field boundaries for the pulpwood market.

Similar to other plantation species (Parrotta *et al.*, 1997), eucalypt plantations have been shown to foster or catalyze regeneration of native forests when they are planted close to seed sources and protected from human and animal disturbances, thereby contributing to rehabilitation of degraded lands and increasing biodiversity. To illustrate this, a few examples are given below.

For instance, the influence of human disturbance on three 34-year-old tropical artificial *Eucalyptus* forest ecosystems had been studied in China (Shaolin *et al.*, 1996). Some parts of these forests were protected from any human disturbance for 8 years while the other parts were left open for disturbance. The results revealed that a three-layered tree-shrub-herb community structure developed in the long-protected parts while the ground was barren under the parts in which people had always removed litter. In the long-protected parts, plant diversity increased with natural successional development, the structure of the ecosystem tended to be more complex, primary productivity increased and the diversity of soil microbes as well as fauna increased along with soil fertility. It was shown that in the parts where litter had been removed continuously, these patterns were reversed. The authors then concluded that it was not allelopathy of *Eucalyptus* rather human disturbance that led to the barren ground in the unprotected parts of the forests.

Results from the assessment of floristic composition and diversity under an eight-year-old *E. camaldulensis* stand, a one-year-old *E. camaldulensis* coppice stand and an unplanted control site on Ulumba Mountain in Malawi (Bone *et al.*, 1997) indicated that diversity was significantly higher in the coppice stand than the eight-year-old eucalypt and control stands. The herbaceous species composition of the control site was similar to that of the plantation stand. Similarly, the results of a study made on native forest regeneration in pine and eucalypt (*E. saligna*) plantations in northern province of South Africa (Geldenhuys, 1997) showed that the eucalypt stands had denser and taller woody regeneration than the pine stands.

### 5.6.2. Interactions of Eucalypts with Other Plants in Ethiopia

In Ethiopia, two different results have been reported concerning the interaction or association of eucalypts with other plants, i.e. positive interactions (Mebrate Mihretu

1992; Michelsen *et al.*, 1993; Michelsen *et al.*, 1996; Yitebetu Moges, 1998; Feyera Senbeta, 1998; Kidane Woldu, 1998) and negative interactions (Lisanework Nigatu & Michelsen, 1993).

The two relevant reports available on *E. globulus* plantations at the Entoto Hills in Addis Abeba (Mebrate Mihretu, 1992; Kidane Woldu, 1998) indicate that there is a good natural regeneration of *Juniperus procera* within the plantations. The eucalypt stands on the hills are old and probably of third and fourth generation (Kidane Woldu, 1998). Analysis of the inventory made indicated that the juniper regenerated from seeds or by coppicing, and had an average density of 1750 individuals per ha with 26 % of the regeneration originating from stump coppices. The proportions of juniper seedlings (height ≤ 75 cm), saplings (height ≥ 75 cm & ≤ 2 m) and pole-sized trees (height ≥ 2 m) were 44, 13 and 43 % respectively (Kidane Woldu, 1998), suggesting that the regeneration is still at a building phase and human impact is affecting saplings, probably due to cutting them for Christmas trees, fuelwood or construction.

The average density of seeds in the soil (*soil seed bank*) was estimated at 118 seeds/$m^2$, 84 % of which were decayed. It was concluded that despite the potential "allelopathic effects" of the eucalypt trees and nutrient deficient soils, the juniper has grown effectively on the eroded areas competing well with the eucalypt trees (Kidane Woldu, 1998). Analysis of the distribution of height and diameter classes, density and general structure of he juniper population indicates good recruitment and, thereof, good regeneration potential that can contribute to its future provided that the area is protected from grazing and human interference.

Evidently, a dense juniper forest, probably mixed with other species such as *Olea europaea* and *Podocarpus falcatus*, must have once covered the hills before it was deforested and replaced by eucalypt plantations. Apparently, the plantations might have created favorable conditions for the regeneration of juniper by allowing sufficient light through the canopy and protecting the seedlings and saplings from scorching light and desiccating winds. In addition, the presence of mature juniper trees as source of seeds for regeneration and protection of the plantations by the ex-landowners from trespassers and grazing have contributed o the natural regeneration of juniper (Mebrate Mihretu, 1992).

The results from the study made by Michelsen *et al.* (1993), already discussed earlier, revealed that the number of forbs and grasses was high in all the sites, i.e. *C. lusitanica, E. globulus, J. procera* and an adjacent natural montane forest, although their coverage was poor in the *C. lusitanica* site. In addition, the production of fine roots in the topsoil was twice as large in the eucalypt and juniper sites than in the other sites. In another investigation involving 83 plantations and adjacent natural forest stands in the highlands of Ethiopia (Michelsen *et al.*, 1996), it was demonstrated that in contrast to the frequent view of eucalypts as harmful for understorey plants, the richness and biomass of herbaceous plant species in plantations of eucalypts and also of *P. patula*, was as high as those of natural forests. The herbaceous vegetation in *C. lusitanica* plantations older than nine years was distinct in composition, less diverse and much reduced in terms of cover and biomass compared with similar aged plantations of *E. globulus, E. grandis, E. saligna, P. patula* and with natural forests.

The studies made by both Feyera Senbeta (1998) and Yitebetu Moges (1998) at the Munessa-Shashemene Forest Project Area clearly demonstrated that provided

CORDA

that there is a seed source in the vicinity, establishment of forest plantations can help not only to provide wood for various purposes, to rehabilitate degraded lands and to conserve soil and water but also to foster or catalyze natural regeneration of native woody species thereby enhancing biodiversity. *Cupressus lusitanica, Eucalyptus globulus, E. saligna* and *Pinus patula* were the plantation species investigated in association with the adjacent natural forest. The results from the study of Feyera Senbeta (1998) relevant to the topic at hand are summarized in Tables 6 and 7.

**Table 6. Characteristics of the plantation stands sampled at Munessa-Shashemene Forest Project Area. Rotation refers to whether the stand is coppice or not; 1 refers to non-coppiced stand.**

| Species | Distance to natural forest (m) | Age (yrs) | Rotation | Mean Height (m) | Stems / ha | Crown Cover (%) | Richness* | Density of Understorey/ ha |
|---|---|---|---|---|---|---|---|---|
| *C. lusitanica* (CL9) | 200 | 9 | 1 | 10 | 900 | 75 | 30 | 7325 |
| *C. lusitanica* (CL17) | 250 | 17 | 1 | 23 | 575 | 80 | 22 | 7375 |
| *C. lusitanica* (CL25) | 300 | 25 | 1 | 26 | 475 | 65 | 16 | 5950 |
| *E. globulus* (EG13) | 100 | 13 | 1 | 31 | 275 | 50 | 16 | 6550 |
| *E. globulus* (EG16) | 200 | 16 | 1 | 26 | 900 | 65 | 13 | 2300 |
| *E. globulus* (EG22) | 350 | 22 | 2 | 27 | 625 | 60 | 17 | 13400 |
| *E. saligna* (ES11) | 250 | 11 | 1 | 28 | 450 | 55 | 18 | 3575 |
| *E. saligna* (ES22) | 350 | 22 | 2 | 21 | 900 | 65 | 23 | 10100 |
| *E. saligna* (ES27) | 1000 | 27 | 3 | 17 | 100 | 10 | 25 | 18650 |
| *P. patula* (PP10) | 200 | 10 | 1 | 15 | 750 | 80 | 18 | 2325 |
| *P. patula* (PP21) | 500 | 21 | 1 | 25 | 500 | 85 | 16 | 3750 |
| *P. patula* (PP28) | 100 | 28 | 1 | 31 | 475 | 70 | 15 | 2525 |
| Natural Forest (NF) ** | - | - | - | 26 | 142 | 30 | 27 | 9658 |

Source: Feyera Senbeta (1998); * number of species; ** Only upperstorey trees ≥ 10 cm diameter

The number of naturally regenerated native woody species ranged between 13 and 17 in *E. globulus* stands (13 to 22-year-old) as well as between 18 and 25 in *E. saligna* stands (11 to 27-year-old) with densities ranging between 2300 and 13,400 as well as 3575 and 18,650 individuals/ha respectively (Table 6 & 7). There was a disparity between the floristic composition of he soil seed banks and the above ground naturally regenerated woody species, and all of the naturally regenerated woody species are represented by mature trees in the adjacent natural forest (Feyera Senbeta, 1998) suggesting that the source of seed for the regeneration is the natural forest. It is worth mentioning that human impact on the plantations stands is very minimum since they are protected and wood supply and grazing areas are obtained from the natural forest.

The potential allelopathic effect of *C. lusitanica, E. globulus, E. camaldulensis, E. saligna* on seed germination, radicle and seedling growth was investigated with four crops: chickpea, maize, pea and teff (Lisanework Nigatu & Michelsen, 1993). The results revealed that aqueous leaf extracts of all the tree species significantly reduced both germination and radicle growth of the majority of the crops. It has been shown that the shoot and root dry weight increase of the crops was significantly reduced after 10 weeks treatment with leaf extracts. Among the four crops chickpea and teff were most susceptible with respect to germination, and teff with respect to growth. From the overall data, the leaf extracts of the four tree species had been arranged according to increasing allelopathic potential: *C. lusitanica, E. globulus, E. saligna* and *E. camaldulensis*. Based on these results, the authors suggested that the planting of

**Table 7. The most common naturally regenerated woody plants beneath eucalypt plantations at Munessa-Shashemene Forest Project Area. Nomenclature follows Cufodontis (1953-1972), Hedberg & Edwards (1989) and Friis (1992). Figures in the table indicate density per 400 m$^2$.**

| SPECIES | *E. globulus* | | | *E. saligna* | | | NF |
|---|---|---|---|---|---|---|---|
| | EG13* | EG16 | EG22 | ES11 | ES22 | ES27 | |
| *Acokanthera schimperi* | | | | | | 11 | |
| *Adhatoda schimperiana* | | | | | 43 | | |
| *Albizia gummifera* | | | | | | | |
| *Albizia schimperiana* | | | | | | | |
| *Allophylus abyssinicus* | 17 | | | | 12 | 13 | 44 |
| *Apodytes dimidiata* | | | | | | 9 | |
| *Bersama abyssinica* | 34 | 11 | 83 | 22 | 19 | 16 | 35 |
| *Brucea antidysenterica* | 29 | 15 | 44 | 9 | | 19 | 34 |
| *Calpurnia aurea* | | 11 | 47 | | 21 | 21 | 43 |
| *Carissa edulis* | | | | | 14 | | |
| *Cassipourea malosana* | | 2 | 17 | | 3 | | 4 |
| *Celtis africana* | | | | 3 | 25 | 74 | 47 |
| *Clerodendrum myricoides* | | | | | | 2 | |
| *Cordia africana* | | | | | 4 | | 20 |
| *Croton macrostachyus* | 18 | 10 | 42 | 5 | 11 | 21 | 79 |
| *Diospyros abyssinica* | | | | | | | 19 |
| *Discopodium penninervium* | | 3 | | 3 | | | |
| *Dovyalis abyssinica* | 5 | | 8 | | 6 | 9 | 13 |
| *Ekebergia capensis* | 4 | | 3 | | | | |
| *Elaeodendron buchananii* | | | | 1 | | | |
| *Euclea divinorum* | | | | | | | |
| *Fagaropsis angolensis* | | | | | | | 27 |
| *Flacourtia indica* | | | | | 5 | 8 | 4 |
| *Galiniera saxifraga* | 3 | | | | | | |
| *Ilex mitis* | | | | | | | |
| *Jasminum abyssinicum* | 8 | | | 2 | 3 | | 8 |
| *Maesa lanceolata* | 2 | | | 4 | 1 | | |
| *Millettia ferruginea* | | | 1 | | | 2 | 5 |
| *Maytenus ovatus* | 36 | 16 | 40 | 13 | 53 | 1 | 163 |
| *Olea europaea* | | | | | | | |
| *Olea capensis* subsp. | | | | | | 1 | 2 |
| *Hochestetteri* | | | | | | | |
| *Olinia rochetiana* | | | | | | | |
| *Osyris quadripartita* | | | | | | | 1 |
| *Phoenix reclinata* | | | | | | 4 | |
| *Podocarpus falcatus* | 1 | | 1 | 19 | 46 | 443 | 2 |
| *Prunus africana* | 1 | 1 | | 2 | 2 | 14 | 7 |
| *Rapdrax schimperiana* | 66 | 5 | 20 | 41 | 71 | 47 | 293 |
| *Rhamnus prinoides* | | 1 | | | 3 | 2 | |
| *Rhus glutinosa* | | | | | | | |
| *Rumus communis* | | | | 1 | | | |
| *Rubus apetalus* | | | 1 | | 4 | 3 | |
| *Rubus steudneri* | 1 | 2 | 2 | 2 | 5 | | 5 |
| *Rumex nervosus* | | | | | | | |
| *Rytigynia neglecta* | | | | | | | 7 |
| *Scolopia theifolia* | | | | | | | |
| *Similuna oxyacantha* | | | | | | | |
| *Solanum guineense* | | | 5 | 2 | | 7 | |
| *Tacca nobilis* | 5 | | | | | 2 | 27 |
| *Tabtalia asiatica* | | | | 3 | 2 | 1 | 7 |
| *Trichocladus ellipticus* | | | | | | | |
| *Vernonia amygdalina* | | | | | | 3 | |
| *Vernonia stipulacea* | 32 | 9 | 90 | 9 | 29 | 13 | 104 |
| *Zizia* (C) | | | 55 | | | | 78 |
| *Vernia* (C) | | 6 | 77 | 2 | 22 | | 81 |

Source: Feyera Senbeta (1998); * Refer to Table 6 for abbreviations; C = common name of the species

CCRDA

*E. camaldulensis* and *E. saligna* should be minimized in integrated land use systems, whereas the use of *C. lusitanica* and *E. globulus* was considered less damaging environmentally.

## 5.7. Eucalypts as Windbreaks and Shelterbelts

These are probably the most important effects that eucalypts have on other vegetation. Because, in some regions, and especially where the climate is hot and dry for most of the year, the only way that agricultural crops can be grown is by protecting them from strong winds. Eucalypts make good shelterbelts, and *E. camaldulensis* has been recommended for this because even in low rainfall areas it rapidly develops an efficient roots system and a sheltering crown.

Windbreaks are fairly narrow strips of trees and shrubs, or they can be single rows of leafy bushes. Their effectiveness depends on a dense barrier of vegetation being created. A close row of trees not only blocks the wind, but also confines its effects closer to the windbreak. A more open row of trees which allows some of the wind to pass through means that the effects of the wind are felt further away. In arid regions a density of 60 % to 80 % of total closure seems to work best.

Shelterbelts are generally wider and more closely grown than windbreaks. If they are tall and dense enough they can protect downwind areas for distances of up to 20 times the height of the shelterbelt. A well chosen mixture of species will not only shelter crops from wind but will also yield fruit, fodder and firewood. Eucalypts are useful trees for starting shelterbelts because they are hardy and can establish themselves quickly. Farm animals do not eat most species of eucalypt, so they do not need to be protected when they are young. The taller eucalypts can be grown together with other trees of *Acacia,* pine and *Albizia* choosing trees of different average top heights to give the correct profile.

Trees that can be used as fodder will need protection from grazing herds at first. A series of shelterbelts spaced every 250 m, for example, can protect crops from wind scorch and sand encroachment over a wide area and also provide sheltered grazing. Simple windbreaks screen farm buildings from dust storms. If gaps have to be left in shelterbelts, the openings should not be opposite each other because the wind will funnel through. By 'staggering' the gaps the force of the wind is reduced.

CORDA

# 6. Eucalypts and People

Eucalypt plantations have become a subject for argument in some countries because *the needs of the local people and the forestry objectives likely to be achieved by planting eucalypts have not been well matched.* **In other places, eucalypt plantations are making a useful contribution to the needs of the community because the advantages obtained outweigh the disadvantages**. It would be unwise to grow eucalypts if it were not the most beneficial land use for the majority of local people.

Among the chief necessities for people to lead acceptable lives are food, shelter, and energy for cooking and warmth. Forests can make an important contribution to these essential requirements, and enlightened foresters are aware that a new

approach to the old concept of **social forestry** is needed. Three components are involved - *rural forestry on communal land*, *farm forestry on private land*, and *urban forestry in high-density areas*. Eucalypts can play an important part in developing the objectives of social forestry. These are to:

- create new sources of forest produce in rural areas (firewood, charcoal, building poles, and small timber);
- help farm owners by growing useful trees, including those that can be sold as cash crops;
- improve living conditions for town dwellers by planting trees on roadsides, and in residential and industrial areas;
- protect exposed land for the benefit of people, their crops and their animals;
- conserve soil and water as well as provide amenities such as recreational areas.

## 6.1. Plantations and Natural Forests

The question of whether rural people should obtain their fuel and domestic timber requirements from plantations or natural forests depends on many factors. Plantations may supply greater quantities of material within a fixed time period. But natural forests supply a wide variety of benefits that can be very important to the community in the long term. A crucial factor is the most appropriate use of each type of land available (depending on climate, soil topography or other factors) to meet the needs of the community. It is very difficult to justify clearing natural forest if deforested areas appropriate for tree plantations but not agriculture are available.

Growth in populations and greater demands for food, fuel, water and other commodities means that land use planning and allocation must be more careful and thorough than before. However, these greater demands may strain economic and human resources in developing countries making this more difficult than ever. It is critical for communities and governments to support land use that is technically sound, which can be continued for many years and which meets the practical needs of the community.

One of the important reasons for introducing fast growing exotic tree species into rural areas is to help meet the increasing demand for domestic fuel supplies and for housing timber. Fuel, for example, is so scarce in some places that people burn cow dung or agricultural waste such as straw, dead leaves and stalks instead of allowing it to contribute to the fertility of the soil. Gathering and transporting daily supplies of fuel is time consuming and strenuous work, robbing people of time and energy needed for many other community endeavours. Many eucalypt species such as *E. teretiornis, E. globulus, E. camaldulensis* and *E. grandis* and hybrids are suitable species for fuelwood plantations on the appropriate sites. In addition to fuelwood, eucalypts can supply building poles and small timber, in good quantities in four or five years from comparatively small areas. Most eucalypt species do not have to be replanted after felling because they can be regenerated by coppicing. The second crop matures more quickly than the original one because it has well developed roots left by the first crop. However, eventually replanting must take place.

CCRDA

Farm owners may benefit by having better supplies of fuel and small timber, but plantations of exotic tree species can also bring other advantages as cash crops. In certain situations, farmers may expect higher returns per hectare of land by raising trees rather than agricultural crops, and if there is an assured demand for the produce, a suitable agroforestry mixture may help to increase farm income. An example of the benefit obtained by combining agriculture and forestry comes from Pakistan, where intercropping with strips of *E. camaldulensis* increased the production of cotton under irrigation. The fuel and timber produced was an additional benefit adding to the profits.

Most of the social objectives of forestry are included in the policy of 'multiple use'. Although eucalypts do not provide fodder or add nitrogen to the soil like some species of *Acacia* and *Leucaena*, there are many instances where they make an important contribution to improved rural living.

## 7. Making the Right Decisions

Arguments for and against eucalypts have been presented in previous sections. The information presented may help local communities and decision-makers determine whether eucalypt plantations are best land use in a particular area. The best land use can be determined by analyzing the overall needs of the community for food, fuel, timber, clean water and such important values as wildlife, genetic resource conservation and recreational sites and then determining the productive capacity of the land available to the community. Each judgment will be specific. **In some areas, eucalypts will not be appropriate; in some areas eucalypt plantations will be very useful**. Such decisions are complex, and no one knows all the right answers. It is important to obtain sound technical advice, to objectively evaluate the situation, and to avoid oversimplifying the solution. For example, if a community perceives a need for more wood, decides that eucalypts can produce more wood than a native forest, and simply cuts down the forest to plant eucalypts without considering the other benefits of this forest, then a careful decision may not have been made.

Eucalypts will not normally supply fodder for animals, and if they grow quickly they will utilize large quantities of water. But they may produce more utilizable wood than other available species on some sites, and as vigorous growers, they may require less work and tending than other species to supply the required benefits. **As with other forestry and land use decisions, careful analysis of the communities' needs and potential productivity of sites is the key to success.**

## 8. Conclusion and Recommendations

Farmers in Ethiopia plant large numbers of eucalypts, particularly *E. globulus*, on small areas of land and manage them to yield a variety of products including leaves and small branches for fuelwood, and poles and posts for house building and other farm uses. Farmers who have insufficient land to have woodlots often grow a few large trees, which can be harvested and sold when cash is required. The use of trees, especially eucalypts, as a living bank account (Turnbull, 1999), to be harvested when there is a need for cash, is widespread. Many people in Ethiopia are absolutely

CORDA

dependent on eucalypts as a source of fuel and house building material. This being the reality, the arguments *for* and *against* planting eucalypts in Ethiopia is mounting from time to time. These arguments are summarized below.

## 8.1. Arguments for Planting Eucalypts

The points raised by supporters of establishment of eucalypt plantations include the following:

- They can provide benefits such as fuel, timber for construction and making different furniture, fiber for pulp and paper, etc. very quickly.
- They provide multiple benefits in rural areas – fuel, shade, poles, windbreaks, soil stabilization in a short period of time.
- Several species produce nectar for honeybees and oil can be distilled from their leaves.
- A variety of species is available, which can be grown on all site types in all ecological zones of the country except the most arid.
- Many of the species, particularly those with glaucous (white cover) juvenile foliage do not require special protection from grazing animals.
- Some of the species can foster regeneration of native woody species under their canopy provided that there is ample seed source in the vicinity.
- They do not seem to have upset local values and traditions; in fact they have become an accepted part of rural life in Ethiopia.

## 8.2. Arguments against Planting Eucalypts

The points raised by those against establishment of eucalypt plantations include the following:

- Fast growth and high biomass production require more water than slow growth but eucalypts are most frugal with the amount of water used to produce a unit of biomass being much less than for most agricultural crops, conifers, acacias and other broad-leaved species of trees. Water consumption rate can be managed by controlling productivity.
- Periodic removal of large quantities of biomass will affect soil fertility, but this is often less than for most agricultural crops. Depletion can be much reduced by leaving leaves and bark in the forest area and by not harvesting material at too young an age since nutrient content in eucalypts is highest in the leaves, bark and sapwood (the proportion of sapwood in the stem decreases rapidly with age after about four to five years).
- Sparse canopies of eucalypts cannot protect the soil from erosion. It is true that some species have particularly sparse canopies, and canopies of most eucalypt species are less dense than those of other genera. But, developing unevenaged stands, layered coppice or mixed plantations can offset this problem.

CCRDA

Despite the growing concern against planting eucalypts, most of the reports available on eucalypts in Ethiopia (and elsewhere) are in favour of planting them since the authors acknowledge that:

- The negative impacts can be minimized provided that the choice of species and site as well as the management of the stands are appropriate (Yitebetu Moges, 1998; Feyera Senbeta, 1998; also see Poore & Fries, 1985; FAO, 1985)
- The benefit derived can offset the losses that can occur from such plantations (Davidson, 1989; Pohjonen, 1989; Pohjonen & Pukkala, 1990a; Mebrate Mihretu, 1993; Persson, 1995; Turnbull, 1999; also see Poore & Fries, 1985; FAO, 1985;)
- No other species, be it indigenous or exotic, can replace them in the near seeable future to bridge the ever-widening gap between demand and supply of wood (Davidson, 1989; Pohjonen & Pukkala, 1990b; Mebrate Mihretu, 1993; Persson, 1995; Turnbull, 1999) or
- The profit derived from eucalypt plantations is considerably higher than cultivating crops (Pohjonen & Pukkala, 1988b; Daba Wirtu, 1998)

However, in future endeavors, the choice of eucalypt species for plantations should be based on many criteria (Friis & Michelsen, 1995), for example maximum wood production, ecological sustainability, marketability of the planted species (commercial production of timber), usefulness of the species to the local population, etc. All these criteria involve not only a choice of species planted but also a choice of plantation management methods from initial planting to final cutting of the trees.

From the foregoing discussion, it appears that there does not seem to be any profound reason why eucalypt planting should not continue in Ethiopia until such time that alternative species are discovered. The establishment of eucalypt plantations could take different forms, e.g. huge number of small woodlots, groups, belts, lines and single trees scattered throughout the rural, but also urban areas. However, it has to be strongly emphasized that **careful selection of appropriate species and matching of species with appropriate sites must be taken as prerequisites and the right management practices should be employed.**

CRDA

## 9. Acknowledgements

First of all I would like to thank organizers of this timely workshop for inviting me to prepare and present this paper. I am very gratefully to all authors of the documents that I have consulted and used to compile this report. I want to extend my thanks to W/O Atikilt Bekele and Ato Tadesse Woldemariam for providing me with relevant literature as well as W/O Tigist Admasu and W/T Kelemwa Negussie for their efficient secretarial services.

# 10. References


Adugna Zerihun. 1981. Adaptability Trial of Several *Eucalyptus* Species in Hararghe Administrative Region. *Ethiopian Journal of Agricultural Sciences* 3: 31-48.

Amare Getahun & Girma Balcha (eds.). 1995. *Research on Seed and Nursery Technology at the Forestry Research Center.* Forestry Research Center, Addis Abeba.

Assefa Kuru. 1990. Roots of Deforestation Problems in Ethiopia. In Palo, M. & Mery, G. (eds.), *Deforestation or Development in the Third World? Vol. III.* Finnish Forest Research Institute, Helsinki, pp. 71-79.

Azene Bekele-Tessemma, Birnie, A. & Tengnäs, B. 1993. *Useful Trees and Shrubs for Ethiopia.* Regional Soil Conservation Unit, Swedish International Development Authority, Nairobi.

Amanuel Mehari. 1996. *Establishing Fuelwood Plantation and Fire Wood Tree Crop Performance on the Highlands of Ethiopia: The Case of Eucalyptus globulus Labill. subsp. globulus.* Swedish University of Agricultural Sciences, Department of Silviculture, Umeå.

Betre Alemu. 1998. *Spatial Study of Soil Nutrient Status After Natural Forest Conversion to Plantation and Secondary Forests at Munessa Montane Forest, Ethiopia.* MSc thesis, Swedish University of Agricultural Sciences, Skinnskatteberg.

Bone, R. , Lawrence, M. & Magombo, Z. 1997. The effect of *Eucalyptus camaldulensis* Dehnh. Plantation on Native Woodland Recovery on Ulumba Mountain, Malawi. *Forest Ecology and Management* 99: 83-99.

Cufodontis, G. 1953-1972. Enumeratio plantarum Aethiopiae Sepermatophyta. Bull. Jard. Bot. Etat. Brux. Vols. 23-42, Bruxelles.

Daba Wirtu. 1998. *Economics of Growing Eucalyptus globulus on the Highlands of Oromia, Ethiopia. with Special Reference to Intoto and Chancho Areas.* MSc thesis, Swedish University of Agricultural Sciences, Skinnskatteberg.

Davidson, J. 1989. The Eucalyptus Dilemma, Arguments for and against Eucalypt planting in Ethiopia. *Seminar Note Series No. 1.* Forestry Research Center, Addis abeba.

FAO. 1979. *Assistance to Forestry Research, Phase I, Ethiopia: Project Findings and Recommendations.* FAO, Rome.

FAO. 1983. *Assistance to Forestry Research, Phase II, Ethiopia: Project Findings and Recommendations.* FAO, Rome.

FAO. 1988. *The Eucalypt Dilemma.* Food and Agriculture Organization of the United Nations, Rome.

Gebrekidan Teklu. 1997. *Above-Ground Biomass of Eucalyptus saligna Coppice Trees, A Case Study from Munessa-Shashemene, Oromia Region, Ethiopia.* MSc thesis, Swedish University of Agricultural Sciences, Skinnskatteberg.

Feyera Senbeta. 1998. *Native Woody Species Regeneration under the Canopy of Tree Plantations at Munessa-Shashemene Forest Project Area, Southern Oromia, Ethiopia.* MSc thesis, Swedish University of Agricultural Sciences, Skinnskatteberg.

Fichtl, R. & Admasu Adi. 1994. *Honeybee Flora of Ethiopia.* Margraf Verlag, Weikersheim.

Friis, I. 1992. Forests and forest trees of Northeast Africa. Kew Bulletin Additional Series XV: 1-383.

Friis, I. 1995. Myrtaceae. In Edwards, S., Mesfin Tadesse & Hedberg, I. (eds.), *Flora of Ethiopia and Eritrea, Vol. 2 (2).* Addis Abeba University, Addis Abeba & Uppsala University, Uppsala, pp. 71-106.

Friis, I. & Michelsen, A. 1996. Selection of Appropriate Species and Management Methods in Tree Planting: Case Studies from Ethiopia. In Reenberg, A., Marcussen, H.S. &


CRDA

Nielsen, I. (eds.), *Proceddings of the 8th Danish Sahel Workshop*. Sahel-Sudan Environmental Research Initiative, Copenhagen, pp. 101-117.

Gebre Markos Wolde Selassie. 1998. The Forest Resources of Ethiopia: Past and Present. *Walia* 19: 10-28.

Geldenhuys, C. J. 1997. Native Forest Regeneration in Pine and Eucalypt Plantations in Northern Province, South Africa. *Forest Ecology and Management* 99: 101-115.

Hedberg, I. and Edwards, S. (eds.). 1989. *Flora of Ethiopia. Vol. 3*. The National Herbarium, Addis Ababa and Uppsala University, Uppsala.

Horvath, R. J. 1969. The Wandering Capitals of Ethiopia. *Journal of African History* 10: 205-219.

Kidane Woldu. 1998. *Natural Regeneration of Juniperus procera Hochst. in Eucalyptus globulus Labill. Plantation*. MSc thesis, Swedish University of Agricultural Sciences, Skinnskatteberg.

Lisanework Nigatu & Michelsen, A. 1993. Allelopathy in Agroforestry Systems: the Effects of Leaf Extracts of *Cupressus lusitanica* and Three *Eucalyptus* spp. On Four Ethiopian Crops. *Agroforestry Systems* 21: 63-74.

Lisanework Nigatu & Michelsen, A. 1994. Litterfall and Nutrient Release by Decomposition in Three Plantations Compared with a Natural Forest in the Ethiopian Highland. *Forest Ecology and Management* 65: 149-164.

Mebrate Mihretu. 1983. Assessment of Species Trials. *Research Note No. 2*: 1-23.

Mebrate Mihretu. 1992. The Regeneration of *Juniperus procera* in *Eucalyptus globulus* plantations. *FRC Newsletter* 3 (1-3): 2-3.

Mebrate Mihretu. 1993. Research in Silviculture at the Forestry Research Center: Past, Present and Future Programmes. In Berhanu A. G. (ed.), *proceedings of the National Workshop on Setting Forestry Research Priorities in Ethiopia*. Forestry Research Center, Addis Abeba, pp. 12-23.

Michelsen, A., Lisanework Nigatu & Friis, I. 1993. Impacts of Tree Plantations in the Ethiopian Highlands on Soil Fertility, Shoot and Root Growth, Nutrient Utilization and Mycorrhizal Colonization. *Forest Ecology and Management* 61: 299-324.

Michelsen, A., Lisanework Nigatu, Friis, I. & Holst, N. 1996. Comparison of Understorey Vegetation and Soil Fertility in Plantations and Adjacent Forests in the Ethiopian Highlands. *Journal of Applied Ecology* 33: 627-642.

Negash Mamo, Berhane Habte & Dawit Beyan. 1995. *Growth and Form Factor of Some Indigenous and Exotic Tree Species in Ethiopia*. Forestry Research Center, Addis Abeba.

Parrotta, J. A., Turnbull, J. W. & Jones, N. 1997. Catalyzing Native Forest Regeneration on Degraded Tropical Lands. *Forest Ecology and Management* 99: 1-7.

Persson, A. 1995. Exotics – Prospects and Risks from European and African Viewpoints. *ICEL. AGR. SCI.* 9: 47-62.

Pohjonen, V. 1989. Establishment of Fuelwood Plantations in Ethiopia. *Silva Cerelica* 14: 1-388.

Pohjonen, V. & Pukkala T. 1988a. *Nazret Fuelwood Plantation Forest Management Plan for 1989-1994*. United Nations Sudano-Sahalian Office, Addis Abeba.

Pohjonen, V. & Pukkala, T. 1988b. Profitability of Establishing *Eucalyptus globulus* Plantations in the Central Highlands of Ethiopia. *Silva Fennica* 22: 307-321.

Pohjonen, V. & Pukkala, T. 1990a. *Eucalyptus globulus* in Ethiopian Forestry. *Forest Ecology and Management* 36: 19-31.

Pohjonen, V. & Pukkala, T. 1990b. Which *Eucalyptus* Grows Best in Ethiopia. *Biomass and Bioenergy* 1: 193-195.

Poore, M.E.D. & Fries, C. 1985. *The Ecological Effects of Eucalyptus*. FAO Forestry Paper Series 59, Food and Agriculture Organization of the United nations, Rome.

ICRAF

Pukkala, T. & Pohjonen, V. 1988. *Debre Birhan Fuelwood Plantation Forest Management Plan.* United nations Sudano-Sahalian Office, Addis Abeba.

Pukkala, T. & Pohjonen, V. 1989. *Yield Models for Ethiopian Highland Eucalypts.* United Nations Development Programme, Addis Abeba.

Pukkala, T. & Pohjonen, V. 1990a. Yield Models for *Eucalyptus globulus* Fuelwood Plantations in Ethiopia. *Biomass* 21: 129-143.

Pukkala, T. & Pohjonen, V. 1990b. Use of Linear Programming in Land Use Planning in the Ethiopian Highlands. *Silva Fennica* 24: 235-247.

Shaolin, P., Wei, F., Cao, H.L., Yu, Z.Y., Li, Z.A., Yi, W.M. & Hei, R. 1996. Influence of Human Disturbance on Tropical Artificial *Eucalyptus* Forest Ecosystems. In Anonymous (ed.), *Abstracts of the Symposium/Workshop on Accelerated Native Forest Regeneration on Degraded Tropical Lands.* IUFRO-World Bank-USDA Forest Service, Washington. p22.

Teferi Haile. 1961. Menelik Zaf. *Ethiopian Forestry Review* 2: 41.

Tsegaye Bekele. 1996. *Utilization of Sawn Boards From Young Eucalyptus Plantation Timber Grown in Ethiopia.* PhD thesis, Swedish University of Agricultural Sciences, Uppsala.

Turnbull, J. W. 1999. Eucalypt Plantations. *New Forests* 17: 37-52.

von Breitenbach, F. 1961. Exotic Trees in Ethiopia. *Ethiopian Forestry Review* 2: 19-38.

von Breitenbach, F. & Koukol, J. 1962. Menagesha State Forest: A Description of the Forest, its Management and its Future Development Including the National Park. *Ethiopian Forestry Review* 3 / 4: 17-34.

von Breitenbach, F. 1962. National Forestry Development Planning, A Feasibility and Priority Study on the Example of Ethiopia. *Ethiopian Forestry Review* 3 / 4: 41-68.

von Maydell, H.-J. 1986. *Trees and Shrubs of the Sahel: Their Characteristics and Uses.* GTZ, Eschborn.

Wolde Michael Kelecha & von Breitenbach, F. 1961. Savannah Afforestation. *Ethiopian Forestry Review* 2: 43-51.

Wood Utilization and Research Center (WUARC). 1995. Commercial Timbers of Ethiopia. *Research Report - Technical Bulletin No. 2.* 1-110.

Yitebetu Moges. 1998. *The Role of Exotic Plantation Forests in Fostering the Regeneration of Native Trees in an Afromontane Forest Area in Ethiopia.* MSc thesis, Wageningen Agricultural University, Wageningen.

Örlander, G. 1986a. *Growth of Some Forest Trees in Ethiopia and Suggestions for Species Selection in Different Climatic Zones.* Swedish University of Agricultural Sciences, Umeå.

Örlander, G. 1986b. *Volume Tables for Ethiopia.* Swedish University of Agricultural Sciences, Umeå.

CRDA

# ECOLOGICAL IMPACTS OF *EUCALYPTUS* PLANTATIONS IN ETHIOPIA

By

LISANEWORK NIGATU (PH.D.)

ALEMAYA UNIVERSITY OF AGRICULTURE,
P.O. BOX 138, DIRE DAWA, ETHIOPIA.

CCRDA

A REVIEW PAPER TO BE PRESENTED ON "EUCALYPTUS DILEMMA" WORKSHOP, NOV. 15, 2000, GHION HOTEL, ADDIS ABABA, ETHIOPIA.

October, 2000
Alemaya University

## TABLE OF CONTENT


Page

**SUMMARY** ..... III

**1. INTRODUCTION** ..... 1

**2. EUCALYPTUS TAXONOMY AND GENETICS** ..... 2

2.1. Problems of Identifying Eucalyptus ..... 2
2.2. The Genetic Material used in Eucalypts Plantings ..... 3

**3. THE USE OF NUTRIENTS BY EUCALYPTS** ..... 4

3.1. Adaptation of the Eucalypt to low nutrient soils ..... 4
3.2. The nutrient cost of harvesting fast growing eucalyptus stand ..... 5
3.3. The nutrient cost on high quality or fertilised sites ..... 6
3. 4. The nutrient cost of removing litter from the site ..... 7
3.5. Indirect losses of nutrients ..... 8
3.6. Discussion of site nutrients ..... 9

**4. THE EFFECT OF THE EUCALYPTS ON THE BIOLOGICAL** ..... 9

**CONDITION OF THE SOIL** ..... 9

**5. THE USE OF WATER BY EUCALYPTS** ..... 12

5.1. The use of water by the eucalypts ..... 12
5.2. Factors affecting water use ..... 14
5.3. Water use efficiency ..... 15
5.4. Discussion of water use ..... 16

**6. CONCLUSIONS** ..... 17

**7. REFERENCES** ..... 19


CCRDA

## Summary

The planting of eucalyptus is perceived in Ethiopia, as elsewhere in some countries, to have undesirable environmental consequences. These relate mainly to the way the eucalypt uses water and nutrients and otherwise affects the soil condition. This paper explores the basis of some of these concerns. As a prelude, the nature the genetic material in *Eucalyptus* and the potential for more effective use of that material in planting programmes in Ethiopia is critically examined.

There are five main conclusions:

I The remarkably wide range of genetic material in Eucalyptus has not been adequately tapped in species introduction programs.

II With careful husbandry, the eucalypts is capable of producing wood at a lower nutrient cost than many other fast growing tree species.

III Some observed effects of eucalyptus, growing drier climate, on the soil condition might be attributed to higher production of allelopathic substances combined with the stress of direct soil moisture deficit.

IV In contrast to the frequent view of eucalyptus as suppressive for understory plants in highland Ethiopia, the biological diversity, cover and biomass of herbaceous plant species in plantation of *Eucalyptus spp.,* has been observed to be similar to the adjacent natural forests and higher than those under *Cupressus* and pine plantations.

V With careful species selection and management practices based on understanding of natural succession and nutrient cycling processes, Eucalypts plantations established in humid wetter Ethiopian highlands are a promising tool for rehabilitation of degraded lands.

VI Where trees replace grasslands or a low natural vegetation, a reduction in water yield from Catchment should be expected. Where eucalyptus are planted, high rates of wood production will be matched by high rates of water use- but whether the water use efficiency declines to any appreciable degree under some environmental conditions can not be determined from the available evidence.

VII In drier regions, particularly, it may be necessary to determine the eucalyptus species and patterns of land use which will be best meet the objectives of land management and avoid undue social conflict.


CCRDA

## 1. INTRODUCTION

Eucalypts have been planted in countries other than Australia for nearly 200 years The initial cultivation of eucalyptus were to satisfy curiosity or for ornamental purposes, firstly in England and later in many other temperate and tropical countries (Florence,1981).. Soon it was realised that the fast growth of some species made them likely for other purposes, e.g. poles, firewood and shade. This eventually led to small managed plantations in the late 19$^{th}$ and early 20$^{th}$ centuries. One such outstanding example was the introduction of eucalypts to Ethiopia, in 1895 by a French philologist named Mondon-Vidallet,(Horvath, 1968; Friis, 1995) at a time when the residents of Addis Ababa were desperate for a solution to wood- shortage problem.

The initial eucalypts planting trials in Ethiopia consisted of a number of species from Australia:*E. amygdalina ,E. bicolar* now ( *E. largiflorens,*) *E. camaldulensis, E. caldocalyx, E. cornlatal, E. diversicolor, E. globulus, E. incrassata, E. leucoxylon, E. milliodora, E. patens, E. resinifera, E. rudis.* ( similar with *E. terticornis), E. salburis,* and *E. terticornis* are listed by Von Breitenbach (1961*).* Most of these species did not perform well under the local conditions, and at first only *E. camaldulensis* and *E. globulus* were really successful in cool highlands around Addis Ababa (Lisanework,1994; friis, 1995).

At present, the most widely planted species of *Eucalyptus* are probably, *E. camaldulensis, E. citrodora, E. globulus sub sp. globulus, E. grandis, E. regans, E. saligna and E. tereticornis.* Eucalypts plantation in Ethiopia developed majorly in the highlands, at altitudes over 1500 m. and receiving favourable rainfall between 700-2,000mm per annum (Pohjonen,1989). Many other species have been planted as ornamentals, in arboreta (tree- collection), in trial plots, or in pilot plantations on a comparatively small scale.

The eucalypts in Ethiopia are mainly grown with primary objective of increasing the supply of fuel wood, timber and construction materials both in large scale plantations and in small woodlots. Extensive eucalypts plantations have been developed mainly after the removal of slightly disturbed natural forest or, occasionally, of secondary forest and degraded forestlands, presumably involving manual labour only. They are also planted as shelterbelts in farmlands, and to form shady groves in and around villages, churches and other dwellings.

The Eucalypts plantations in Ethiopia and elsewhere, are managed on coppice rotation a silvicultural method which generally places a high demand on nutrient and water resources of the soil (Miller, 1986;Michelsen et. al., 1996). Despite the contribution of eucalypts to the economic and social well being of people, there has been concern expressed in recent years about the social and environmental consequences of planting the species. There is a well- publicised campaign against eucalypt plantations in India (Shiva & Bandyopadhgay, 1983) and in other countries; and in Spain an organization promoting the use of native trees is called the "phoracantha club" in praise of a bark beetle which kills the exotic eucalypt (Madeira, 1989).

There are both positive and negative arguments for planting eucalypts. On the positive side it is recognized that eucalypts have many advantages for both small and large

ICRDA

operations, particularly their fast growth rates, resistance to grazing and ability to coppice, supply of a range of wood products in high demand, and the significant contribution they can make to farm incomes. Alternatively, the planting of eucalypts has been criticised because it is claimed that the soil will be degraded through enhanced erosion, nutrient depletion and biological changes; that the established plantation affects the diversity of the underlying vegetation and the performance of cultivated crops adjacent to the plantation through reduced water availability; and that when planted in semi-arid water catchment areas, total water yields will be substantially reduced. Similarly, the anxiety that eucalypts may have a deteriorating effect on the environment is growing also in Ethiopia.

While it is evident that any comprehensive evaluation of eucalypts being planted in this country will involve cinsiderations of many ecological, economic and social questions, the presented review is primarily concerned with ecological component of the problem. In addressing that problem it is essential to examine not only the influence of the eucalypt on its environment but also the puestion of species material currently used in Ethiopian plantation forestry. It is possible some ecological effects of growing eucalypts may be modified by changes to silvicultural and cultural practices, and by drawing on a wider range of environmentally- adapted species and provenances. There is within *Eucalyptus* a remarkably wide range of genetic material, and this might be tapped to provide trees with growth and physiological characteristics most appropriate to specific soils and land use patterns.

CCRDA

## 2. Eucalyptus Taxonomy and Genetics

While eucalypts have been introduced to many countries in the world, the basis of introduction has frequently been poor in terms of the number, range and identity of species tested, and the breadth of the original genetic base (seed from few trees usually from a single point species range). Moreover, mixing of species in arboreta and plantations has led to hybridisation, and this to high variability and loss of vigour when seed from such stands was harvested and used to extend eucalypts plantings. Thus, there are two main problems of taxonomy and genetics: that of correctly identifying the species which have been or are being planted and the nature of the genetic materials currently being used in many planting programmes.

### *2.1. Problems of Identifying Eucalyptus*

Identification of the many eucalyptus species introduced in tropical Africa, including Ethiopia, has been difficult for long mainly due to inadequate and reliable information about the taxa from early introductions. For example, due to misidentification problems of the seed source, the *E. grandis* plantation were wrongly referred to by many foresters and botanists as *E.saligna (Pohjonen,1989).* Until recently, few foresters or taxnomists know the salient identification points of many species, and mostly rely on the label information, if available any. The problem of identification of eucalyptus species is further complicated by hybridization which masks or distorts many of the key characteristics used in species identification. According to Friis (1995), identification of Eucalyptus species planted in Ethiopia has been unsuccessful for long due to disparities of the features of the species in plantation with those

description given based on characters found in natural populations. Hybridization is a very common phenomenon in the genus and hybrids have appeared in the plantation, which by virtue of thier natural habitats are quite unknown in the wild in Australia. It is possible to find in Eucalyptus plantations that trees marked under the name, *E. camaldulensis* are not a pure species but hybrids with other eucalyptus; such as *E. tereticornis* (Pohjonen,1989). Yet, the problem of identification can be compounded when literature is often scant and few but unavailable for most in country keys to identification have been devised.

### *2.2. The Genetic Material used in Eucalypts Plantings*

It is evident that for the success of eucalypts plantation programmes seeds of the best genetic quality must be obtained in large quantities and as cheaply as possible. These seeds must carefully be collected from the natural stands or locally, from plantations established for this purpose. Contrary to this, the eucalypts plantation has been carried out with seeds of genetically and physiologically inferior quality. Use of inbred and hybrid seeds or seed of unknown parentage and genetic history have been common in the Ethiopian plantation forestry (Aalbaek, 1993). The haphazard and mostly undocumented early introduction of the *Eucalyptus* species in Ethiopia and the current seed collection practices often strengthen the problem of genetic material, i.e. seed source, in the planting programmes.

For example, the early introduced seeds of euclypts may have been likely obtained from seed suppliers elsewhere in Africa or the Mediterranean than from country of origin (Davidson, 1989; Friis, 1995). Seed transfer from one country to another often suffer from lack of adequate collection supervision with seed coming from hybrid plantations, road side stands, arboreta, or stands of unknown origin and limited genetic base. The imported seeds have often been viewed in terms of their availability in large quantities and the concomitant cheaper price to purchase the seeds. In Ethiopia eucalypts seeds, notably, that of *E. globulus* and *E. camaldulensis* are collected from mainly individually identified mature trees (but not specially selected good genetic quality) occurring along roadsides and arboreta. Information on the origin and size of the base population, genetic quality of the parent trees, possibilities of inbreeding depression, etc. may not be known with regards to such collections. The collected seed most likely of inferior quality. For instance, the *E. camaldulensis* planted from these seedling seed stand did not perform up to expectations because of the inadequate genetic base and effects of inbreeding and uncontrolled hybridazation in the source collections (Davidson, 1989). Even those planted in dry lowland zones of the country did not show remarkable growth performance (Pohjonen, 1989).

To counter this narrowing of the genetic base that result in inferior seed quality there should be a need to introduce provenances of the eucalypts in line with the end use and maintain them in an *ex-situ* gene conservation area of genetic archives. This will develop in land race as freely interbreeding population and at intervals replanting be forwarded using bulk collections of seed representing all the trees in the population, not just the best one.

When eucalypts are taken from their natural habitat and introduced to a new environment, it is necessary to select a species which is well adapted to the new environmental conditions. Detailed information on the biogeography, ecology,

CERDA

silviculture, and utilization of the more commonly planted eucaltpts have now been documented in several publications: Pryor and Johnson (1981), Florence(1981), Ovington and Pryor(1983), etc. As the early introduction of the genus to Ethiopia, often involved limited number of species, there may well be merit in reviewing the species in use where problems of poor adaptation, unacceptable ecological effects, or unsuitable produce have become evident.

The information ton the potential of many species in plantation is continually improving, and consequently it is always possible to identify species for use as plantation crops (Florence 1981). The key steps are choosing and using the correct provenance of the species selected, obtaining an 'adequate' base population of that provenance, minimising the influence of inbreeding which will often be present in a natural population from a small geographic range and then planning a seed production regime which takes advantage of this base and any further selection which is possible, but which avoids uncontrolled hybridisation. Given qualified expertise and technical resources available and the scale of the planting is adequate to warrant the effort, it is possible to undertake more complex breeding strategies offering high rates of improvement in sustaining productivity.

## 3. THE USE OF NUTRIENTS BY EUCALYPTS

### *3.1. Adaptation of the Eucalypt to low nutrient soils*

It may appear to be something of a paradox that the eucalypt can make a productive forest on nutritionally impoverished soils, yet attract a reputation for excessive site nutrient depletion on others. In seeking to resolve the latter question, we might begin by addressing the former.

It is now accepted that *Eucalyptus* was a response to several powerful selection pressures from about the mid-Tertiary, associated with continental drift. There were declining soil fertility associated with massive soil erosion, leaching and subsequent laterisation, a rapidly drying climate, and fire, possibly in this order (Pryor, 1976; Florence, 1981).

There may be no single attribute which enables the eucalypt to grow into a tall-boled, long lived tree on poor soils. Rather many attributes may be involved including an extensive root system; access to some of the nutrient in highly weathered soils which may not be so readily available to other tree species: a fine mycorrhizal root system enhancing the uptake of soil phosphorus and other nutrients; a capacity to take up nutrients when available in the soil , to conserve them within the biomass, and utilise them over an extended period; and through efficient internal cycling of nutrients, a capacity to make use of a limited nutrient pool within the biomass(Bowen,1981; Florence 1981, Lisanework and Michelson, 1993). While there is supporting evidence for each of these concepts it is recognised the need to better establish the physiological processes and plant-soil relationships contributing to the growth of eucalypts on poor soils.

The eucalypts adaptation to low nutrient soils should not be taken to mean that the eucalyptus can grow rapidly on such soils, or that a fast growing eucalyptus stand will be appreciably less demanding of soil nutrients under all circumstances. Within the

CORDA

native eucalypt forests, vegetation patterns reflect, in part, the way species differ in adaptation to, or ability to compete on infertile soils; euclypt species may be seen to occur along a vegtational gradient associated with a gradient from high to low soil fertility (Florence, 1981).

It is no surprise, then, to find that many of the faster growing species, including those which have been most successful as exotics, are more characteristic of the higher fertility end of the edaphic and vegetation gradients. Thus in examining the way fast growing eucalypt forests use soil nutrient, the concern is with those species which can respond more positively than others, to more fertile soils Bowen, 1981; Poor & Fries, 1985).

### *3.2. The nutrient cost of harvesting fast growing eucalyptus stand*

The amount of soil nutrient removed from a plantation site at harvest will depend on
(i) The concentration of nutrients within the various components of the biomass and,

(ii) The extent of utilisation of the biomass (that is, whether stem wood only, stem wood plus bark or the whole tree is harvested). Where there are successive rotations it will also depend on the rate of biomass changes with stand age. If the forest floor litter is removed regularly, this will entail a further, and sometimes substantial drain on the soil nutrient reserve. It will be necessary to take account of all these factors in evaluating the effect of a eucalypt planting regime on the long term nutrient supplying capacity of soil.

During a plantation early growth phase, the rate of biomass production, nutrient uptake and the concentration of nutrients within the biomass will be greater than in subsequent growth phases. As the stand develops and the proportion of stemwood in the biomass increases, the rate of biomass production and nutrient uptake will decline. The average concentration of nutrients will also decline as nutrients are redistributed within the biomass. Within the developing eucalypt stand, redistribution will involve an efficient withdrawal of nutrients from the wood as heartwood begins to form.

Heartwood formation begins at about age 7 in eucalyptus (Raison *et al* 1982) but may be earlier under some conditions. Ferreri et. al. (1984) attribute a rapid decline in stemwood phosphorus concentration in *E. grandis* to heartwood formation as early as 38 to 51 months after planting. Trees sampled 51 months on a good quality site had an average concentration of 6.4 ppm in the heartwood at the stem base, compared with a sapwood concentration of 71 to 121 ppm. This represents a withdrawal of 91 to 95 percent of phosphorus at heartwood, formation.

A number of studies have shown that the proportion of sapwood in the bole (wood and bark ) decreases faster with tree age in the eucalypt than in pine and efficient withdrawal of nutrients can be observed at heartwood formation; suggesting that the nutrient cost of producing eucalypt wood should be appreciably less than that producing pine wood. For example, Crane and Raison (1980) estimated the quantities of phosphorus which would be removed per unit weight of wood (stemwood plus bark) from the stands of *Pinus radiata* at 18 years (clear felling) and 40 years (final harvest plus thinning); and from natural stands of commercial quality *E. delegatensis* forest at 18 years (pulpwood) and 57 years (sawlogs).

CSIRO

The 40 year old *Pinus radiata* stand produced commercial wood faster than the 57 year old *E.delegatensis* forest (Table 1); it also contained three time the amount of phosphorus per tonne of harvested wood. When the greater rate of wood production in the *Pinus radiata* stand is taken into account, 4.5 times as much phosphorus is removed per hectare per 100 years by growing *Pinus radiata* on a 40 year rotation than by growing *E. delegatensis* on a 57 year rotation. Other estimates of the amount of phosphorus removed per tonne of wood in harvesting boles from *eucalypt* and *Pinus radiata* stands are given in Table 2 ( data summarised from Crane and Raison, 1980). While these data do not take rate of commercial wood production into account they again confirm the lower nutrient cost of producing eucalypt wood, and the substantial reduction in the cost through larger rotations. However, on a very, short rotation the nutrient cost of producing eucalypt wood may be similar to that for other species.

Table 1 Comparison of the nutrient cost of growing a *Pinus radiata* stand and *E. delegatensis* stand (from Crane & Raison, 1980)

| | *P.radiata* | | *E.delegatensis* | |
|---|---|---|---|---|
| Rotation length | 18 | 40 | 18 | 57 |
| Volume harvested (m3/ha) | 345 | 911 | 220 | 740 |
| Concentration of P in stemwood +bark (gP/tonne) | 258 | 169 | 87 | 51 |
| Rate at which P is removed( Kg/ha/100 years) | 214 | 197 | 73 | 44 |

Table 2 Phosphorus removal (g P per tonne of wood) when harvesting *Eucalypt* and *Pinus radiata stands*.

| | *P. radiata* | *Eucalyptus* species |
|---|---|---|
| Stand age | | |
| STAND<10Yr. | | |
| No estimates | 3 | 4 |
| Mean P/g/ton wood removed | 246 | 145 |
| Range in P | 207-313 | 89-179 |
| STAND >10Yr | | |
| No. estimates | 6 | 7 |
| Stand age range | 12-40Yr | 18-66 Yr |
| Mean P(g/ton wood removed) | 162 | 59 |
| Range in P | 93-258 | 43-87 |

### *3.3. The nutrient cost on high quality or fertilised sites*

Where eucalypts are grown on more fertile soil or where fertilisers are applied, there will be an increase in the rate of biomass production, but the efficiency of use of phosphorus in producing that biomass might be reduced. Ferreira et. al. (1984) show that at around 70 months, the concentration of phosphorus in the stemwood of *E.grandis* growing on a poor site was about 70% of that on a good site (Table 3), that is, trees on the poor site are more efficient in terms of biomass produced per unit of

CCRDA

phosphorus used. The phosphorus on the poor site suggests there was little opportunity for 'luxury uptake' of phosphorus in the early years and its storage in the wood. Nevertheless, as heartwood began to form on the poor site, there was a sharp redistribution of stemwood phosphorus; beyond 43 months, the sampled trees contained 3.2 ppm of phosphorus in the heartwood and 83 to 132 ppm in the sapwood, representing a withdrawal of 96 to 98% of heartwood phosphorus. It is the extent of translocation of phosphorus which must be contributing to the high efficiency of phosphorus usage of eucalyptus growing on poor soils.

Table 3. Stemwood phosphorus in *E. grandis* growing on good and poor sites (From Ferreira, Kimmins and Barros, 1984).

| **Good quality site** | | **Poor quality site** | |
|---|---|---|---|
| Age (months) | gP/tonne biomass | Age(months) | gP/tonne biomass |
| 15 | 294 | 21 | 75 |
| 26 | 206 | 32 | 75 |
| 38 | 195 | 43 | 74 |
| 51 | 111 | 56 | 74 |
| 62 | 113 | 67 | 73 |
| 73 | 116 | | |

There can also be a greater nutrient cost in producing wood where fertilisers are used. In a 9.5 year old *E. globulus* plantation fertilisation produced a three fold increase in wood production (Raison et. al., 1982 using data from Cromer et. al., 1980). While there was little change in the amount of nitrogen used to produce a unit weight of wood (Table 4), the addition of phosphorus supply was used much less efficiently. There was close to a 50 % increase in the amount of phosphorus used to produce a tonne of stemwood plus bark in the fertilised stand (from 89 to 135g /tonne) but only an 8% increase in the amount of phosphorus used to produce the full tree ( stemwood, bark and crown). This suggests the 'unused' phosphorus being taken up and stored within the stemwood and bark of trees in the fertilised stand.

Table 4. Nutrient cost of biomass production in fertilised and unfertilised stands of *Eucalyptus globulus*.

| | **Biomass (tonnes/ha)** | **Nitrogen (g/tonne)** | **Phosphorus (g/tonne)** |
|---|---|---|---|
| Stemwood and Bark | | | |
| *unfeftilised* | 19.2 | 1042 | 89 |
| *fertilised* | 58.4 | 1062 | 134 |
| Full tree | | | |
| *unfertilised* | 31.2 | 2212 | 157 |
| *fertilised* | 83.3 | 1837 | 169 |

### *3. 4. The nutrient cost of removing litter from the site*

In many tropical countries the eucalypt forest litter is removed regularly and utilised in a number of ways. This can add appreciably to the nutrient cost of the eucalypt

CSIRO

plantation. The amount of nutrient removed from the site will depend on species, site quality and the regularity with which the litter is harvested.

Some two thirds of the gross annual nutrient uptake is returned to the soil in litter (Lundgren, 1978; Lianework & Michelsen, 1994). Estimates of annual litter fall in eucalypt plantations range from about 5 to 8 ton/ha/yr: the amount of phosphorus contained in the litter from 1 to 3 Kg/ha, and nitrogen from 20 to 50 Kg/ha. The annual litterfall (5.83 ton/ha/yr) and the subsequent nutrient release by decomposition in *E. globulus* were higher than *Cupressus lustanica stand (5.01 ton/ha/yr).* Litterfall in the natural forest amounted to be 10.9 ton/ha/yr but had slower rate of decomposition and nutrient release compared to *E. globulus* stand investigated in Menagesha, Ethiopia (lisanework & Michelsen, 1994). A similar annual litterfall and nutrient release pattern have been documented in plantations of tropical Africa (Lundgren, 1978). Assuming little or no return of nutrient to the soil before litter removal, and taking account of periodic stand re-establishment phase, it is conservatively estimated that the nutrient cost to the site of litter removal could be the order of 50 to 150 Kg P/ha/100 yr, and 1000 to 3000 kg N/ha/100 yr (Florence 1981). Thus the phosphorus cost of litter removal from an euclypt forest stands would be at least equal to and probably greatly in excess of that of harvesting stemwood ( Table 1).

### *3.5. Indirect losses of nutrients*

So far the nutrient cost of growing eucalypt plantation has been considered only in terms of the direct export of nutrients in harvested biomass. However, nutrient losses from the site as a result of disturbance during harvesting and site preparation for replanting may again exceed those for biomass harvesting.

The scale of indirect nutrient losses has been reviewed by Raison (1984). Some of the conclusions follow:

I Loss or displacement of soil during harvesting and site preparation can reduce site productivity appreciably. Removal of about 1 cm depth of soil exports about the same quantity of nutrients as is removed in a single harvest of biomass surface soil also usually has superior properties which enhance root growth.

II Where an intense slash fire is used to remove logging slash, large volatile losses of carbon, nitrogen and sulphur occur from the fuel and sometimes from the surface soil. For *Pinus radiata* 420 to 920 Kg/ha/yr can be lost in this way, a quantity equivalent to or exceeding that removed in the harvested biomass. The potential also exists for greater loss of phosphorus by volatilisation and export of ash than would have been removed in harvested biomass.

III Clearcutting of vegetation increases the rate of nutrient mineralisation in soil; it also removes the vegetation which is a sink for both water and nutrients. As a result, increased leaching losses of nitrogen, potassium, calcium and magnesium are likely. These losses will be much greater where intense fires have been used to dispose of slash, especially on sandy soils.

CCRDA

### *3.6. Discussion of site nutrients*

For any plantation species, the nutrient cost of harvesting boles may not cause any significant short-term depletion of the soil nutrient pool on a fertile site, even where the biomass production is rapid. Alternatively, where a soil is less fertile, and particularly where a high proportion of the total nutrient pool is unavailable for plant uptake (as is the case for phosphorus in a highly weathered soil), an appreciable proportion of labile ecosystem nutrients may be located within the biomass. For example, there is almost as much phosphorus within the biomass of a dry sclerophyll (open or low open) *E. marginata* forest as there is "available phosphorus" in the soil to 1m. depth (Hingston et al 1980). In this case, the measure of available phosphorus has been based on analytical techniques developed for agricultural crops and may not be relevant to forest trees , particularly the eucalypt. Nevertheless, it could be expected that continuing short rotation bole wood cropping would reduce the soil nutrient reserve to the stage where growth of the tree is decreased.

Against this general background, the important point to emerge from the information presented here, is that the eucalypt is unlikely to deplete the soil nutrient reserve any more rapidly than any other tree species producing wood at a comparable rate. Moreover, with careful husbandry, the eucalypt is capable of producing wood at a lower, and sometimes substantially lower nutrient cost. Careful husbandry could involve adoption of longer rotations (at least 20 to 30 years), prohibition of the removal of litter, avoiding the use of fuel-reduction and slash burning, in corporation of the use of legumes in the cropping cycle, and operational practices designed to minimise soil erosion and other nutrient losses. Alternatively, where a low to moderately fertile site is subject to short rotation cropping (eg. 10 years), litter is removed and environmental standards at harvesting are poor site nutrient depletion could be expressed in decreased site productivity within a few rotations.

CCRDA

## 4. THE EFFECT OF THE EUCALYPT ON THE BIOLOGICAL CONDITION OF THE SOIL

Another of the beliefs about the eucalypt is that it can render the soil unfavourable in some way to growth of other plants, for example, by directly inhibiting understorey species or crop plants being grown in the vicinity of a eucalypt stand. It is also said that where a eucalypt stand is harvested, and replaced by an agricultural crop, that crop will not do well, at least for a number of years.

The impacts of eucalypt on the ground vegetation depend very much upon the climate and edaphic factors. In drier climate where the fast growing eucalypt are planted on soils of reduced fertility, it is likely that the stand may exhibit strong competition for soil's nutrients and water. For example, the drought tolerant eucalypt may maintain transpiration under developing drought, dry out the surface soil, and subsequently depend on survival and growth on tapping water at depth. As mentioned earlier, the low nutrient soils adaptive attributes of eucalypt may also favour its strong competitive ability to exploit effectively the available nutrient resources of the soil. Unless understorey species or adjacent crop plants are particularly adapted to drought

they may succumb under these conditions.

It has also been suggested that the *Eucalyptus* can affect other plants more directly through the inhibitory effects of leaf, litter and root exudates, or through the effect of litter incorporation on nutrient mineralization and the soil micro flora. What evidence is there on this?

The eucalypt has been suspected of interference through allelopathy, the direct or indirect effect of one plant on another through the production and liberation of chemical compounds in to the environment (Rice 1984). The presence of inhibitory compounds, allelochemicals, such as phenolics, terpenoids and flavinoids have been identified from leaves, roots exudates or residual parts of eucalypts (Singh 1991; Lisanework & Michelsen 1993). Allelopathic interferences with these inhibitory chemicals are reported to be more significant in soils of low fertility or during periods of low fertility (Stowe & Osborn 1980) and under conditions of soil moisture stress (Inderjet & del.Morals 1997). Further more, it has been shown that eucalypts grown under deficient nutrient conditions and drought produce more allelochemicals in their tissues than those growing in soils with adequate moisture and fertility conditions (Inderjit & Dakshini 1995). The allelochemicals may when adsorbed to soil particles, retain activity and inhibit germination of seeds and the ensuing radicle elongation (Singh et. al. 1991). The bioassay study conducted by Lisanework and Michelsen (1993) using leaf-extracts *of E. globulus, E. camaldulensis and E.saligna* demonstrated that seed germination and radicle growth were affected to higher extent by increasing the concentration of the allelochemicals. A similar negative effects were observed on a range of bioassay plants growing on soils collected from under the canopy of the Ethiopian eucalypt plantations (Michelsen, et al 1993;1996). It can be safely said that the allelopathic effects could be more pronounced in areas where rainfall is low or erratic and thus insufficient to dilute phytotoxin substances by run-off or leaching from the top soil.

Allelopathic effects in natural systems are to a larger extent than laboratory experiments subjected to mitigation or intensification by physico-chemical characteristics of the soil and the microbial activity (Harborne,1988). It is thus not easy to relate results from bioassay studies with leaf extracts and soil to processes in the plantation forests and agroforestry systems. However, the information presented in here and the field observation made for the presence of very few undergrowth vegetation cover strongly suggest that allelopathic substances from eucalypt affect some herbaceous plants and crops adjoining shelterbelts and consequently may reduce the farmer's benefit from planting eucalypts. Accordingly, in drier regions where eucalypt is planted as shelterbelt it has been recommended that a 5-7m wide stretch of land be left next to eucalypt belt uncultivated (Singh & Kohli, 1992).

Undergrowth vegetation cover composed of graminoids and forbs have been encountered under the canopy of eucalypt plantation forests in the Ethiopian highland. In humid and wetter climates, ground vegetation in plantations are less affected than those experiencing drier conditions (Poore and Fries, 1985). Observations into the plantation forests established at Belete, North facing slopes of Entoto, Menagesha-Suba and Degaga are evidences for th regeneration of native forest species such as *Juniperus procera, Prunus africana, Podocarpus fulcatus, Acacia abyssinica, Carrisa edulis. croton machrostachys, Olea spp.* etc under Eucalyptus canopy. It has been

CCRDA

suggested that old Ethiopian plantations in the long run might undergo succession in which the indigenous species regenerating there establish and ultimately replace the exotic plantation species (Pohjonen & Pukkala, 1990). In contrast to the frequent view of Eucalypts as suppressive for understorey plants, the richness and biomass of herbaceous plant (Table 5),species in plantations of Eucalyptus species was found to be of the adjacent natural forests (Michelsen *et al* ,1996).

Table 5: Herbaceous species richness, cover, biomass in plantation stands of age more than 9 years and in the adjacent natural forests. The plot size was 100 $m^2$ natural forests. The plot size was 100m2 in plantations and 400m2 in natural forest.

| Stand type | Number of species | Cover(%) | Biomass(g/m-2) |
|---|---|---|---|
| *Cupressus lusitanica* | 10.9 | 1.6 | 4.4 |
| *Eucalyptus globulus* | 24.2 | 73.1 | 200.1 |
| *Eucalyptus grandis* | 25.5 | 63.5 | 182.0 |
| *Eucalyptus saligna* | 23.0 | 73.2 | 167.0 |
| *Pinus patula* | 20.8 | 47.0 | 231.3 |
| Natural forest | 31.5 | 71.3 | 232.7 |

Source: Michelsen *et al*(1996).

According to the study, the frequent planting of eucalypts does not appear to result in any noticable effects on under storey performance in the highland areas. Furthermore Pohjonen (1989) has documented that at the beginning of the plantation establishment the grass growth strongly boosted under plantation canopy accounting to 1615- 4250 Kg/ha of forage biomass being obtained in plantations with stocking density ranging 1470-1020 trees/ha and ages of 1-4.8 years. Where Eucalyptus plantations, on the other hand, are established for the purpose of achieving good performance and greater stand volume, the plantation management option is to intensively discourage the undesirable species found within the plantation stand. This is done in and attempt to avoid resource competition between the plantation trees and other plants growing in the area. Besides, the frequent visits by local community members in search of litterfall collection may have its negative impacts on the growth performance of the undergrowth species in plantation forests. Thus, management of eucalypts plantations should optimally aim at retaining undergrowth vegetation in order to foster biological diversity and development of mixed secondary forests which may eventually replace the monospecific plantation stands. Given the necessary management practices, undergrowth vegetation cover serve as an important reservoir of organic carbon and nutrients and helps to insulate the mineral soil surface, there-by moderating fluctuations in soil humidity. The ground vegetation cover also acts as a physical barrier that reduces the kinetic energy of incoming rainfall and through fall, and thus its capacity to leach available nutrients from upper soil horizons. The plantation ground cover vegetation may also play and important role in forest tree seed germination and seedling survival of native species regenerating there.

The foregoing information reveal that effects of the fast-growing eucalypt plantations on the biological conditions of the soil differs with climate. In drought prone areas the

CERDA

eucalypts influence is majorly attributed to increased production and release of allelochemicals in combinations with resource competition for moisture and perhaps for nutrients. In wetter climate the eucalypts plantations have been observed to serve as fostering ecosystem to regeneration of indigenous species and development of better undergrowth vegetation cover. If plantations of eucalypts established in highlands are devoid of undergrowth vegetation cover, this can be largely attributable to plantation management than to effects exerted by the eucalypts. Nevertheless, it is acknowledged that there is plenty of scope for objective research into eucalypt-soil interactions and their consequences for plant growth.

## 5. THE USE OF WATER BY EUCALYPTS

Water use by eucalypts is a controversial topic in some countries such as Burma, India, and Tanzania where eucalypts are used extensively in plantations. Some critics strongly believe that eucalypts have deleterious effects on the hydrological cycle, that is on catchment yield, ground water levels, and aspects of soil moisture including soil water extraction, infiltration and water holding capacity. Others, however, reject such claims. The debate is characterised by conflicting information and a lack of clear definition or discussion of the physical and biological processes controlling water use and the hydrological effects of eucalypts.

In this paper, we attempt to assess the available evidence regarding water use by eucalypts. and to discuss the physical and biological process determining water use. There are broadly three questions we can ask, - what information is there about water use by eucalypt forests-including the effects of management practices. How do environmental factors- including the effects of management practices. Affect the way the eucalypt uses water. And how efficiently does research directed to these questions. We can at least summarise the available evidence and reach some tentative conclusions about them.

### *5.1. The use of water by the eucalypts*

Because of interception losses and the way the root system can tap water at depth, a forest will generally yield less water than grasslands (Holmes & Wronski, 1982). Thus it is likely that where grassland or low natural vegetation is replaced by a plantation forest. The yield of water from the catchment will be reduced. Nevertheless. Even in a significant catchment a forest cover may still be preferred because of more uniform seasonal water yields and the protection of soils.

While there have been no direct measurements on water use by eucalypt forests, indirect determination from a weighing lysimeter in New South Wales, Australia (Dunin and Mackay, 1982) suggest that the eucalypt forest uses water conservatively and to the same extent as coniferous forests under comparable energy inputs and leaf area indices. Similar conservative water use has been noted with the jarrah forest. *E. marginata* and an introduced *E. maculata* community in Western Australia.

Because the water yield from the eucalypt forest catchment can be influenced by management practices. It may be important in preparing management prescriptions to

CCRDA

define the objectives of management for the catchment- particularly the priorities which will be given wood production and water yield . It is possible to indicate some effects on water yield of thinning, clear felling, rotation length and the manipulation of understorey by prescribed burning.

Thinning and selective cutting can reduce transpiration temporarily and increase streamflow. For example, strip-thinning of a *Eucalyptus reganans* forest to 50% of its previous density increased stream flow by 14 to 19 % (Ronan et. al.1982), whilst each 30% reduction in the canopy density of an *E. marginata* forest resulted in a 10% increase in water yield (langford et.al., 1982).

Clearfelling of the forest can result in an immediate increase in stream flow( up to a factor of 3) but this may decline rapidly as the regrowth forest develops. The magnitude and duration of the increase and subsequent decline depend on age and density of the forest removed, amount of understorey present, and the rate of establishment and growth of the regeneration ( Langford *et.al.* 1982: Stokes and Loh 1982)

Streamflow may vary with stand age or rotation length. For example, simulation of the streamflow from an *E. regnans* forest over 170 years following regeneration( Ronan *et.al.* 1982) showed streamflow to be at a maximum at the time of regeneratin after which it decreased rapidly for 7 to 10 years reaching a minimum of about 50% of the maximum after 30 years. Water yield then gradually increased between ages 30 and 150 years to about 75% of the maximum.

Prescribed burning for fuel reduction may also increase water yield from the eucalypt forest by eliminating transpiration from understorey vegetation. Beyond this the long term effects of a reduction in wildfire frequency are difficult to assess. Within the catchment of a fire-sensitive eucalypt the immediate effect of a wildfire may be similar to that of clear cutting. That is, an increase in total water yield. Increased runoff and greater peak flows ( Mackay *et al,* 1980). This may be followed by significant reduction in streamflow, becoming increasingly severe for up to 20 years as the regrowth foliage increases(Langford et.al,.1972).

Overall, the limited Australian information indicates that eucalypts in Australia use water conservatively and that water use is generally consistent with stands of other tree species. Moreover, a smaller interception loss is consistently recorded in eucalypts than in coniferous stands ( 10 to 20 % *cf.* 20 to 40%), and this should increase water yields from the eucallypt stands.

In contrast to the Australian data, there is some evidence from overseas countries that eucalypts are not as conservative when grown in 'alien' environments. For example, studies in Brazil (Lima and Freire 1976) suggest interception losses and transpiration in both eucalypts and pines are higher than in native vegetation: and in South Africa. Vander Lill *et.al.*(1980) found *E. grandis* plantations used more water than pines and natural forests.

It is important to explore the causes of these apparent differences.

CSIRO

### *5.2. Factors affecting water use*

The transpiration (E1) of field-grown trees can be approximated by the relationship:

$$E = \Delta e \times g_c$$

where $g_c = [g_s (LAI \times 2)]$

This shows that leaf area index (LAI). stomatal conductance($g_s$), and vapour pressure difference between leaf and atmosphere ($\Delta e$) are the main factors affecting transpiration. The way each affects transpiration is discussed below.

**Leaf area index (LAI):** Transpiration increases with canopy LAI up to a certain maximum level at which most of the available radiation is absorbed. An increase in LAI above this level has a minimal effect on water use. It is important to note that 'effective' leaf area, *i.e.* leaf area actually absorbing radiation at any one time is almost certainly less than 'total' leaf area due to leaf angle and canopy architecture. In 'alien' environments leaf areas ( and hence water use) of eucalypts may be greater than in native stands due to the absence of leaf predators and to more fertile soils.

For an evergreen tree the life of the eucalypt leaf is short, the average being about 18 months. The leaf system can also be dynamic, for example, Pook(1985) found that while a severe 7-month drought in New South Wales reduced the LAI of a stand of *E. maculata* from *ca.* 4.3 to 0.8, the crowns of these trees recovered to pre-drought levels rapidly in autumn after the break of drought. The shedding of leaves may be a mechanism aiding eucalypts to survive drought stress.

**Stomatal conductance:** For transpiration to occur, stomata must be open to allow the movement of water vapour from leaf to atmosphere. Stomatal movements in trees depend on both morphological and physiological factors.

Morphologically, trees differ in the extent to which their root systems explore the soil laterally and at depth, and their ability to exploit available soil moisture at depth during drought may be a major factor in their survival and growth, and hence in their water use as well. Leaf area dynamics, *i.e.* rate of leaf turnover, retention of older leaves, and nutrient cycling within leaves, could also have a considerable influence on water use due to effects on effective leaf area, and the physiology of stomatal response in leaves of different ages.

While morphological differences between species can result in marked differences in water use, at least at some times of the year and under some environmental conditions, there are instances where morphological differences cannot explain differences in water use between species or provenances of the same species (Colquhoun *et.al.,* 1984). Physiological controls of water use appear to be important but there is little definition, let alone explanation, of these. There is some evidence *(e.g.* Myers and Neales, 1984) that, unlike most crop plants. there is no critical water potential at which stomata of eucallypts close, and some species, at least, can maintain open stomata at very low tissue water potentials, for example, down to -5mpa or less in some species.

CCRDA

This aspect of eucalypt water relations requires much further study.

**Vapour pressure difference:** The vapour pressure difference between leaf and atmosphere is influenced both by the water content of the leaf, and hence the ability of the plant to exploit soil water, and the vapour pressure deficit of the atmosphere. If transpiration were a purely physical process, it would increase linearly with an increase in vapour pressure difference when the stomata are open. Doley (1967) found such a relationship in *E. marginaata* even under dry conditions. However the vapour pressure difference ($\Delta e$) can in itself affect stomatal conductance, and Myers and Neales (1984) found that as $\Delta e$ increased from 0.5 to 3.0 kpa, stomatal conductance in seedlings of two E*ucalyptus spp* was reduced by 75 pre cent. Such a stomatal response to vapour pressure difference appears to a common feature in tall, woody evergreens (Aston, 1984) and may be more pronounced than in crop species. The stomatal response of eucalypts, grown in different environments, to vapour pressure difference has received little study, and since it could significantly affect water use deserves considerably more investigation.

### *5.3. Water use efficiency*

In examining water use by plants it is necessary to consider 'effective' water use, or water use efficiency, defined here as the unit of dry matter produced per unit of water used. Tanner and Sinclair (1983) have recently reviewed this topic.

In its simplest form water use efficiency may be defined by the term:

$$Y/T = k/(e^* - e)$$

Where Y = crop yield

T = water used in transpiration

$(e^* - e)$ = saturation deficit of the air

k = crop constant

Clearly, water use efficiency (Y/T) is inversely related to the saturation deficit of the air ($e^* - e$), and efficiency is greatest in humid environments. However, actual yields may not be highest in these environments because of reduced sunshine.

In determining water use efficiency it is also imprint to distinguish between transpiration (T) efficiency and evapotranspiration(ET) efficiency. It appears that an increased water use efficiency, brought about by improved management practices, may be due to the decrease in evaporation more than compensating for an increase in transpiration. Conditions such as low fertility, water stress, plant disease, or insects which reduce the leaf area to the extent that the canopy is no longer closed could increase soil evaporation and lower Y/ET. However, a decrease in LAI has to be rather severe before substantial changes in Y/T are observed.

Although different crop species can differ in T efficiency, Tanner and Sinclair (1983) believe that these differences can be attributed to differences in carboxylation pathways (different for $C_3$, $C_4$ plants) and energy requirements to produce biomass of

CCRDA

different chemical compositions. Thus, water use efficiency is relatively stable between crops of the same general type as was found by Dunin and Mackay (1982) who demonstrated little difference in water use efficiency between natural eucalypt communities. *Pinus radiata* plantations and cereals.

Yields of crops vary with growing conditions but, in general, the decrease in dry matter production caused by water deficits is in proportion to the decrease in transpiration. In the context of this paper it is probably more pertinent to look at the increased transpiration and water use. Hence, effects of any vegetation on water use and water yield must be viewed in the context of the objects of management.

### *5.4. Discussion of water use*

Water used by tree species is influenced by a wide variety of factors--atmospheric, edaphic, physiological and morphological. Our understanding of the influence of these factors, and their interactions, is too limited at present for us to make definitive statements about the water use of trees in specific environments. Nevertheless this review has indicated some behavioural patterns of importance and identities avenues along which water use by eucalypts plantations should be explored.

There is little evidence that eucallypts growing in their natural environment are more demanding on soil water than other species. Nevertheless, the genus *Eucalyptus* comprise many species (some 550 species) and it is probable that the natural distribution and associations of eucalypt species are due to their adaptations to the environment, including adaptations to water availability. Hence species with a high rate of water use and little capacity to regulate water loss (*E. regnans*) may only occupy more fertile sites with near optimum water status. As water becomes progressively less available, such species may be replaced progressively by others better able to regulate water loss and conserve soil water. Adaptations of this nature could lead to the conclusion that in the water-limiting Australian environment eucalypt communities are conservative in water use.

Where a eucalypt is planted outside its natural habitat such as Ethiopia, often on a more fertile soil, or where the root systems can develop rapidly, the checks and balances on water use imposed by competition and site factors in the natural environment may no longer apply. Consequently, growth rates may be very high, particularly where there is also a high effective LAI. In this case an important question is that of water use efficiency--does the fast-growing exotic eucalypt use more water per unit of biomass production than it would in its natural environment, or when compared with another fast-growing tree?

There are a number of points which emerge from the review which may be significant in appreciating water use by eucalypts. Particularly in drier environments. These can be summarised as follows:

(i) There is some evidence that there is no critical water potential at which stomata of many eucalypts close, and some species can maintain open stomata at very low leaf water potentials ( to-5 MPa in some species). This in turn would enable such species to draw water from considerable depth or distances from the tree.

CCRDA

(ii) Eucalypts capable of growing under dry conditions may have extensive root systems, laterally and to depth, thus maximising access to water supply.

(iii) Water use efficiency is inversely related to the saturation deficit of the air, that is, in dry environments more water might be transpired than is commensurate with photosynthesis and biomass production. However, the possible significance of this for the eucalypt is not understood - stomatal responses in rapidly growing eucalypt plantations to large vapour pressure differences need to be determined.

Based on these 'principles' it is possible to appreciate how high rates of growth may be obtained in some semi-arid regions. This could be expected, for example, where the soil is moderately fertile, where the physical soil conditions facilitate development of an extensive root system and tapping water at depth, where the eucalypt species has a high effective LAI, where the stomata remain open at very low leaf water potentials, and where there is a long period of the year with a high atmospheric saturation deficit and energy input.

It follows that high rates of wood production cannot be achieved without high rates of water use, but whether the water use efficiency of the eucalypt declines to any appreciable degree under these conditions cannot be determined on the evidence available to us.

This review demonstrates a clear need to expand studies on water use by eucalypt species and communities, both in the natural environment and overseas. When more is known about the physiological attributes of different eucalypt species, the way water use can be affected by environmental factors, and the water use efficiency under differing conditions, we will be in a better position to formulate advice on tree planting, which takes account of both the environmental conditions and the social needs of people ..

CCRDA

## 6. CONCLUSIONS

It will be evident from this review that attempts have been made to explore the eucalyptus- site interaction in order to uncover the ecological implications of the Eucalyptus established in plantations. The presented review revealed that the ecological consequences of Eucalyptus plantations on soil fertility, undergrowth biodiversity and soil water are related to specific characteristic of the species, the management of the plantations, and silviculture. Rotation length, the intensity of biomass removal, the nature and management of plantation in relation to the interfering vegetation and the morphological, physiological characteristics and extent of the genetic variations, must all be considered to evaluate the ecological influences of Eucalyptus plantations in Ethiopia.

This review has also established a framework within which continuing in vegetations of those eucalypt-environment interactions might be developed. Research will be needed at a number of levels as follows:

I At more fundamental levels, research studies are needed on the genetics of eucalyptus and on the effects of species, sites and other environmental factors on the physiology of water use and nutrient uptake and translocation.

II A more systematic approach to tree introduction is required; in this way it will be possible to make more effective use of the genetic material in *Eucalyptus*, and to provide a firmer basis for selecting species and provenances compatible with climate , site factors, and such social constraints as the need to minimise the effects of tree planting on water table and other crops.

III Finally, social studies are needed to establish regional land use priorities, the objective of planting eucalypts, and ways in which that planting might be better integrated within existing land use and land management regimes.

It is believed that a more concerned, integrated and objective approach to eucalypt studies will be needed in order to fully realise the social benefits that eucalypt can bring, particularly in Ethiopia.

CCRDA

## 7. REFERENCES


Aalback, A. 1993. Tree Seed Zones for Ethiopia. May/June 1993. FRC/National Tree Seed Project, Shola, Addis Ababa. Prepared for Danida Forest, Seed Centre, Humleback, Denmark. pp.120.

Ashton, D.H. and Willis, E.J.,1982. Antagonisms in the regeneration of *Eucalyptus regans* in mature forest. In the plant community as a Working Mechanism. pp.113-128. Special Publication Series. British Ecol.Soc.No.1. Blackwell, Oxford.

Aston, A.R., 1984. Evaporation from eucalypts growing in a weighing lysimeter: the test of combination equations. Agric.and For. Meteorol. 31:241-249.

Bowen, G.D.1981. Coping with low nutrients. In The Biology of Australian Plants (eds. T.S. Pate and A.J. McComb) pp.33-64. University Australia Press.

Colquhoun, I.J.,Ridge, R.W., Bell, D.T., Loneragan,W.A. and Kuo,J.,1984. Comparative studies in selected species of *Eucalyptus* used in rehabilitation of the northern Jarrah forest. Western Australia. I. Patterns of xylem pressure
potential and diffusive resistance of leaves. Aust. J. Bot. 32: 367-373.

Crane, W.J.B. and Raison, R.J.1980. Removal of Phosphorus in logs harvesting *Eucalyptus delegatensis* and *Pinus radiata* forests on short and long rotations. Aust. For. 43: 253-260.

Cromer, R,N.,Williiams, E., and Tompkins, D., 1980: Biomass and nutrient uptake in fertilised *E. globulus*. Paper presented at IUFRO symposium and Workshop on Genetic Improvement and Productivity of Fast- growing Trees. Brazil.

Davidson, J., 1989. Preparatory Assistance to Research for Afforestation and conservation, Ethiopia. Research Management at the Forestry research centre. FO:DP/ETH/85/012., Field document 1,Vol.1-2, FAO.UNDP, Addis Ababa. pp.184.

Doley, D.,1967. Water relations of *Eucalyptus marginata* under natural conditions. J Ecol. 55: 597-614.

Dunin, F.X. and Mackay, S.M., 1982. Evaporation of eucalypt and coniferous plant communities. Proc. First Nat. Symp on For. Hydrol., Melb. Inst. Eng. Aust. pp 18-25.

Ferreira, M.D.G., Kimmins, J.P., and Barros, N.F., 1984. Impact of intensive management on phosphorus cycling in *Eucalyptus grandis* plantation in the savannah region, Mina Gerais. Brazil, Proc. IUFRO Symp. on site and Productivity of Fast-growing plantations, South Africa Vol. 2; pp 847-856.


CGRDA

Florence, R.G. 1981. The biology of the eucalypt forest. In The Biology of Australian Plants (eds. J.S. Pate and A.J. McComb). pp. 147-180. University of Western Austrlian Press.

Friis, I., 1995. Myrtaceae. Flora of Ethiopia and Eritrea, Vol. 2, part 2: canellaceae to Euphorbiaceae (eds. S.Edwards, Mesfin T., and I. Hedberg). pp 71- 106. Addis Ababa, Ethiopia.

Harborns, JB., 1988. Introduction to Ecological Biochemisyry. 3rd ed. Academic press, London.

Hingston, F.J. Dimmock, G.M. and Turton, A.G., 1980. Nutrient distribution in *Eucalyptus marginata* ecosystems in the south west of Western Australia. Forest Ecol. Manag.3: 183-207.

Holmes, J.W. and Wronski, E.B., 1982. On the water harvested from afforested catchments. Proc. First Nat. Symp. on For. Hydrol. Melb., Inst. Eng. Aust. pp.1-6.

Horvath, R.J., 1968. Addis Ababa's eucalypts forest. J. Ethiopian Studies. 6: 13-19.

Inderjit and Daknhini, K.M.M., 1995. On laboratory bioassays in allelopathy. Bot. Rev.
(Lancaster) 61:28-44.

Inderjit and del Moral, R. 1997. Is separating resources competiton from Allelopathy realistic? Bot. Rev. (Lancaster) 63: 221-230.

Langford, K.J,. Moran, R.J, and O`Shaughnessy, P.J., 1982. Coranderrk experiment-the effects of roading and timber harvesting in a mature mountain ash forest on streamflow yield and quality. Proc. First Nat. Symp. on For. Hydrol., Melb. Inst. Eng. Aust.pp 92-102.

Lima, W., and Freire, O. 1976. Evapotranspiration in plantations of *Eucalyptus* and *Pine* in natural herbaceous vegetation. IPEF 13:103-117.

Lisanework, N. and Michelsen, A., 1993. Allelopathy in agroforestry systems: the effects of leaf extracts of *cupressus lusitanica* and three *Eucalyptus* species. on four Ethiopian crops. Agrofor. Syst., 21: 63-74.

Lisanework, N. and Michelsen, A. 1994. Litterfall and nutrient release by decomposition in three plantations compared with a natural forest in the Ethiopian highland. For. Eco. Man., 65: 149 - 164.

Lisanework, N. 1994. Ecological Studies of plantations in some parts of Ethiopia, with special regard to ecological effects of the use of *Eucalyptus spp.* Ph.D. Thesis, Addis Ababa University, Addis Ababa. pp 114

CCRDA

Lundgren, B. 1978. Soil conditions and nutrient cycling under natural and plantation forests in Tanzanian highland. Rep. For. Ecol. For. Soils 31. Department of Forest Soils, Swedish University of Agricultural Sciences, Uppsala, 426 pp.

Mackay, S.M., M ichell, P.A. and Young, P.C. 1980. Hydrologic changes after wildfire in small catchments near Eden. N.S.W. Proc. Hydrol. Symp. Inst. Eng. Aust. pp. 149-55.

Madeira, H.A.V., 1989. Changes in soil properties under Eucalyptus plantations in Portugal. Biomass Production by Fast-growing Trees (eds J-J pereira and J.J. Landsberg) pp.81-99. Kluwer Academic Publishers, Dordrecht.

Michelsen, A., Lisanework, N. and Friis, I. 1993. Impact of Tree plantations in the Ethiopian highland on soil fertility, shoot and root growth, nutrient utilisation and mycorrhizal colonisation. For.Eco. and Manage. 61: 299-324.

Michelsen, A., Lisanework, N., Friis, I and Holst, N., 1996. Comparison of undersotrey vegetation and soil fertility in planations and adjacent natural forests in the Ethiopian highlands. J. App. Ecol. 33: 627-624

Miller, H.G., 1986. Effect of Management Operations on nutrient cycles and the consequences for tree growth. 1. Congresso Florestal National. Sociedade Portuguesa de cieneias Florestais, Lisbon. pp 304 15.

Myers, B.A. and Neals, T.F., 1984. Seasonal change in the water relations of *Eucalyptus behriana* and *E. mirocarpa* in the field. J. Bot. 32: 495-510.

Ovington, J.D. and Pryor, L.D., 1983. Temperate broad leaved evergreen forests of Australia. In Ecosystems of the World, Vol. 10. Temperate broad leaved evergreen forest (ed. J.D. Ovington) pp.73-101. Elsevier, Amestrdam.

Pohjonen, V., 1989. Establishment of fuelwood plantations in Ethiopia. Silva Carelica 14, University of Joensuu, Joensuu, Finland.

Pohjonen, V. and Pukkala, T. 1990. Eucalyptus globulus in Ethiopian forestry. For Ecol. Manage. 36: 19-31.

Pook, E.W., 1985. Canopy dynamics of *Eucalyptus maculata*. III. Effects of drought. Aus. J. Bot. 33: 65 - 80.

Poor, M.E.D and Fries, C. 1985. The ecological effects of Eucalyptus. FAO. Forestry papers 59. FAO, Rome, Italy.

Pryor, L.D., 1976. The biology of eucalyptus. Studies in Biology No. 51. Edward Arnold.

Pryor, L.D. and Johanson, L.A.S., 1981. Eucalyptus, the universal Australian. In

CCRDA

Ecological Biogeography of Australia (ed. A. Keasi). pp 499 - 536. Junk. The Hague.

Raison, R.J., 1984. Potential adverse effects of forest operations on the fertility of soils supporting fast growing plantations. Proc. IUFRO symp. on site and productivity of Fast - growing Plantations. South Africa. pp. 457 - 472.

Raison, R.J., Khanna, P.K. and Crane, W.J.B., 1982. Effects of intensified harvesting on rates of nitrogen and phosphorous removal from *Pinus radiata* and Eucalyptus forests in Australia and New Zealand. J. For.Science 12: 393 - 403.

Rice, E.L., 1984. Allelopathy, 2nd ed. Academic Press, New york.

Ronan, N.M., and Langford, K.J. and O' Shaughnessy, P.J., 1992. Simulation of the long-term hydrological effects of different approaches to timber harvesting in a large forested catchment. Proc. First Nat. Sym. on Forest Hydrology. Mell. Inst.Eng. Aust. ppl 139 44.

Shiva, V. and Bandyopadhyay, J., 1983. Eucalyptus - a disastrous tree for India. The Ecologist 13: 184 - 187.

Singh, D 1991. Phytotxic properties of Eucalyptus with special reference to the role of its volatile components. Ph.D. thesis. Panjab University, India.

Singh, D, Kohli, R.K. and Saxena, DB., 1991. Effects of Eucalyptus oil on germination and growth of *Phaseolun aureus* Roxb. Plant Soil 137:223-227.

Singh, D and Kohli, R. K., 1992. Impact of *Eucalyptus tereticornis* sm. shelterbelts on crops. Agrofor. Syst. 20: 253-266

Stokes, R.A. and Loh, I.C., 1982. Streamflow and solute characteristics of forested and deforested catchment pair in South Western Australia. Proc. First Nat. Symp. on For. Hydrol. Melb. Inst. Eng. Ast. pp 60 - 66.

Stowe, L.G. & Osborn, A. 1980. The influence of N and P levels ofn the phytotoxicity of phenolics compounds. Canad. J. Bot. 88: 1149-1153.

Tanner, C.B. and Sinclair, T.R., 1983. Efficient water use in crop production research. In Limitations to Efficient Water Use in Crop Production (ed. H. Taylor) pp. 1-28. Am. Soc. Agronomy, Madson.

Van der Lill, W.S., Kruger, T.J. and Van WYK, D.S., 1981. The effect of afforestation with *Eucalyptus grandis* and *Pinus patula* on stream flow from experimental catchments at Mokobulaan. J. Hydrol 48: 107 -18.

Von Breitenbach, F. 1961. Forests and Wood lands of Ethiopia. For. Rev., 1: 5 - 16.

CCRDA