Forestry Department

Food and Agriculture Organization of the United Nations

Forest Plantations Working Papers

ANNOTATED BIBLIOGRAPHY ON ENVIRONMENTAL, SOCIAL AND ECONOMIC IMPACTS OF EUCALYPTS

Compilation from English, French and Spanish publications

Between 1995-1999

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The Forest Plantation Working Papers report on issues and activities in forest plantations which do not reflect any official position of FAO. Please refer to the FAO website (http://www.fao.org/forestry/Forestry.asp) for official information.

The purpose of this working paper is to provide annotated bibliographies, previously printed in three different languages, under a single language.

This Working Paper supplements Working Paper 16, "*Annotated Bibliography on Environmental, Social and Economic Impacts of Eucalyptus*" a compilation from literature from 1985 to 1994. This update covers the period 1995 to October 1999 and was prepared for a meeting on the environmental effects of Eucalyptus, held in Mexico City, Mexico in 1999. FAO wishes to thank Mr. Fernando Patiño for his contribution in the elaboration of this paper.

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INTRODUCTION

FAO Forestry Paper No. 59 "*The Ecological Effects of Eucalyptus*" (1985) included an extensive bibliography concerned mainly with the environmental effects of Eucalyptus plantations. Since then there has been an enormous output of studies published on the impacts of plantations of the eucalypts, with more emphasis on their social and economic as well as their ecological effects.

This annotated bibliography was prepared to update the FAO Forestry Paper No 59, produced in 1985 and supplement Forest Plantation Working Paper FP/16 *"Annotated Bibliography on Environmental, Social and Economic Impacts of Eucalyptus"*, 1985 to 1994. This update covers the period, 1995 to October 1999 and was prepared for a meeting on the environmental effects of species of the genus Eucalyptus, Mexico City, Mexico, 1999.

These three linked reports do not purport to be a complete listing of Eucalyptus references but they provide a useful bibliographic guide.

Users of this annotated bibliography are invited to send additions or amendments to:
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LIST OF ACRONYMS

ACIAR Australian Centre for International Agricultural Research

CSIRO Commonwealth Scientific & Industrial Research Organisation

IPF International Panel on Forests

IUFRO International Union of Forest Research Organizations

IPEF (Instituto de Pesquisas e Estudos Florestais) Research and Forestry Studies Institute

PNG Papua New Guinea

ANNOTATED BIBLIOGRAPHY [a]

Anon., 1992. *Eucalyptus: curse or cure? The impacts of Australia's 'world tree' in other countries***.** ACIAR Bulletin. Australian Centre for International Agricultural Research. 6 pp.

The genus *Eucalyptus* is large, comprising about 600 species[b]. Eucalypts are found in almost all the major habitat types in their native Australia (+ Indonesia, PNG, Timor, Philippines**).**

About 40 percent of all trees in plantations in the tropics are of Australian origin, and most of these are eucalypts. Most of the large plantations are used for pulpwood or industrial charcoal, but there is a great range of uses for eucalypts. Millions of eucalypts are also planted in single rows roads, waterways and bordering farmers' fields. Planting eucalypts as single trees, rows of trees or in small woodlots, may have very different ecological effects than those produced by plantations in extensive blocks.

Benefits:

- easy to cultivate;
- not palatable to grazing animals and therefore easy to protect;
- tolerate sites of low inherent nutrient status (and so require little fertilizer);
- drought-resistant;
- coppice readily;
- produce superior short-length fibre for paper-making;
- make excellent charcoal;
- useful for shelterbelts, erosion control, land reclamation, drainage;
- produce valuable non-wood products such as honey and leaf oils, thus seen in many countries as ideal for both;
- rural woodlots and larger plantations.

Controversial aspects and criticisms:

Water use

(i) Interception by crown

On average, the most commonly planted eucalypts intercept less than half of the amount of incoming rainfall, compared with some widely grown species. The amount of interception is governed by the surface area on which water can be retained and the orientation of the

[a] Some footnotes by C. Palmberg-Lerche (CPL) in the original language (Spanish or English). N.B. the information provided in the references do not always reach the same conclusions and the information is sometimes contradictory. No attempt was made to harmonize these contradictions.

[b] N.B.: Davidson (1995), states, "The genus *Eucalyptus* now encompasses some 700 species."Exact number will depend on taxonomic authority consulted. Davidson (1995) notes, however: " Despite [the existence of] many species, commercial and rural forestry based on *Eucalyptus* worldwide still depend on relatively few species ".

leaves in the canopy (in eucalypts generally pendulous). However, the amount intercepted depends on the particular eucalypt species and local climate.

ii) Soil water reserves

The re-charging of water reserves is important for forest growth and downstream water supplies. Forested catchments usually reduce the amount of water in ground water reserves because they use more than non-forested catchments. However, they regulate the water flow more efficiently, preventing the extremes of flow that are characteristic of deforested catchments in areas of high rainfall. experimental data show that in semi-arid climates such as Middle East and North Africa, eucalypts reduce the amount of water entering groundwater reserves more than open areas without trees. In wetter areas, e.g. in the Nilgiri Hills in India, surface run-off is greater under eucalypts than shrubland or grassland, but is the same as run-off from native forest. Stream flow is affected differently: eucalypts contribute less, about one third, of usable water than natural forest. These differences in water use between eucalypts and the natural forests are caused by the greater loss of water from the leaves of rapidly growing eucalypts. However, there is evidence that eucalypts may actually use less water per unit of wood produced than other trees, by using it more efficiently.

(iii) Water table

If large blocks of fast-growing eucalypts are planted on previously treeless ground, they may reduce the water yield and lower water tables in catchments. In drier regions, eucalypts compete vigorously with undergrowth for water.

Soil erosion

Clean weeding is necessary to establish plantations of eucalypts, and this may increase the risk of surface runoff and sheet erosion of top soil.- In dry zones, eucalypts can prevent the formation of an understorey layer that would otherwise stabilize the soil surface. They may do this through competition for water and/or light, and by processing only small amounts of leaf litter. Litter removal and sheltering of stock under trees can increase erosion. Wide spacing of trees can promote development of understorey. The pros and cons of eucalypt growing for erosion control will depend on local conditions and uses of the trees.

Eucalypts are often used as windbreaks, and can be successful in halting wind erosion. their effectiveness to do so will depend on the physical characteristics of the site and the construction of the shelterbelt. These considerations apply equally to all general.

Soil fertility

It is often stated that eucalypts impoverish soils especially if repeatedly cropped. Nutrients are lost through this process as well as through increased run-off and soil erosion. In contrast it has been shown that eucalypts actually *increase* soil nutrient status when planted on degraded or deforested sites. They improve soil structure by penetrating previously impermeable layers and by drawing up nutrients from deep in the soil.

Naturally, if repeatedly harvested, nutrients are also removed. Further losses may occur if the logging residues (bark, twigs, leaves) are burnt or removed. The rate of nutrient removal depends on plantation management and harvesting methods. Despite this eucalypts seem to be more efficient than most tree species in returning nutrients to the soil through litter fall, and bringing nutrients to the surface from deep in the soil.

Use of nutrients is not higher than in other crops, and of some essential elements only one tenth of those of some agricultural crops[c].- Evidence also points to greater soil enrichment beneath eucalypts compared with other forest trees, especially on degraded sites, through improved soil organic matter content. The benign and beneficial effects of eucalypts on soil nutrient and organic matter are especially pronounced in sites with low fertility. NB. the greater efficiency of nutrient use by eucalypts is maintained only if they are grown for rotations of more than approx. seven years[d]. With earlier harvesting the high proportion of sapwood results in increased export of nutrients and there may be no nutritional advantage in such cases of eucalypts over other tree species. The effect of eucalypts on soil fertility depends primarily on the state of the soil before planting, the rate of growth and the harvesting interval.

Allelopathy

Most of the influences of eucalypts on the understorey vegetation depend on water use. Eucalypts use water very
efficiently. Because of their fast height growth they also tend to shade out competing plants regenerating beneath them. However, not all *Eucalyptus* species cast heavy shade, and there are complex interactions between species, light and water: no generalizations are possible.- There are laboratory evidence that a few species of eucalypts produce chemicals that inhibit germination and growth of other plants. This may influence choice of species when erosion control or grazing are important functions of the forest.

Wildlife

Plantations usually contain less species of animals and plants than those natural forests which are more diverse. Native Australian Eucalypt forests have a rich diversity of wildlife that evolved with the trees and adapted to them in special ways that non-Australian flora and fauna frequently does not do; however this will depend on management strategies (*e.g.* mixtures, spacing, age classes etc.) Eucalypts are less detrimental to native fauna than agricultural crops.

Social implications

Eucalypts have been blamed for a range of socio-economic problems, but few are unique to eucalypts. The major criticism includes the loss of agricultural land for food production, reduction in rural employment, diversion of forest products from local markets to larger industrial users, and transfer of public or common land to private corporations. All lead to further imbalances in the distribution of wealth in poor rural communities. Furthermore, the high expectations have sometimes led to disappointment when the wrong species was grown, or where there was insufficient planning and local consultation. The problems are however not the result of special features of eucalypts.

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[c] Davidson (1995) includes a table on relative use of nutrients of a range of agricultural crops and forest tree species.

[d] *See* Bouvet (1999), who makes same observation, however, mentions 10 years as the age to be exceeded.

Solutions

Growing a crop is a matter of choice. Decisions such as what, where, why and how to grow have to be made, and the social and ecological implications of each decision, as well as the economic implications, have to be weighted up.. Wise choices will lead to a balance in which growing the trees contributes to improved quality of life for the majority concerned.

Some of the perceived problems with eucalypts can be avoided by applying sensible management practices. If the adverse effects of the trees are intolerably great, then other crops should be considered.

Conclusions

Eucalypts are neither good nor bad, and careful analysis of the ecological and social implications[e] should be undertaken before planting.

While there may be genuine grounds for concern in some cases, most problems with eucalypts as exotics arise from two main causes: imprecise definition of the objectives of growing trees in the first instance; and the use of eucalypts where other species or alternative land uses may be more appropriate[f].

Anon., 1997a. *Proc. XI World Forestry Congress, Turkey***.** FAO, Rome.Vols I-VIII. (English, Spanish, French).

A series of papers relevant to the theme, incl. *Anon (1997b); and Evans (1997),* mentioned below.

Anon., 1997b. *Report on the 12 Session: Reforestation and forest plantations. Proceedings of the XI World Forestry Congress, Turkey*. FAO, Rome Vol VII. (English, Spanish, French). pp. 65-66.

The meeting addressed plantations established for industrial wood and firewood production. It was highlighted that none of the plantations systems can ensure the delivery of a wide variety of goods and services such as that provided by natural or semi-natural forests. Another issue addressed related to world data showing that wood production from forest plantations may become sustainable, as soon as the species will be adapted to the land and forest management is adopted. Plantation increase is important for carbon absorption due to their potential to provide alternative sources of wood, different to those from natural forests and recovery, and at the same time, of degraded lands.

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[e] CPL comment: In addition to economic impacts..

[f] CPL comment: these two "problems" stated are the same. I would have thought that a second issue would be to stress the need for appropriate and wise forest management and silvicultural methods.

During the environmental impact analysis of forest plantations, it was emphasized that plantations should not be established on land occupied by natural forests; nevertheless, it was also said that plantations play a role in maintaining the water cycle. It was also stressed that management practices should maintain and strengthen such role. The potential of forest plantations to create jobs and income-generating opportunities (specially in developing countries), was also taken into account. Yet it was also said that during the planning and implementation stages of plantation programmes, it is necessary to take into account the wide social impact that those programmes may have, specially on landless and poor people.

The meeting identified two different ways of developing forest plantation programmes in the future. On one side, large-scale plantations with one species and a simple structure aimed at providing industrial wood; on the other, plantations with a more complex structure, including mixed species of different ages in a variety of situations, will decrease the risk for small farmers and will satisfy other purposes, such as restoring degraded land or other purposes associated to recreation.

Anon., 1999a. *Informe sobre la Reunión Internacional de Expertos sobre el Papel de los Bosques Plantados en el Manejo Forestal Sostenible. Auspiciado por los Gobiernos de Chile, Dinamarca, India, Nueva Zelanda y Portugal.* Santiago de Chile 6-10 de abril de 1999. (Trilingual). 72 pp.

The document contains general information relevant to the theme.

Recomendations/Context :
(i) Planted forests play many and diverse roles. There is a wide variety of forest types that range from highly protected conservation forests to short-rotation plantation forests for productive purposes.

Recommendations/Role of planted forests:
(v) Observing IPF recommendation, "... the adoption of all possible actions to avoid the replacement of natural ecosystems that harbour important ecological and cultural values, for forest plantations...and give preference to native species where appropriate" ...
(viii) To consider environmental, economic and social principles of sustainable forest management, in the relevant levels of planted forests planning and management.

Recommendations/planted forests and general terms:
(ix) To encourage the development of strategies through the utilization of planted forests, where appropriate, for conservation and management of forest genetic resources. The utilization of reproductive material of high genetic quality must also be encouraged.

(x) To urge countries for adequate participation of concerned parties in decision-making and policy implementation.

(xii) To urge countries to raise awareness through campaigns on the ecological, social, cultural and economic roles of planted forests and on the impact they may have.

Anon, 1999b. *Bosques cultivados. Proyecto B7-3011/93/156, "Producción Forestal en Bosques Cultivados".* Secretaría de Agricultura, Ganadería, Pesca y Alimentación. Subsecretaría de Agricultura, Ganadería y Forestación. Dirección Nacional de Producción y Economía Agropecuaria y Forestal, Dirección de Forestación, Argentina. (Spanish). 110 pp.

The document includes an environmental impact analysis of forest plantations. It also includes observations on the impact of *Eucalyptus* spp.

Eucalyptus spp. Plantations, as a possible alternative and in general terms, produce the following effects on:

(i) **annual or woody agricultural crops needing soil preparation**:

- less erosion
- environmental diversification
- more water consumption
- less fertilizer and agrochemical needs
- more fire risks

(ii) **non degraded perennial pastures**:

- equal or, sometimes higher erosion
- environmental diversification (if in mosaic)
- more water consumption
- increased fertilizer and agrochemical needs

(iii) **resinous plantations:**

- equal or greater erosion
- more water consumption
- less or equal need of fertilizers and agrochemicals (during long periods)
- less fire risks

(iv) **plantations with other broadleaved species**:

- more erosion
- less environmental diversification
- more water consumption
- more need of fertilizers (during long periods)
- less or equal need of agrochemicals
- more fire risks.

In general, it is recommended to avoid extended, pure plantations of this species. Also, extreme caution must be applied to cases where organic matter is present on the ground or in case of higher fire risks, in swamps, and finally, in acid soils.

Ball, J.B. and Brown, C., 1999. *World view of plantation grown wood. Invited Paper***,** Sub-Plenary Session A5. XXI IUFRO World Congress, 7-12 August 2000. Kuala Lumpur, Malaysia.

At present only the summary is available (paper in preparation). It gives general data on plantation percentage in various geographical regions and ecological zones, as well as plantation types (softwood, coniferous) etc. of general relevance to the present discussion.

Ball, J.B. ,1995. *Development of Eucalyptus Plantations – an Overview.* Proceedings of the Regional Expert Consultation on Eucalyptus, Bangkok, Thailand 4-8 October 1993. Vol .I. pp.15-27.

The economic and social effects are now seen as being the consequences not only of the effect of *Eucalyptus* plantations on the site and its environs but also of political decisions affecting the forest sector and in particular the supply of wood for industry. In this connection plantations must be considered not just for the production of timber or fuelwood but for other outputs and for the services that can be provided by trees. If society wants industrial roundwood cheaply, quickly and of a particular technical specification, then plantations of *Eucalyptus* may well be the answer, with other goods and services provided from elsewhere. If society wants multiple benefits from the same piece of forest land, then the eucalypts are not likely to provide the answer, and society must select another option - and be prepared to pay the cost.

Recognition of the need for sustainable forestry practices is leading to better matching of species and provenances with site, to establishment practices that are less damaging to the soil, such as the use of lighter equipment or the elimination of fire in site preparation, to quantification of benefits, such as employment or the provision of social services, to measurement of the effects of plantations on the environment, particularly on ground water and soil fertility, and to evaluation of the plantations in the local or national economies, rather than from the point of view only of financial return. The participation of people in rural development through forest plantations is now emphasised more strongly than ever. Examples include the outgrower scheme established by the Paper Industry Corporation of the Philippines for the provision of up to one third of its pulpwood requirements, where the company provides seedlings (including *Eucalyptus deglupta*), loans and advice The participation of the involved public (including people living in or off the forest or woody vegetation) in decision making and in management is frequently omitted when new plantations are planned, often leading to unforeseen social consequences. These consequences are as yet still inadequately quantified, and even data on the areas or growth rates of *Eucalyptus* are scarce and where available, generally unreliable. Sound, unbiased data obtained from properly planned research is fundamental to the political process leading up to the establishment of *Eucalyptus* plantations. In considering objections to *Eucalyptus* plantations due to their effects on the environment or society it is important to identify whether the objections are to the effects of *Eucalyptus* as species, to the effects of the plantation or whether the complaints about the species are in fact concealing other political grievances.

Bernhard-Reversat, F., 1986. *Quelques observations sur l'effet allélopathique des Eucalyptus plantés au Congo***.** ORSTOM, Pointe-Noire. Leaflet. 10pp. (French).

Tests were made in eucalypt litter. It was noted that species of Graminae grew badly in soils covered with eucalypt litter. Hypothesis was made that this was due to allelopathy (however, little evidence was shown, preliminary study)[g].

Bouvet, J.M. (1999*).* *Les plantations d'Eucalyptus: évolutions récentes et perspectives.* Le Flamboyant no.49: Spécial Eucalyptus. pp.4-14. L'association Silva, Paris, France. (French).

Literature survey. Includes general considerations related to establishment and management of eucalypts, and to environmental effects of *Eucalyptus* species.

"The Big Eucalypt Debate" has arisen in the wake of increasing areas of plantations of eucalypts. It refers to especially intensive debate in India, Thailand, Myanmar; and to the FAO Meeting in Thailand (see ref *to FAO 1995* below). In summary, nothing special about eucalypts: <u>all</u> species have good and bad sides, which need to be weighted between them, in the light of plantation objectives.

Eucalypts and water

Do eucalypts use more water than other species; and are they more efficient water users than other species?; As it regards the first question, water use will depend on environmental factors, however, in absolute terms eucalypts seem to use more water than other species. As it regards the second question (efficiency), author refers to *Davidson 1995*- see below- and Davidson's table re water use

Eucalypts and soil

When eucalypts are planted in savanna areas, there is a notable increase in humus. Roots also improve aeration of the soil. This latter positive effect is especially noticeable in compacted soils, and soils without structure, e.g. sandy soils. Author refers to Davidson's papers (Davidson (1995) - *see* below- and Davidson's table re use of nutrients of various crops). In summary he states that eucalypts in general terms use less nutrients than other crops (30-50 percent less than annual plants, 50 percent less than, fruit trees); however, this holds true only in rotations less than 10 years[h].

Eucalypts and erosion

Strong competition for water diminishes undergrowth esp. in dry conditions, and therefore a number of species of eucalypts do not help stop surface runoff. However, the author points out

[g] CPL comment*: see* however also Loumeto and Bernhardt-Revesat 1997.

[h] *Cf.* Anon 1992 above: same argument, however rotation recommended not less than "approx 7 years".

that there are a number of drought tolerant eucalypt species which are small and shrubby, which certainly would likely do be very much suited for erosion control, but these are rarely used as exotics. At the present, eucalypts planted in dry areas are selected for their ability to produce wood in dry conditions, not with a view to erosion control; to produce wood in such conditions, there needs to be careful removal of competing weeds and vegetation, which aggravate the issue. In summary: species choice – which eucalypt species- will determine effects.

Eucalypts and allelopathy

Author refers to *Bernhardt-Revesat (1986)* -see above-, who made some experiments and showed negative effects of eucalypt litter on growth of other plants. Concludes that "it is generally accepted" that in rainfall regimes of less than 400mm/an, there are some allelopathic effects[i]; in areas which get between 400 and 1200 mm/an active management interventions are needed to favour an understorey if this is an objective; whereas in rainfall areas of more than 1200 mm/an there is no adverse effects of eucalypts on undergrowth.

Eucalypts and biodiversity

Author refers to *Loumeto, J.-J. and Bernhardt-Revesat, F. (1997)*- see below- who showed that native herbaceous and woody species established themselves profusely under eucalypts, grown in plantations in Congo.

Eucalypts and fauna

Notes that exotic *Eucalyptus* plantations usually have less wildlife than the natural forest, however, eucalypt plantations are more rich in fauna than the savanna which they frequently replace. Author refers *to Loumeto, J.-J. and Bernhardt-Revesat, F. (1997)*- see below- who noted large increase in soil microbes under eucalypt plantations, as compared to the savanna they replaced. Older age-classes of eucalypt plantations in Congo house large populations of antelopes which had disappeared from the savannas, and large populations of buffalos and some other large animals[j].

Campinhos, Edgard Jr, 1999. *Sustainable plantations of high-yield Eucalyptus trees for production of fibber*: the Aracruz case. New Forests Vol.17:129-143. Kluwer Publishers, Netherlands. (English).

Stresses that significant investments must be made in research and development, and technological adaptation to local conditions. Stresses that with high yields, wood can be grown on relatively limited area, setting natural forests aside for other uses or for protection.. – "In various parts of the world eucalypt plantations have generated much debate regarding their ecological impacts. The biggest argument against extensive eucalypt plantations is that they reduce the availability of water in a given region. On the other hand, soil that is well covered with trees, dead leaves and branches promotes greater availability of water in rivers

[i] CPL comment**: NB** document by Davidson (1985) comes to similar conclusion, but puts the 'critical rainfall limit' at 700mm.

[j] CPL comment: issue is shelter and continuing supplies of food rather than what species constitutes the upper layer of the forest.

during periods of drought, and diminishes the possibility of erosion. If trees are removed there will be periodic cycles of flooding alternating with little usable river water. The ecological characteristics of a region where eucalypts or other fast-growing trees are planted must be carefully studied to assess feasibility in relation to local hydrology (Author refers here to FAO 1990, "El Dilema del Eucalipto"). Another argument against eucalypt plantations is that they are gigantic silent environments, green deserts without biodiversity, monotonous and not aesthetically pleasing. While the overstorey is simplified, the understorey in a eucalypt forest contains considerable biodiversity, which does not occur in an agricultural field (Author refers here to Eldridge et al 1994). Author also points to native vegetation along rivers which will be left to house additional native biological diversity. Author points out the carbon sink function of fast-growing eucalypt plantations[k].

Cannell, M.G.R., 1999. *Environmental impacts of forest monocultures: water use, acidification, wildlife conservation, and carbon storage.* New Forests Vol.17:239-262. Kulwer Publishers, Netherlands. (English).

Reviews establishment and impact of forest plantations in general, and makes the following observations:

Water consumption

Total water loss from planted monocultures[l] will normally be greater than from short vegetation, because of greater interception loss. Total water loss form conifer forests will usually be greater than from deciduous hardwood forests because conifer canopies usually have a greater water storage capacity. However, total water loss from *Eucalyptus* in the dry tropics is often no greater than from native hardwoods, although it is greater than from agricultural crops, especially if water is accessed at depth by the *Eucalyptus* roots.

Acidification

Forests can significantly increase the transfer of acidifying pollutants from the air to terrestrial surfaces, and thence to groundwater, compared with short vegetation. This is a large effect where forests are exposed to high concentrations of "reactive gases" and to polluted cloud water. Conifers are more likely to cause acidification than are hardwoods.

Conservation

While planted [forest] "monocultures" may not be as highly valued for conservation as unmanaged[m] forests, there are clear trade-offs between maximising volume production and protecting wildlife diversity, and there are some habitats that can only be provided by old-growth forest. There are usually sufficient plantation management options

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[k] CPL comment: not only eucalypts, all fast-growing species.

[l] CPL comment: here, and elsewhere, reference should be to: *single species plantations*, not "monocultures"; plantations of trees are not monocultures in the same sense as in the case of agricultural crops: unless of clonal origin, a forest plantation possesses a large amount of intra-specific variation.

[m] CPL comment: Reference should be to natural, or native, forests, rather than "unmanaged".

available to make most plantation landscapes the homes of a rich diversity of flora and fauna.

Chatuvedi, A.N. (1983). *Eucalyptus for Farming. Uttar Pradesh.* Forest Bulletin No. 48. Lucknow, U.P., India.

Private tree planting is relatively new in India, although Forest Departments have been raising eucalypt plantations on public lands for over a century. The paper provides an account of the biological and silvicultural characteristics, management problems, and economics of eucalypt planting for the farmer.

Chatuvedi, A.N., 1985. *Firewood Farming on Degraded Lands. Uttar Pradesh Forest* Bulletin No. 50. Lucknow, U.P., India.

In growing fuelwood and wood crops on degraded soils in India, fertilizer dosages when used should be low and well distributed over the first part of the growing season; the crop uptake can be calculated from biomass production. Nitrogen is the most crucial nutrient element, and also the most expensive, and is desirably supplied from biological fixation[n].

Chatuvedi, A.N., Sharma, S.C., Srinivasan, R, 1988. *Water consumption and biomass production of some forest tree crops.* The International Tree Crops Journal No.5.

Water consumption and biomass production of 10 species were compared. "*Eucalyptus hybrid*" was found to be the most efficient.

Davidson, J. (1985). *Setting aside the idea that eucalypts are always bad. Working Paper No.10*, May 1998. Project FAO/UNDP/BGD/79/017, "Assistance to the Forestry Sector". FAO, Dhaka (Bangladesh).

Provided proper land and water resources surveys and planning are carried out, suitable species selected and properly matched to sites, no significant ecological damage is expected to arise from planting *Eucalyptus* in Bangladesh. Where *Eucalyptus* species are planted on denuded or degraded sites, it is expected that the environment will be significantly improved. The paper looks at issues under the below headings:

[n] CPL comment: undercropping by legume species is likely referred to here.

Water runoff and soil loss

If eucalypts were to be used to replace, say, a natural undisturbed moist deciduous forest, water runoff and soil loss would probably be increased. If however eucalypts were planted on degraded lands with no trees, sparse tree cover or poor degraded forests, then runoff and soil loss can be expected to decrease. "It depends"! Planting eucalypts does not necessarily lead to an increase in runoff and soil loss.

"Does not enrich the soil"

Eucalyptus species do not fix atmospheric nitrogen, however, the physical growth and the decay of roots have beneficial effects on the soil. There is also nutrient return to the soil through litter fall, and stem flow and through fall of precipitation.

Many species of *Eucalyptus* have moderate requirements of nutrients from the soil in relation to some agricultural crops[o]. Under *Eucalyptus*, there is often enrichment of soil due to incorporation of organic matter.

In summary, *Eucalyptus* species normally enrich the soil, especially on degraded sites**.**

Soil acidification

Eucalypts are very well adapted to growing on acid soils, but do not make the soils acid. On the contrary, the very high rates of return of Calcium to the soil through litter fall form eucalypts tends to raise the soil pH towards neutral, rather than reduce it. Eucalypts usually do not make the soil more acid.

Undergrowth

Sweeping statement. What undergrowth will grow under eucalypts will depend largely on what was the previous vegetation on the site, the species of eucalypt, what planting density is adopted, and what are the surface soil conditions. Davidson notes that, an interesting point to note is the prevalence of legume species and the presence of native forest species which have come up under the protection of the eucalypts on degraded hill sites, which had been devoid of tree vegetation for some time before plantation establishment [in Bangladesh][p].

In summary, eucalypts do not necessarily prevent undergrowth.

Water consumption

The only reliable measure of water consumption efficiency by plants is the weight of biomass produced per unit volume of water consumed, though some guidance can be gained from ratios of evapotranspiration to pan evaporation for different species or vegetation types. Considerable work on evapotranspiration rates and water balance of *Eucalyptus globulus* has been done in e.g. India. The annual transpiration of the eucalypts was reported to be about 3 475 metric tons/ha, which corresponds to only 347.5 mm equivalent of rainfall in an area

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[o] *See* corresponding Table in Davidson (1995).

[p] S*ee* also Loumeto and Bernhard-Revesat (1997).

where 1 300 mm rainfall is received; this means, in the case quoted, that 953 mm are available to be apportioned to interception, surface runoff, evaporation, deep percolation (ground water re-charge), water yield and soil moisture storage.

On the basis of unit weight of dry biomass produced eucalypts consume very little water.

Water table

Eucalypts have less effects on the water table than several other species of commonly planted trees.

Poor fuelwood value

This controversy probably has its origin from the historical fact that in the early 19th Century eucalypts were planted in t he Pontine Marshes near Rome and these marshes subsequently dried out and were reclaimed. Out of 600 species of eucalypt only a few have been grown successfully on waterlogged sites (*E. robusta*, *E. deglupta*, *E. tereticornis, E. siderophloia, E. ovata*, *E. hemiphloia).* Only two species have shown the ability to grow aerial roots on waterlogged sites (*E. deglupta, E. robusta)*. What ahs to be considered is the relative ability of the root system of different species to tap the ground water resources and the rate at which those ground water resources could be recharged. Water infiltration and sub-surface run-off are favoured by rapid development of tree root systems, whatever the species. Most eucalypt root systems are more specifically adapted to using rainfed soil moisture from the upper soil profile rather than from the ground water table at considerable depth. NB also that transpiration of water by eucalypts is a function of atmospheric humidity, soil water availability and leaf water potential. The stomatal mechanism is directly controlled by ground water availability through the resulting turgor pressure (leaf water potential). Under ground water stress, the leaf water potential or turgor pressure is lowered resulting in closure of the stomata, severely reducing transpiration. This means that when soil water availability is not a limiting factor, eucalypts use more of it, particularly when atmospheric humidity at the same time is low. When the soil dries out, the eucalypts have an adaptive mechanism which conserves soil water, irrespective of whether the atmospheric humidity is high or low. Another adaptive feature is that eucalypts maintain biomass production under moisture stress. All this helps explain why eucalypts consume a smaller amount of water per unit of biomass produced, compared to some less well-adapted species of trees. *In summary,* Eucalypt species recommended for use in Bangladesh are satisfactory fuel

"Poisons the soil"

All species of eucalypts, and some species in particular (e.g. *E. citriodora*), produce oils and waxes in their leaves. The latter produced on the surface of the leaves is an adaptation preventing water loss and is common to other xerophytic plants as well. It is generally believed that *Eucalyptus* leaf litter makes the soil toxic for seed germination and plant growth and thereby reducing the yield potential for a particular crop grown under or close to these species. The genus *Eucalyptus* has also long been known to produce several volatile turpenes and several of them have been shown to be toxic to seed germination and seedling growth of numerous plants, and one of the species studied has been *Eucalyptus camaldulensis* in which the fresh leaves contain large amounts of turpene. Many studies carried out. However, it is evident from many of these studies that the toxicity is severest when fresh leaves are extracted and the tests are carried out in the laboratory. Secondly, the studies are reported from zones which are dryer than any in Bangladesh; and thirdly, the toxic substances are volatile and water-soluble, *i.e.* they evaporate or are leached over time. Thus, studies have concluded that normal germination occurs in the field in contrast to the laboratory because the inhibitors are diluted and leached from the soil in nature. In some crops, such as cowpeas, germination has been shown to actually increase under the influence of leaf extracts from eucalypts. What can be concluded is that in very low rainfall areas - less than 700 mm per year[q] with particular soil physical properties, toxic substances added to the soil through leaf letter remain for a long time and will have an inhibitory effect on seed germination of some crop plants.[r].

"Not a multipurpose tree"

Criticism made with narrow view that eucalypts do not fix nitrogen and do not provide fodder. This is true, but on the other hand eucalypts produce timber, poles, posts, oils, medicines, honey, [raw materials for-] pulp and paper, fuelwood, charcoal, reconstituted wood products.

Davidson, J. (1989). *Eucalypt tree improvement and breeding.* Field Document FAO/ETH/88/010. FAO, Rome. 93 pp.

Document focused on species introduction, but with some information also on environmental effects.

Because of rapid disappearance of the highlands natural forests in Ethiopia, *in situ* and *ex situ* conservation of forest genetic resources must be given high priority. Pressures to convert these forests to non-forest uses such as coffee should be resisted. Similarly, they should not be converted to 'monoculture' plantations of eucalypts or any other [tree] species, even native ones. While eucalypts will continue to play an important role in Ethiopian forestry, there is a need to embark on similar tree improvement and breeding programmes for non-eucalypt indigenous and exotic species.

Natural forest should not be cut down to plant eucalypts. Eucalypts, however, have a role in providing buffer plantations around remaining patches of natural forest to reduce encroachment and illegal cutting[s].
The acceptance of local people in Ethiopia of eucalypts for fuel and roadside plantations, and in peri-urban areas, means that species of this genus have become, and are likely to remain, a permanent feature of the rural landscape in Ethiopia. 'Monocultures' of eucalypts would best

[q] CPL comment: Bouvet (1999), refers to same principle, but puts the "critical rainfall limit" at 400mm.

[r] CPL comment: but not all- see mention *e.g.* of cowpea above.

[s] CPL comment: During Meeting of 11th Session of the FAO Panel of Experts on Forest Gene Resources (Rome 29.9-1.10.99), Dr. P.Y. Kageyama of Brazil related the success of eucalypt block plantations among local communities in the cerrado areas of Brazil; firstly, local populations realized that the eucalypts provided a larger range of goods and services than did alternative crops, *e.g.* soya; secondly, they had noted the excellent source of honey that eucalypt plantations provided, if beehives were placed under the trees. In relation to above note from Davidson *re* Ethiopia, and also in relation to other places where eucalypts are planted around natural vegetation in a "buffer zone", CPL believes that this would provide an even better alternative for beekeeping: the bees need continuing availability of flowering plants; the existence of natural vegetation beyond the buffer zone would likely provide a supplemental source of flowering plants in this regard.

be managed as uneven aged stands on a partial cutting, rather than clear felling systems, if they are to retain their erosion control effect. Apart from these intensive 'monocultures' there is much scope for mixed planting of eucalypts of different species and eucalypts with species of other genera, such as *Acacia* and *Casuarina*.

Other management interventions to counteract possible adverse environmental effects of eucalypts mentioned:

On sloping ground spacing of eucalypt planting should be adjusted to provide for ground covers of creeping legumes and grasses. Physical soil conservation measures must be combined with tree planting and a vegetative cover of shrubs and ground covers. Many of these associated plants would be leguminous fodder species which could be harvested by cut-and-carry methods. Alternatively, eucalypts could be planted at a wider spacing, improved pasture developed underneath and the area managed for grazing on a strictly controlled, rotational basis, or if that is not feasible forage harvested on a cut-and carry basis.

"Whatever the kinds of uses for eucalypts, all situations would be improved by having available the best performing, most adaptive species for the purpose, by ...... provision of seed of the highest genetic and physiological quality to the users."

Davidson, J., 1995. *Ecological aspects of Eucalyptus plantations*. Proceedings of the Regional Expert Consultation on Eucalyptus, Bangkok, Thailand 4-8 October 1993. Vol. I. pp.35-60.

Key Reference.

A number of useful references to other documents on the biogeography, ecology and controversies, are given on page 41 of this paper by Davidson.

S*ee* especially Table 2 "Water Use by plants through evapotranspiration"(p.49). *See* also Table 3, "Uptake and removal at harvest of nutrients for fast-grown eucalypts in relation to an *Acacia* and other crops" (p.53). Other interesting Tables include, Table 4, "Nutrients in the litter of a fast-growing plantation of *Eucalyptus*";and Table 5, "Comparison of nutrients in litter fall under plantations of *Eucalyptus* and *Acacia*".

Overall conclusions:

Eucalypts can provide many benefits very quickly, ranging from industrial wood and fibre, poles and posts, through fuelwood and timber for household use, to nectar, oils, tannins and many other products. Several species are used for windbreaks and shelter.

On the debit side, fast growth and high biomass production of eucalypts require the consumption of much water and this consumption, though efficient in terms of biomass produced and one-half to one-third of that used by many agricultural crops, must be balanced with other requirements of finite water supplies such as for agriculture, livestock, and human consumption. Although trees take up as little as on-half to one-tenth of the nutrients than do most agricultural crops, the soil nutrient reserve on a site also is finite and there is a nutrient cost for high biomass production of the trees. The eucalypts, like many other tall trees, by themselves, may not protect the soil from erosion perfectly. They may not provide ideal habitats for the native wildlife and they may upset local traditions and values, if projects are not carefully planned. Nevertheless, in most respects, the eucalypts cannot be singled out as being always bad or as being uniquely different from other kinds of fast-growing trees under the same management conditions. Planted E*ucalyptus* trees will be successful only if they can grow well in the local conditions of climate and soil and only if they can provide the benefits required, either for industry or rural people in a sound land use and environmental management programme. The tree planting project must be accepted by, and bring benefit to, the people both directly and indirectly affected [t].

The issues addressed in this paper are:

Climate and microclimate

There is nothing to distinguish eucalypts for plantations of any other tree or from different types of native forests in their effects on regional rainfall or regional climate patterns. There are however effects of eucalypts on micro-climate at the local level. These effects depend on the amount of leaf surface carried by the trees in relation to the surface of ground covered. The greater the leaf area and the more horizontal are the leaves the greater the shading effect and the greater the evapotranspiration. In the shaded area, average air temperatures are lower, extremes of air and surface soil temperatures are reduced, and there is higher surface air humidity compared to areas with no trees. Eucalypts cast less shade, on average, than other broadleaved trees, but there are big differences in the amount of shade cast by different species because they have different leaf sizes and orientations. If a benefit is to shade out *e.g. Imperata* grasslands, more shading is an advantage; if one of the objectives is grazing under the trees, or to provide a living ground cover to protect the soil against erosion, species which cast less shade need to be chosen- or the trees must be planted at wider spacing.

Hydrology

Higher interception means less through fall and stemflow from a given rainfall event and therefore less rainwater reaching the soil. The dominating causal factor of interception loss is evapotranspiration of rainwater from leaves. Surface area of leaves will determine to a large extent, this varies among species. Wider spaced trees will intercept less rain; comparisons between species can only be generalized, as interception is also controlled by periodicity and intensity of rainfall. The majority of eucalypts intercept 10-25 percent under a wide range of conditions. Runoff rate depends more on ground surface conditions (slope, soil porosity, moisture conditions of the soil and litter before rainfall). Litter under pines, casuarina and acacia impede runoff more than litter under eucalypts in high runoff situations; under low runoff conditions there are no differences.

Water repellancy is caused by hydrophobic coating of organic origin on the soil particles; common sources of these organic coatings are soil microbes and fungal mycelia. Water repellant soils cause impeded infiltration and percolation, resulting in water moving along

[t] CPL comment: the fact that eucalypts are not "uniquely bad", is well demonstrated by the fact that identical or very similar critisisms are being raised in many countries in respect to pines (notably *Pinus radiata*, Australia); *Pseudotsuga menziesii* (notably in France); *Acacia* spp. (notably *Acacia mangium*, Malaysia); *Tectona grandis* (SE Asia); *Populus* spp. (Europe); and, in more general terms, single-species plantations.

preferred paths over and through the soil, causing patchy wetting of the upper soil horizons. Some Australian studies have shown that soils under eucalypts were more water repellent than adjacent similar soil after conversion to pine 23 years before. In South Africa, studies indicated that soils under eucalypts were water repellant (as compared to grasslands, pine, wattle soils) –refer in this latter case to: Scott (1991); and Scott and Schultze (1991) – see list of references. It must be noted that water repellancy is also found e.g. under citrus orchards, juniper and chaparal vegetation (California). Most forests, regardless of type, reduce greatly peak flood flows and buffer the influence of flood flows by increasing dry season flows and decreasing wet season flows. However that forested catchments yield less water than grassed catchments, because trees normally use more water than grasses. In regard to catchment management and ground water, site influences seem to be greater than species influences. Soil water balance and height of the water table at a particular site also can be influenced by factors far away from the site because water is mobile in underground aquifers.- Eucalypts use less water per unit weight of biomass produced than other kinds of trees and many agricultural crops (Table 2), however, their potentially high biomass production under low rainfall conditions may reduce stream flow more than slower growing trees or plants. Rate of biomass production in eucalypts can be regulated by species choice, fertilization and/or degree of fertilization, application of cultural practices, spacing,. Given proper planning there is no need to exclude the eucalypts because of their perceived high rate of water consumption.

Soil erosion

There is no reason to single out eucalypts for special criticism re erosion by water under trees; erodability of soils is more important than crop management, and crop management is more important than type of tree crop.

Erosive energy of rain under tree crowns will depend on surface area of leaves: large leaves produce large droplets which have a greater impact energy on the ground. Eucalypts, as a mean, medium sized leaves as compared to alternatives (extremes: casuarinas, teak). However, ground cover activities are more important (e.g. removal of litter livestock grazing/trampling, compaction by human use, harvesting/logging etc.). Eucalypts have been found to be very effective windbreaks, mitigating wind erosion, especially in semi-arid areas. Eucalypts are more effective than other tree species in this regard notably for ability to grow in harsh conditions, rather than for any physical attribute as such. –There is nothing special about the root systems of eucalypts *vis a vis* erosion as compared to other species; there are both shallow and deep-rooting species within *Eucalyptus* (and soil depth and aeration often determine root architecture to a greater degree than genetic makeup of the species) Many species of eucalypts coppice vigorously when cut, and have therefore been used widely in reforesting erosion-prone soils, especially slopes. N.B. that reforesting slip-prone soils can help prevent shallow landslips, but not the kinds of mass-wasting which are common geological processes in mountain terrains.

Soil nutrients

Table 3 shows that eucalypts can achieve high biomass production on a low nutrient uptake. The formation of ectomycorrhizae on the roots plays a major role in nutrient uptake in eucalypts. A substantial part of the nutrients are in the leaves, and returned periodically to the soil, and plantations thus improve the soil fertility on previously cleared sites. Maintenance of the nutrient cycle is critical to the long-term productivity of soils and it is essential that foliage and leaf litter are not removed from the site. Even greater benefits accrue if bark is also left behind at harvesting (up to 90 percent of the nutrients in the wood are withdrawn to be kept in the mobile shell of sapwood and pholoem of the tree, after about age 7). Needless to say, sufficient fertilizers or mulch should be applied to compensate for the loss of nutrients in harvest[u].

Competition and other interactions with flora and fauna

Criticism directed at planted trees which replace natural forest are proper, since a "monoculture" cannot replace the varied range of products and benefits which come from most indigenous forests,. However, there is a case for planting trees on degraded lands, for land stabilization etc.

All plants compete. In the case of planted trees, the actual situation has to be examined on each individual site. What is a competitive weed in one place may be a saviour in another.

A 20 ha woodlot, a 200 ha pole plantation and a 200 000 ha pulpwood plantation will have markedly different effects on the local flora and fauna, as will management regimes. Planted stands of any tree will generally contain a lower number of animal species than natural forests, where these are more diverse[v].

Allelopathy

Most of the studies put forward as "evidence" for eucalypts being strongly allelopathic involve laboratory studies of artificial extracts on germination of seeds *in vitro* or early growth of potted plants which provide conditions probably far removed from those found in the field. In the field, the effects observed on understoreys or adjacent intercropped food crops is, more often than not, the result of extreme competitiveness for water and nutrients[w]. N.B. that eucalypts are extremely difficult to establish in many conditions, especially in humid, fertile sites, because of competition of weed growth implying that, allelopathic effects, if present, are masked by good climatic and soil conditions and/or the trees are less competitive than the weeds under such conditions. On infertile soils in dry climates often no understorey develops under eucalypts grown on infertile soils; probably both extreme competition for soil water and nutrients, soil non-wettability, and allelopathy may here be operating together.

Susceptibility to fire

Virtually all planted forests are susceptible to fire damage, and more so at less than 5 years of age. The vulnerability of eucalypts is often due to the fact that the plantations are established on land covered with grass, weeds, brush, which is highly flammable in dry weather. Peasants often set fire to hunt, to improve grass palatability, or to clear fallows[x]. Flammability: under similar fire hazard conditions species of widely planted genera such as *Casuarina, Juniperus,*

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[u] CPL comment: while experiences *e.g.* in Swaziland- *see* Evans (1997); and Brazil- *see* Campinhos (1999)- seem to demonstrate that correct management will minimize needs for fertilization, this is an aspect which must be monitored in serious short-rotation plantation schemes.

[v] CPL comment: see however e.g. references in Bouvet (1999).

[w] CPL comment: referenence to competition for *light* should be added.

[x] CPL comment: sometimes burning is done even only due to "tradition" (*e.g.* Papua New Guinea), with original purpose having been removed and forgotten.

Pinus, are equally or more flammable. In the tropics and sub-tropics, a relatively greater area of *Pinus* plantations has been lost to fire than that of *Eucalyptus*.

Most thick-barked eucalypts above approx.3 years are resistant to permanent damage from fire; dormant buds sprout and renew the canopy in a relatively short time. Some species of eucalypts have lignotubers which are fire resistant.

Davidson, J. (1998*)* *Domestication and breeding programmes for Eucalyptus in the Asia/Pacific.* Field Document -Project FAO/RAS/91/004. FAO/RAP, Bangkok, Thailand).

Despite many reports on their success, in many respects, planted eucalypt trees in the Asia/Pacific region have not been seen as ideal or lived up to most expectations. One of the reasons for this is the low and declining genetic quality of recent large-scale plantings.

[Productive benefits] with proper planning and management, will accrue to all levels of society from the national level (e.g. export income) through provincial (e.g. taxes, revenue), company (profits) and individual (wages, sale of products) levels. The effort extended by governments and corporations have the potential to filter through to rural growers since the benefits of better survival and greater vigour of the trees are advantageous also to eucalypt planting in small woodlots on farms[y].

Del Moral, R. and Mueller, C.H., 1970. *The allelopathic effects of Eucalyptus camaldulensis.* American Midland Naturalist 83:254-282.

The absence of natural vegetation near naturalized stands of *E. camaldulensis* could according to the author not be explained by differences in soil, grazing or light. Extracted terpenes and water soluble toxins proved toxic to germinating seeds of annual crops on heavier soils but not on sands (laboratory test). Ten phenolic toxins were isolated.

Eldridge,K., Davidson, J., Harwood, C., Van Wyk, G.,1993. *Eucalypt domestication and breeding***.** Clarendon Press, Oxford.. 306 pp

The document notes that it has been said that "Eucalypt plantations are without biodiversity, monotonous and not aesthetically pleasing". While the overstorey is simplified, the understory in a eucalypt forest contains considerable biodiversity, which does not occur in an agricultural field[z].

The ranking of the most important species in terms of annual increment of wood, include: *E. grandees, E. camaldulensis, E. tereticornis, E. globulus, E. urophylla, E. viminalis, E. saligna,*

[y] CPL comment: coraollary here is that if rural people and farm owners are not involved or get benefits, they will oppose eucalypt –or any tree- planting.

[z] CPL comment: more than on what species is used, this will also depend on the size of the plantation, surrounding landuse, age, and management; and whether it is the first or subsequent generations.

E. deglupta, E. exserta, and then either *E. citriodora, E. paniculata* or *E. robusta*. Of these, the four first mentioned ones are by far the most important on a world basis.

Evans, J., 1997. *Wood production sustainability of forest plantations.* Proceedings of the XI World Forestry Congress, Turkey. Vol III. pp.39-46. (English, French, Spanish).

In the last 40 years there have only been two important examples of general productivity decrease in successive rotations of: *Pinus radiata* in southern Australia, and *Cunninghamia lanceolata* in subtropical China. The situation in Australia was repeatedly corrected through a careful management of organic matter and tree fertilization, weed control and genetic improvement programme of forestry species. In China, similar improvement of local characteristics probably will avoid the problem of production decrease, at least where *Cunninghamia* has been appropriately planted.

In Swaziland, productivity evaluations of successive rotations of *Pinus patula* were carried out in Usutu Pulp Company plantation since 1968. After three complete rotations, productivity levels were maintained or have lightly increased in most of the forest, without the use of fertilizers o genetic improvement. In a small proportion of the forest (13 percent) productivity decreased between the first and the second rotation but not between the second and third. This problem may be solved in a localized way by fertilizing with phosphates ...Trials show that so far the forest plantation is sustainable. The introduction of genetically improved material must increase the production of future rotations.

Trials show that well managed forest plantations at world level constitute a total sustainable silviculture for wood production.

FAO, 1981. *El Eucalipto en la repoblación forestal.* Collección FAO Montes No.11. FAO, Roma. (English, French, Spanish). 723pp.

General references on taxonomy, characteristics, plantation, improvement *etc*. of *Eucalyptus* spp.

FAO, 1987. *Los efectos ecológicos de los eucaliptos*. Estudio FAO: Montes 59. FAO, Roma. (English, French, Spanish). 106pp.

Document based on the revision of literature, including three bibliographic studies: FAO (1994a), (1994b), (1994c). The information was completed by opinions of experts in a meeting organized to discuss a preliminary draft.

It is suggested to make reference to this document jointly with documents: FAO (1986) and FAO (1990) – that reached the same technical conclusions.

General observations

Ecological effects may only be assessed taking into account, as a basis for reference, what society deems necessary.

There is no global answer to the question whether eucalypts consume significant quantities of water or not; the hydrologic impact of *Eucalyptus* spp. Must be studied in different environments. If trees are removed, there will be periodic flood cycles alternated by low quantities of river flows. The ecological characteristics of a region where *Eucalyptus* spp. or other fast-growing species may be planted, must be studied in order to evaluate the feasibility in relation to local hydrology.

Water

Catchment areas in forests have higher water yield than those located in shrublands or grasslands, plus they better regulate the water flow, according to the type of terrain (all genera/species, incl. *Eucalyptus* spp.). Nevertheless it was proved that in humid tropics, fast-growing young eucalypt plantations consume more water and do not regulate water as appropriately as natural forest do. When eucalypts are planted in treeless terrain, water provision to the catchement areas is reduced and hydrostatic level decreases. Probably other genera produce the same results. The strong superficial roots of some *Eucalyptus* spp. force them to vigorously compete with ground vegetation and nearby crops when water is scarce.

Erosion

Eucalypts do not give good results in erosion control in dry conditions, as they eliminate ground vegetation by absorbing the water through their roots. As protection barrier, *Eucalyptus* spp. show similar results to those produced by other trees of equal size and shape.

Nutrients

The effects of non-felled eucalypts that remain in plantations depend on their state. *Eucalyptus* spp. are beneficial when the soil is degraded, but they are not beneficial when they replace natural forests. When *Eucalyptus* spp. are planted in bare land, organic matter is accumulated and incorporated, thus having a beneficial impact on the soil. Felling of eucalypts in short rotation schemes, specially if all the biomass is extracted, produces a rapid depletion of soil nutrient reserves. This is a direct consequence of their fast growth: the same would happen with any other high productivity species, a characteristic that is closely linked to the duration of the rotation. Proof exists that nutrient consumption in *Pinus* spp. plantations is higher.

Competition

The effects of *Eucalyptus* spp. On ground vegetation depend in great measure on climate. In most of the cases these effects are due to species competing for water; while effects due to light reduction are probably minor compared to those of other broadleaved species or *Pinus* spp., due shade scarcity of *Eucalyptus* spp. foliage. Ground vegetation is not as affected in humid environments as in a dry ones. It is known that some *Eucalyptus* spp. produce toxins that hamper growth of some annual cycle weeds. The number and diversity of fauna (mammals, birds, insects) are less in *Eucalyptus* toxic species plantations than in natural forests. Such effect may be reduced, but not eliminated, through appropriate management to create an adequate habitat.

Displacement

Eucalyptus spp. plantations tend to displace previously existing ecosystems. The importance of these original ecosystems should be carefully assessed both in ecological and social terms and compared with the advantages that new plantations may produce.

After a careful analysis of trials, it must be stressed that there is not a solution universally valid about favourable or negative effects of plantations of *Eucalyptus* spp. A universal response is not credible, a case by case analysis must be done. Apparently, this conclusion has not been changed by new general research however detailed it is.

A plantation of *Eucalyptus*, spp. specially a large-scale one, may be established only after a careful and insightful evaluation on the social and economic effects, together with a comparative approach to find out what the advantages or disadvantages are. The best way to reach this purpose is probably to study with an open mind the ecological circumstances and the needs of the local population, for which, the results of basic research on water, nutrients etc. may be useful. [in other countries and locations]. Nevertheless, the extrapolation of results to different situations is not recommended, nor making unjustified generalizations deriving from them.

FAO, 1986 *¿Los eucaliptos son ecológicamente nocivos? Unasylva Vol.38 (152):2-5*. FAO, Roma. (English, French, Spanish).

Extract of FAO Forestry study No. 59 (FAO 1987).

Suggestion is made to refer to this document jointly with the following documents: FAO: (1987) and FAO (1990)– as they have reached the same conclusions.

FAO, 1990. *El dilema del eucalipto*. FAO, Roma. (English, French, Spanish, Portuguese,Lao,Thai). 26pp.

Suggestion is made to refer to this document jointly with the following documents: FAO: (1986) and FAO (1987)– as they have reached the same conclusions.

FAO, 1992. *Plantaciones monoespecíficas*. 33ª Reunión del Comité Asesor sobre la Pasta y el Papel. Roma Italia 18-20.5.1992. Documento FO:PAP/92/Inf.16. (English, French, Spanish). 11 pp.

Suggestion is made to refer to this document jointly with the following documents: FAO (1995) and FAO (1999)– as they have reached the same technical conclusions.

FAO, 1994a. *Bibliografía Anotada sobre efectos ambeintales, sociales y económicos de los eucaliptos***.** Publicaciones en Español. FO:MISC/94/11. FAO, Roma. (Spanish). 16pp.

Bibliography prepared by FAO (1986).

FAO, 1994b. *Bibliographie annoteé sur les effets écologiques, sociaux et économiques des eucalyptus.* FO:MISC/94/11. FAO, Rome. (French). 25pp.

Bibliography prepared by FAO (1986).

FAO, 1994c. *Annotated bibliography on the ecological effects of eucalypts***.** Publications in English. FO:MISC/94/11. FAO, Rome. 70pp.

Bibliography prepared by FAO (1986).

FAO, 1994 d. *El desafío de la ordenación forestal sostenible: perspectivas de la silvicultura mundial*. FAO, Roma. (English, French, Spanish). 122pp.

This paper gathers general sylviculture principles. *See section on* "Forestry myths" pp. 38-40 concluding that*:*

It is always necessary to be careful when selecting and planting trees, not only to have species adequate to the season and use required for by people, but due to the impact, specially in agricultural land. The rejection of many schemes by the population, in spite of the enthusiastic defence of forest plantations, is not always deprived from fundament as it was usually thought of in the past.

FAO, 1999. *Plantaciones forestales mixtas y puras de zonas tropicales y sub-tropicales*. Estudio FAO: Montes 103. FAO, Roma. (English, French, Spanish). 166pp.

Suggestion is made to refer to this document together with the following papers: FAO (1992) y FAO (1999)– which have reached the same technical conclusions. Also see Wadsworth (1997).

Environmental impact is analysed in terms of aspects related to soil, including erosion, climate and fire, wildlife and flora and pests and diseases of pure and mixed plantations, including:

- conservation of topsoil layer and of organic matter;
- nutrient replacement restoration of physical conditions once the exploitation operations are carried out;
- nutrient requirements.

Effects of plantation management are examined. It was frequently observed that plantation management planning does not always give the necessary attention to sustainability and fertility on the long-term.

NB. The debate and conclusions on mixed and pure plantations, as well as that on eucalyptus are the same: *"it depends";* as well as the emphasis that many problems may be to solved with *"good forestry practices"*.

FAO, 1995. *Sistemas de realización de la ordenación forestal sostenible***.** Estudio FAO: Montes 122. FAO, Roma. (English, French, Spanish). 292pp.

It must be stressed that it is necessary to carry out "good forestry practices". General principles are identical to those principles used to minimize damaging effects of eucalypts.

Establishment of plantations is a valid alternative for forestry production. Plantations usually have the important objective of producing wood, but also provide services such as housing and shelter; at the same time, they provide non-wood products, but they cannot provide a series of goods and services produced by natural forests, and thus may be used as a complement. Silvicultural and management practices that contribute to sustainable production include improved/adapted genetic material for planting, maintaining soil fertility through the incorporation of residues or fertilizers, protection against erosion and finally, fight and follow-up actions against diseases, as well as low-impact extraction equipment. It also includes the preservation of a proportion of natural forest area with its local flora and wildlife.

FAO, 1999. *Situación de los bosques del mundo.* FAO, Roma. (English, French, Spanish). 154 pp.

The document gives information on the role that forest plantations play in wood and firewood production, carbon sequestration, land protection in arid areas, etc. The section on mixed and pure plantations has special relevance with regard to the paper by Palmberg-Lerche and Patiño, and also to FAO documents (1992) and (1995). See extract below, that refers to pages 18-23 of the document:

Many of the environmental and social problems that forest plantations pose are related to the way these are established, that is to say as blocks of trees of the same age planted in straight rows in a regular spacing. The criticism expressed about monocultures have awakened great interest in using more than one species in plantations...Nevertheless, the experience and figures available on the establishment and management of this type of plantations of mixed species are still very few, with the exception of some examples such as the long established practice of using protective species in mahogany plantations in western Africa, Central America and Oceania to obtain shade and protection against attacks from *Hypsipyla* insects.

FAO/RAPA, 1995. *Proceedings of the Regional Expert Consultation on Eucalyptus. Bangkok, Thailand 4-8 October 1993.* Vol .I. FAO/RAPA Publication:1995/6. FAO, Bangkok. 96 pp.

The proceedings of this expert consultation held in Bangkok in October, 1993 present a significant number of relevant articles (some of them are referred to in this bibliography). The consultation had the objective of complementing strictly technical information referring to productive aspects of eucalypts with information on the social and economic aspects, with the aim of, (i) facing the confusion existing on technical issues and social and economic issues; and (ii) searching complementary information on social and economic aspects in order to achieve a holistic view on the issue. Some of these aspects have been extracted from the Introduction to the paper[aa]:

"Sometimes it seems, from the extreme statements that are made in the condemnation or defence of species of the genus Eucalyptus, that eucalypts are either loved or hated".

FAO is committed to understanding the reasons for the extreme positions, to identifying the role of the species, and to disseminating the results of the examination. The objectives of the consultation were therefore to review the evidence for or against the use of the eucalypts in given situations by bringing together the growers of eucalypts (whether the private or public sector), the users of the wood of eucalypts, those who research into all aspects of its environmental, economic and social effects, and (most important of all), those who are affected positively or negatively by *Eucalyptus* plantations, to discuss experiences.

One of three Groups reviewed the Bio-Physical and Environmental Impacts of *Eucalyptus* Plantations, under the following headings (pp. 137-140):

- Water Consumption
- Soil Erosion
- Nutrient Cycling
- Allelopathy
- Biodiversity
- Pests and Diseases
- Sylviculture and Management
- Tree Breeding
- Effects on Microclimate.

The Group also discussed, "How to minimize adverse environmental impacts"; and "Alternatives to *Eucalyptus*".

The findings and conclusions differ little if at all from the information given re above references.

[aa]*Also see*: Sharma, J.K., Nair, C.T.S., Kedharnath, S. and Kondas, S. (Eds) (1984)- ref. below.

The other two Groups discussed: Social and Economic Impacts of *Eucalyptus* Plantations (pp.141-143); and Policy Issues, Financial and Institutional Support (pp.144-147).

Florence, R.G.,1986. *Cultural problems of Eucalyptus as exotics***.** Commonwealth Forestry Review Vol. 65:141-163.

Conclusions:

- The remarkably wide range of genetic material in *Eucalyptus* has not been adequately tapped in species introduction programmes.

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

- Some observed effects of eucalypts on the soil condition might be attributed to strong competition for water and nutrients, rather than a direct "toxic influence" on the soil.

- Where trees replace grasslands or a low natural vegetation, a reduction in water yield from the catchment should be expected; where eucalypts are panted, 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 cannot be determined from the available evidence.

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

George, M., 1982. *Litter production and nutrient return in "Eucalyptus Hybrid" plantations.* Indian Forester 108(4):253-260.

Analysed total litter fall, and nutrient concentration in litter in three plantations of "Eucalyptus Hybrid" in Northern India, aged 5,7 and 10 years. A comparison was made of the return of different elements in stem flow, through fall and precipitation.

George, M., 1986. *Nutrient uptake and cycling in young Eucalyptus hybrid plantations*. My Forests, March 1986.

Production of total biomass and non-photosynthetic biomass in a 5-year old "Eucalyptus hybrid" plantation in India was analysed. Amounts of nutrient used and recycled were reported upon, showing that maximum nutrient retention was for phosphorous. The author suggested necessity of fertilizer application for sustained biomass production (under the conditions of the trial investigated).

George, M. and Varghese, G. 1990. *Nutrient cycling in Eucalyptus globulus plantation. Organic matter production, nutrients accumulation in standing crop and nutrients removal through harvest*. Indian Forester 116(1):42-48.

George, M. and Varghese, G.,1991. *Nutrient cycling in Eucalyptus globulus plantation. III. Nutrients retained, returned, uptake and nutrient cycling.* Indian Forester 117(1)- Febr.1991

The two articles above, as the work by George (1986), cover aspects of *Eucalyptus* nutrition. It was noted that the greatest drain of nutrients occurred through wood harvest, and among the nutrients the highest drain occurred for Nitrogen and Kalium. Litter fall contributed maximum amount of all nutrients returned to the soil. Results were compared with other forest plantation species.

Ghosh, R.C., Kaul, O.N. and Rao, B.K.S.,1978. *Some aspects of water relations and nutrients in Eucalyptus plantations.* Indian Forester 104 (7):517-524.

Reviewed literature available on the effect of eucalypt plantations on hydrology and soil properties in a number of countries and concluded that in contrast to some suggestions, the benefits of these plantations outweighed any adverse effects.

Kallarackal, J. and Somen, C.K., 1997. *An ecophysiological evaluation of the suitability of Eucalyptus grandis for planting in the tropics*. Forest Ecology and Management Vol. 95:53-61.

Study based on results from a 4-year old coppiced plantation of *E. grandis* for his experiments. Found that eucalypts are more efficient water users than other tree species. The less water is available, the more efficient is the use of water of eucalypts. *E. grandis* is not a high water consumer because of its good stomatal control of transpirational water loss, especially during the dry season when the atmospheric vapour pressure deficit is high. There is a tendency for the stomata to close in response to atmospheric vapour pressure deficit, in spite of relatively high leaf water potentials; this is a positive feature in an afforestation programme where water conservation is also an important motive. At the same time, (partial) stomatal closure can result in reduction of photosynthesis, thus [negatively] affecting the yield. However, the photosynthesis studies also showed that the dry period experienced in the study location [Kerala, India] does not seriously affect the photosynthetic rate of the trees on a leaf unit area basis.

There are however big difference among species in this- author quotes FAO (1987)- see above- stating that the hydrological impact of the eucalypts will have to be studied in the different environments.

See also reference below to Sharma, J.K. Nair, C.T.S., Kedharnath, S. and Kondas, S. (Eds) (1984).

Kokou, K. et Gabdoe, E., 1999. *Les Eucalyptus de la forêt d'Eto (Togo): pour sauvegarder les forêts naturelles*?. Le Flamboyant no.49: Spécial Eucalyptus. p. 52. L'Association Silva, Paris, France. (French).

The need for appropriate management of plantations in Togo is stressed, and above all, the need to involve rural and local communities in the planning and execution of a plantation programme, which has been established to meet prevailing and increasing needs of wood and help conservation of natural forests in the country. Experience to date has shown that unless this is done, plantations are damaged and burned at regular intervals. While the species appears promising from the technical point of view, such promises have not been realized to date. A new programme tries to rectify this.

Laclau, J.P., Bouillet, J.P., Nizinski, G. et Nzila, J.D., 1999. *La fertilité des sols sous Eucalyptus: impact des plantations en savane autour de Pointe Noire (Congo*). Le Flamboyant no.49: Spécial Eucalyptus. pp.26-28. L'Association Silva, Paris, France. (French).

This paper reviews the impact of *Eucalyptus* plantations on groundwater and soils. These plantations grow in poor-nutrient savana soils with an annual rainfall of 1 200 mm. Plantations cover 42 000 ha and the species used are hybrids). The study confirms that eucalypts have lower water and nutrient requirements than other planted tree species, and they require more of both than the native forest vegetation.

Negative effects on ground-water levels were not found. The paper states that the eucalypt plantations are not considered a threat to water availability in the area planted.

Regarding nutrients, the paper notes that eucalypts are exceptionally efficient in reaching and utilizing scarce nutrients. While the study is too recent to reach firm conclusions, it is noted though, that there is a well-founded need to closely monitor the effects of eucalypts on the savanna soils on which they have been planted, and the need to provide supplements through fertilization.

Lima, Walter de Paulo y Otávio Freire, 1976. *Evaopotranspiracao em plantacoes de eucalipto e de pinheiro, e em vegetacao heracea natural* (IPEF, Piracicaba (12): 103-117. Jun.1976.(Portuguese).

The paper reviews dry season water consumption of eucalypt and pine plantations in Brazil, comparing them to natural herbaceous vegetation, using the soil water budget technique. The study showed no significant difference in soil water regime among these vegetation covers; and thus no adverse effects of eucalypt plantations on the soil water regime, as compared to those observed for the natural herbaceous vegetation (and pine).

Lima, Walter de Paulo, 1984. *The Hydrology of Eucalypt Forests in Australia- a review*. IPEF Bulletin, Piracicaba. Dec 1984. pp 11-32. (English).

Notes that eucalypts in Australia are concentrated mainly in the moister parts of the continent[bb]. Eucalypt forests in catchments are considered the best alternative for water production.

The study concludes that regarding the situation in Australia:

- Interception losses in eucalypt forests range from 11 to 25 percent;
- root system spread and depth varies according to the species, with different effects on water uptake and soil. Stand density is of fundamental importance. In plantations, effects on soil moisture reserves appear at approximately 4-6 years-old in eucalypts, thus soil water deficit becomes larger than in natural forests.

- Transpiration rate varies among species which have not developed mechanisms against higher rates of transpiration, are likely to suffer from drought stress, which limits their range of habitats. The majority of eucalypt species however are drought tolerant. Comparative studies have shown that evapotranspiration in eucalypts is in the same order of magnitude as in pines. Young vigorous stands of *E. reganans* were found to yield less water in comparison with mature forest of the same species, but water yields tend to equalize as stands mature.

- No differences in stream flow from catchments containing different eucalypt species, although there were some differences in amounts of rainwater collected under different species of eucalypts, and possibly differences in quality of water beneath the canopy.

- Comparison of catchment nutrient budgets of different eucalypt forests with data from other forest types of the world shows a conservative balance for the eucalypt forest catchments, which is a reflection of the stable condition of these ecosystems.

- Hot fires in eucalypt forests can increase peak discharge, runoff and summer base flow, but apparently had no effects on stream water quality (possibly some increase in water soluble cations in the soil solution).

- Thinning and selective cutting in eucalypt forests can reduce water consumption and increase stream flow. Clear felling mature, wet euc forest increases stream flow by some 400mm/an. Clear felling has been found in one case to increase stream flow salinity.
- As demand for water increases, one of the options is to increase water yield in catchments through sound forest management.

The paper concludes that additional research is needed on many aspects of water management/use.

[bb] CPL comment: there are some notable exceptions to this statement; the statement refers in essence to the species used in plantations in Brazil.

Lima, Walter de Paulo, 1987. *O* Reflorestamento com Eucalipto e seus Impactos Ambientais. (Portuguese). 114pp.

Lima, Walter de Paulo, 1993. *Impacto Ambiental do Eucalipto.* USP, Editora da Universidade de São Paulo. (Portuguese). 301pp.

The above documents review the following aspects:

Hydrology of eucalypt plantations

- Interception
- Surface runoff
- Water quality
- Soil water and water table
- Stomatal behaviour, consequences for biomass production and transpiration
- Water consumption
- River stream flow

Soils

- Chemical properties
- Physical properties
- Nutrient cycling

Effects on flora, fauna

- Diversity in undergrowth
- Fauna: needs, diversity, adaptation

Use of Eucalypts in agroforestry systems

Plantations and environment

- Maintenance of harmonious functioning of the ecosystem
- Maintenance of productivity
- Maintenance of biological diversity.

Research needs are outlined. General findings are in line with other references above, e.g. Davidson (1989), (1995).

Loumeto, J.-J. and Bernhardt-Revesat, F., 1997. *La biodiversité dans les plantations d'arbres à croissance rapide au Congo.* Bois et Forêt des Tropiques no.253:57-61. (French).

It was noted that a range of native herbaceous and woody species established themselves under the *Eucalyptus* spp. plantations.

A large increase in soil microbes under eucalypt plantations, as compared to the savanna vegetation which they replaced was also noted **(***see* also Davidson (1985)- above).

Morris, J., 1997. *Water use by eucalypt plantations. ACIAR Newsletter No.22*. Australian Centre for International Agricultural Research. pp. 1,4. Canberra, Australia. (English).

Although establishment of eucalypt plantations on previously treeless land is likely to lower the water table, there has been no clear evidence that eucalypt have any greater effect on water use than other fast-growing trees and shrubs.

Present study reports on studies in salt-affected areas in Pakistan, Thailand and Australia, measuring water use by 14 plantations covering a range of species and site conditions. The results suggest that differences between species

(*Casuarina, Eucalyptus camaldulensis, Prosopis pallida, Acacia nilotica, A. ampliceps)* in a given site are largely attributable to differences in their growth rates, in terms of sapwood area per ha. Annual water use by the plantations studied ranged from 300 to 2,100 mm. The combined data set provides a sound basis for further research on the influence of soil and climatic conditions on plantation water use.

N.B. interesting result related to comparisons between tree plots on sites of differing salinity, which confirm that sapwood area is the main source of differences in water use. At a site in N.Thailand, *E. camaldulensis* on a severely saline site transpired only 270mm per year, while trees of the same provenances on a less saline site nearby used 1,230mm. Sapwood area differed by a factor of four.

Nzila, J.D., Loumeto, I. and Mboukou-Kimbatsa, I., 1999. *Propriétés physico-chimiques et biologiques des sols sous Eucalyptus: cas des sols acides du Congo***.** Le Flamboyant no.49: Spécial Eucalyptus. pp.28-30. L'Association Silva, Paris, France. (French).

Studies in Congo indicated a slight acidification of soils at the surface level (0-5cm) which, however, is compensated by increase of organic material of the soil. Notes need to supplement nutrients removed, if lops and tops are not left on the site.

Noted increase in soil microflora, likely due to increased organic matter. Gradual increase of undergrowth and fauna, demonstrating considerable ecological enrichment in the ecosystem, with more diversity present than the adjacent savanna.

Ong. Chin K., 1993. On the Difference between Competition and Allelopathy. Agroforestry Today 5(2).

The literature reviewed focused on allelopathy and competition. The stud concluded that there is a need to carefully distinguish between competition and allelopathy; and that studies pointing to the latter must demonstrate that there is no competition for resources which can be the reason for results of experiments.

Palmberg-Lerche, Christel, 1992. *Conservación de recursos genéticos como parte integral de la estion forestal y el mejoramiento de árboles forestales; incluyendo consideraciones especiales relacionadas al aprovisionamiento de semillas***.** Proc. International Symposium on Seed Procurement and Legal Regulations for Forest Reproductive Materials in Tropical and Sub-Tropical Countries, organized by KEFRI/GTZ/ IUFRO in Nairobi, Kenya 4-10 de October de 1992, in technical cooperation with the FAO. pp. 475-485; pp.189-190 (references). GTZ/KEFRI Forest Seed Centre, Muguga (Kenya). (English, French, Spanish).

A large number of species and genera may provide goods and services usually needed from forestry species such as wood, firewood, fodder and environmental balance. Nevertheless, out of the 500 forestry tree species systematically tried, less than 40 of them are actually being improved for human use. It is also true that many countries and regions use a wide variety of species to provide the same goods and services, even in cases where intensive forestry production programmes are in place. Species and provenances used are adapted against variations in soils and micro-climates. Therefore, the development of well-adapted material for forestry plantations was and will be less subject to a centralized control and commercial interest than species used in agriculture.

Palmberg-Lerche, Christel, 1993. Present situation of forest plantations and tree improvement in the Americas, with special reference to Tropical America. Proc. First Pan-American Forestry Congress and the Seventh Brazilian Forestry Congress, held in Curitiba, Brazil 19-24 September 1993. Vol.III:142-149. Sociedade Brasileira de Silvicultura & Sociedade Brasileira de Engheiros Florestais, Curitiba (Brazil).

The paper reviews past and present trends in plantation forestry. Special reference is made to Tropical Latin American and Caribbean countries. Traditional and new technologies in tree improvement and genetics provide exciting tools for increasing production of a range of goods and environmental services from forest plantations and tree planting. The paper underlines that improvement strategies must be part of sound forest management planning and must be based on technically solid plantation practices, including correct choice of species and provenances and adequate establishment and forest management techniques.

Palmberg-Lerche, Christel y Ball, J.B., 1998. *El estado actual de las plantaciones forestales en Àmerica Latina y el caribe y examen de las actividades relacionadas con el mejoramiento genetico. Trabajo preparado como expositor invitado para la sesión. "Establecimiento, Manejo y Protección de las Plantaciones***".** Primer Congreso Latinoamericano IUFRO/FAO: El Manejo Sustentable de los Recursos Forestales, Desafío del Siglo XXI. Valdivia, Chile 22-28 noviembre 1998. (English, Spanish).

This document looks into the current state of forest plantations in Latin America and the Caribbean. It underlines the need to improve their quality and increase the production of a series of environmental goods and services that may be obtained through the establishment and management of forest plantations, ensuring at the same time, the conservation of the necessary genetic variation. The document stresses that forest plantation strategies and genetic improvement must be an integrated part of a well-conceived forest management process. In order to achieve satisfying results, relevant activities must be supported by adequate policies that take into account the needs of a series of users, that must be supported by an institutional framework, based on scientific practices and well-known techniques that take into account short-term and mid-term benefits, as well as the long-term stability of the programme.

Rao, P.R., 1984. *The Eucalyptus controversy*. Proceedings of Workshop on Eucalyptus plantations, held on June 29, 1984. Bangalore, India. pp. 1-8,.

Overview of ecologically and socially controversial factors in *Eucalyptus* spp. growing in India.

Sargent, C. and Bass, S., 1992. *Plantation politics: forest plantations in development.* Earthscan Publications, London.

In discussing the objections of farmers to the Thai government's plantation programme it has been stated that farmers will not lightly cede rights to land and livelihood, and they have cited the supposed environmental damages of *Eucalyptus* to crusade against the [government's plantation] policy. The battle is not about *Eucalyptus*, however. It is about power.

Saxena, N.C., 1999. *Agrosilvicultura con eucaliptos en la India: ¿Por qué tantas dificultades*? Unasylva Vol. 43 (170) 1992:53-58. FAO, Roma. (English, French and Spanish).

Looks at the sequence of enthusiasm, demise and re-emergence of the will to plant eucalypts by Indian farmers under the following headings, which describe the underlying causes for these developments rather well:

- Production related problems
- unbalance between supply and offer
- commercialisation problems; markets
- negative effects on agricultural production.

Additional to the above, policy level aspects which influenced the attitude towards eucalypts, technical issues came into play. Soils were poor, and no attention was paid in the beginning to replacement of nutrients removed in harvesting. Reproductive materials used by farmers were frequently of poor physiological condition and genetically sub-standard (seed was often collected from hybrid, or lone single, trees). Attention to quality of reproductive materials used, undercropping with leguminous species, rotations of not less than 13-14 years, better matching of choice of species with needs or wishes of farmers as well as with site conditions, are recommended in the article. Author draws attention to potential role of eucalypts in reforestation of wastelands, providing revenue and job opportunities as well as alternatives to poor farmers.

Scott, D.F., 1991. *The influence of eucalypts on soil wettability. In: Shönau, A.P.G. (Ed).* Proc. IUFRO Symposium on Intensive Forestry: the role of Eucalyptus. Vol II, pp.1044-1056. SAIF, Pretoria, South Africa.

Discusses water repellence of soils under eucalypts**.** See also Davidson (1995), and Scott and Schultze (1991).

Scott , D.F. and Schultze, R.E., 1991. *Fire, water and soil erosion. In: Shönau, A.P.G. (Ed).* Proc. IUFRO Symposium on Intensive Forestry: the role of Eucalyptus. Vol II, pp.1057-1068. SAIF, Pretoria, South Africa**.**

Discusses water repellancy of soils under eucalypts. See also Davidson (1995), and Scott (1991), refs above.

Sharma, J.K., Nair, C.T.S., Kedharnath, S. and Kondas, S. 1984.
Eucalypts in India: Past Present and Future. Proc. National Seminar. January 1984, Peechi, Kerala Forest Research Institute, India.

It is suggested to refer to this document together with the paper by Kallarackal and Somen (1997) on water use.

It is suggested to refer to this document together with the paper by FAO (1995), as the latter also refers to a previous meeting on the same theme.

Rao, N.S. and Reddy, P.C., 1984. Studies of the inhibitory effects of "Eucalyptus Hybrid" leaf extracts on the germination of certain food crops. Indian Forester 110 (2): 218-222.

Investigations on *Eucalyptus tereticornis* were carried out to study the effect of leaf extracts on the germination and other growth parameters of selected dryland food crops. Seeds of crop plans were sown in seed pans and in Petri Dishes and treated with a diluted aqueous extracts of eucalypt leaves. Observations on germination were recorded from the third day to the tenth day from sowing, and after 20 days growth behaviour, root and shoot length and dry weights were recorded. It was found that leaf extracts inhibited germination in some plants, whereas they increased and stimulated germination in others (cow pea, horse gram, green gram). In species in which inhibitory effects were found (*e.g. Cajanus cajan.* coriander, beans*)*, seedlings in Petri Dishes died within a few days after germination. Compared with controls, the overall growth rate of these seedlings was also reduced. Heavy mortality and reduced vigour in laboratory conditions indicated that the accumulation of toxic substances is harmful to the growth of [many] crop plants. Gradual recovery of field-grown seedlings indicated that once the inhibitory substances are leached from the soil, harmful effects disappear. The study indicated that there is a need for caution when growing food crops near *Eucalyptus* in areas with low rainfall, in which leaching of toxic substances is slow.

Singh, R.P., 1984. Nutrient cycling in *Eucalyptus tereticornis* plantations. Indian Forester 110(1):76-85.

Nitrogen, phosphorus and calcium content was determined in different parts of trees in 5,6,7,8 and 9-year old plantations of *E. tereticornis* Smith on the Gangetic Plain in India. No consistent differences in concentration of any of the elements was found at the different ages.

Srivastava, K.K., Zacharias, V.J., Bhardwaj, A.K., Jomy, A., Sherly, J., Augustine, J. and Joseph, S., 1994. *A preliminary study on the grasslands of Periyar Tiger Reserve, Kerala (India).* Indian Forester- Special Issue on Biodiversity-II. 120(10):898-907.

Grasslands in India have a very important role in wildlife management as they provide excellent forage for herbivores. The objectives of the present study was to describe the species diversity of grasslands and distribution of different species of grasses; to assess the forage value of the grasslands and the extent of interaction for larger mammals; and to estimate the effect of forest fire on the regeneration capacity of grasses and other herbs seen in grasslands in the Periyar Tiger Reserve, Kerala (India). It was found that, while the cause of erosion in some conditions, fire generally accelerates germination of seeds of grasses and other herbs in grasslands. The planting of forest trees, including *Eucalytus* spp., was detrimental to the grasslands. Very few grasses and herbs were found to survive in the *Eucalyptus* plantations. It was concluded that planting of *Eucalyptus* and other exotic plants destabilized the ecology of grasslands, which are ideal habitats for endangered large mammals.

Tiwari, K.M. and Mathur, R.S., 1983. *Water consumption and nutrient uptake by eucalypts.* Indian Forester 109(12):851-973.

Reviews the water uptake in relation to biomass production in *Eucalyptus tereticornis,* and compared values with those of other tree and fruit species. Found that eucalypts consumed less water per unit biomass produced than the other species included in the experiment.

Turnbull, J.W., 1999. *Eucalypt plantations. New Forests Vol.17:37-52*. Kluwer Publishers, Netherlands**.**

Reviews eucalypt use and introduction to a range of countries in a historical perspective, and examines social, policy and economic aspects of growing *Eucalyptus* as well as the prospects for using the eucalypt in the twenty-first century as an industrial plantation tree and as a component of farming systems in the rural landscape.

The paper notes the controversial aspects of impacts on soil water, soil nutrients, soil erosion, and biodiversity. In regard to social controversies, the author suggests that some eucalypts such as *Eucalyptus grandis* is an excellent industrial species, whereas others, such as *E. camaldulensis, E. citriodora and E. globulus,* can be either industrial or multipurpose, according to the management applied to them. He also notes that the majority of the 500-700 species of *Eucalyptus* have no industrial use and have had little or no role as planted trees.

The main factors controlling the productivity of eucalypt plantations are soil water, nutrient availability, organic matter, effective rooting depth and friability, as well as the quality of seed and seedlings, site preparation, and weed control.

Plantation forestry will require complex inter-disciplinary approaches to define economic, social and environmental contexts in which it is appropriate. However, as large areas of land not subject to tenure problems becomes increasingly difficult to locate, the prospects for greater development of more complex systems of wood production involving small landholders will become more feasible and attractive.

Wadsworth, F. H., 1997. *Forest Production for Tropical America. Agriculture Handbook 710.* USDA Forest Service. Washington D.C., USA pp.170-177.

It is suggested to refer to this document together with the paper prepared by FAO (1995), ref. mixed and pure plantations.

White, Don, 1999. *Trees as Water Pump. "On-WOOD"***.** Research Up-Date from CSIRO Forestry and Forest Products, Australia. Spring 1999, p.2.

Reports on a study aimed to model the water balance and refine strategies for managing problems of water-logging and salinization of soils in Australia. Four species were used in the study: (i) *Eucalyptus saligna* and (ii) *E. camaldulensis,* known to send down roots close to the saturated area just above the water table; and (iii) *Eucalyptus leucoxylon* and (iv) *E. platypus,* known to extract water from the drier soils near the surface.

The hypothesis was that mixed plantings of various *Eucalyptus* species might tap a larger proportion of the soil profile, and thus help remedy the problems of waterlogging and salinization mentioned above.

The study was carried out in Western Australia, in a rainfall area of 480mm/an most of which falls in the winter; with clay soils restricting infiltration. Water that escapes down below the root zone moves lower in the landscape, and can cause a rise in the water table and increased salinity. Dryland salinity now affects 9 percent of the region's arable land, and is projected to rise to 30 percent over the next 30 years.

The study found considerable differences between the eucalypt species tested, with (iii) and (iv) experiencing considerable water stress, while (i) and (ii) did not. This indicated that the latter two species tap groundwater, and suggested that the species would differ substantially also in the amount of water they transpired. However, when examined, this was found not to be the case, and transpiration rate per unit leaf area was virtually the same for all species throughout most of the year. As well as demonstrating that the shallower-rooted trees are very efficient at extracting water from the soil, the results indicate that a good estimate of water uptake can be made from the leaf area of the trees, without having to take account of species differences.

The question in the study was, then: how do the species which do not reach down to the water table maintain their water uptake? It was found that these species use two strategies: their leaf tissue became very elastic during the warmer months, allowing growth and gas exchange to continue in quite dry soils. In addition, solutes concentrated in their foliage, acting *"like a big salt blotter"*[cc].

Because water will be extracted from a range of depths, there seems to be a value in planting mixtures of trees like those in the present study to counteract waterlogging and salinization, making use of the complementary strategies developed by different species, which allow them to tap water from both the saturated zone just above the ground-water (up to a depth of 6 meters, in the present study), and from the unsaturated zone close to the surface.

[cc] Additional information received from Dr. White (e-mail to Palmberg-Lerche dated 21.10.1999): "In other words, organic and inorganic solutes were concentrated in the foliage of these species to counteract drying out. This helped maintain a gradient of water potential from soil to leaf as the soil dried out. This was especially important in the case of *Eucalyptus leucoxylon*, which has inherently low osmotic potential".

L/FORM **25.10.99**

FAO - Forestry Department

List of Working Papers on Forest Plantation

FP/1 *Mean Annual Volume Increment of Selected Industrial Species*. Ugalde L. and Perez O. April 2001.

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