Chapter 2
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THE EUCALYPTUS CONTROVERSY

INTRODUCTION

Eucalypts have become the focal point of a raging controversy over the past two decades vis-a-vis their impacts on the environment. We have mentioned in Chapter 1 that no genera of trees has attracted such intense and acrimonious debate on its perceived ills and virtues as eucalypts. The views for or against eucalypts have become so polarized that at times the criticism or appreciation is based solely on prejudice than on a balanced consideration of the facts.

Eucalyptus first came to India in 1790 during the reign of Tipu Sultan and established itself as a garden tree in Nandi Hills, Karnataka. This activity was primarily intended to meet the firewood demand. Planting on a large scale in India, however began only around 1856. Along with plantations of teak and the exotic acacias, eucalypts were introduced in Nilgiri hills in 1858 where *E. globulus* was planted along with *E. robusta*. Another species of eucalyptus - *E. citriodora* was introduced in mid 1930 in Karnataka and Kerala. The 1960s heralded the introduction of the hybrid *E. tereticornis-E. globulus* popularly known as *E. hybrid* on a massive scale throughout India from the farthest North to the Southernmost tip.

While more than 2.5 lakh hectares of forest and rainfed farmland have been diverted for eucalyptus plantations in the state of Karnataka, in the North-western States of Punjab and Haryana, eucalyptus plantations account for nearly 1.5 per cent of the total land under cultivation.
About 7.5 million hectares of land is currently under eucalyptus plantations in India, accounting for about 8% of the Global coverage.

Why did eucalyptus achieve such a rapid spread? Why has this genera of trees become a favourite of the foresters all over the world? How beneficial is it? Does it have any adverse effects? These are among the questions most frequently asked by ecologists, sociologists, economists, and social foresters.

The spurt in population growth and industrialization during the post-independent years enhanced the demand for wood products in India accentuating the pressure on the forest resources. The demand was far in excess of supply. Several strategies were adopted to increase the output of wood, to meet the industrial and domestic demands. One of the steps was to introduce fast-growing species in plantation forestry which till the mid-50s had been dominated by the slow growing hardwood. This is how eucalyptus, among the fastest growing trees, came into the picture and has since then remained as a favourite in social forestry programmes.

Whatever be the climatic conditions, one or the other species of eucalyptus is always successful in establishing itself. Therefore as a group, the eucalyptus have proven themselves to be extremely successful in a large number of countries. They have been used, for example, as the basis of the massive plantings to supply charcoal to the Brazilian steel industry. In the cooler highlands and inter-Andean valleys of Bolivia, Peru, Ecuador and ports of Colombia, eucalyptus are the species most sought for fuelwood and other uses. They have been widely planted in tropical Ethiopia and other parts of Africa and, as stated earlier, they have proved to be the most popular species in the farm forestry programmes in India.

There are instances when eucalyptus has been even planted as an effective alternative to sugarcane. One such instance occurred in Nasik, India; when resort to eucalyptus was taken after three successive years of drought had caused a collapse of sugarcane production.

A fresh spurt in eucalyptus plantation has occurred in recent years to overcome the serious scarcity of fuelwood. Forestry experts stress that harvesting of eucalyptus for fuelwood can be done once every four years while there needs to be an interval of eight years before eucalyptus can be harvested for pulpwood.

**OVERKILL**

So successful were the initial experiences with eucalyptus that an element of overkill came in. Planters eager to cash in on the virtues of the tree began planting any and every species of the tree even in agroclimatic zones which were totally unsuitable to those species. This has resulted in some well publicised failures. The total destruction of a long stretch of eucalyptus plantation in Kerala, India by the Pink and Blight disease is one such example. Another unfortunate fallout of the high productivity of eucalyptus has been that natural forests have been cleared all over the world to plant it. This had led to an outcry from the environmentalists and social activists.
At present while on one hand official foresters and big farmers have found in the species a panacea for solving the problems of ecorestoration, on the other hand small farmers along with social activist groups all over the country have questioned the preference given to eucalyptus in social forestry programmes. Environmentalists in India have also raised alarm against the expansion of eucalyptus monoculture in the arid and semi-arid regions. The protests gained such a momentum that in March 1983, farmers in Karnataka, India, uprooted eucalyptus seedlings from forest nurseries. In June 1988, farmers in Thailand protested against a eucalyptus tree planting project. In 1989, the chipko activists were arrested for doing what their counterparts did in Karnataka, India. Kerala, India, was also not left far behind.

The controversy has continued to rage because most of the eucalyptus plantations suffer from human interferences and it becomes very difficult to separate the adverse effects of eucalyptus on the environment from other possible causes. This chapter aims to discuss the various elements of the controversy. We have presented the gist of the views of the protagonists as well as the antagonists and then given our own comments on each aspect of the controversy. We have also briefly mentioned how our studies, detailed in subsequent chapters, have covered a major knowledge gap viz extensive long-term experiments on the ecology of undisturbed eucalyptus plantations in comparison with the ecology of other equally undisturbed plantations consisting of various ‘known to be benign’ tree species - in monocultures as well as mixed cultures. Further, these studies have been conducted on plantations grown under identical agro-climatic conditions. The results have thus no danger of being masked or camouflaged by extraneous factors such as human or cattle disturbance.

**ELEMENTS OF CONTROVERSY**

**Eucalyptus as a tree used in social forestry**

The most extensive use to which eucalyptus has been put is in social forestry. The saplings of eucalyptus have a higher survival rate than other trees identified for social forestry - acacia, leucaena, casuarina, prosopis etc. The tree grows fast, needs minimal supervision, and provides greater yield of commercially useful biomass per unit land area and per unit time than most other trees.

Forest Departments in India have taken to eucalyptus in a big way because of the attributes mentioned above. For similar reasons the genus eucalyptus has been a tree of choice for non-governmental entrepreneurs, and farmers.

But the strongest opposition to eucalyptus has also come for its use in social forestry because social forestry is always done on a massive scale, raising large plantations.

What are the views in favour of the use of eucalypts in social forestry, and what are the views against it?

**Views in favour of eucalypts**

According to Kaikini (1967) eucalyptus is highly suitable for social forestry. To meet the raw material demand of pulpwood industries which began to increase very fast during the 1960s, fast growing species were needed which could adopt themselves to the different agro-climatic
zones existing in India. After several other trees were tried the genus eucalyptus was found to be ideal. Pryor (1976) and Tiwari (1983) has expressed similar opinion.

Davidson (1985) supports the introduction of eucalypts in social forestry programme, because of the tree's almost unique ability to adjust and adopt to a wide range of sites and at the same time grow more rapidly than other genera under widely varying environmental conditions.

CSE (1985 a) report that private tree-farmers and foresters love the tree and consider it a God-sent gift which grows well in dry conditions, does not get browsed, coppices well, fetches a high price and stabilises incomes.

Pro-eucalyptus environmentalist Karanth (CSE, 1985 a) states: Claims such as that eucalyptus has caused a drought in Bengal, that these trees do not cast shadows and that thousands of livestock might go without a blade of grass to eat etc are all too fantastic to merit a rebuttal...

The Gujarat forest department, India, states: Eucalyptus is an unmixed blessing for Gujarat farmers.

CSE (1985 a) also report that in Haryana, India, nearly 40,000 hectares of crop land is under eucalyptus, especially in the rainfed areas of Ambala, Karnal and Kurukshetra. Some 150,000 hectares of eucalyptus plantations exist in Maharashtra, India, in combination with other species, of which some 25,000 hectares are irrigated. In Uttar Pradesh, India, eucalyptus covered 82,000 hectares by 1979. In Karnataka, India, about 1,33,000 hectares are under eucalyptus. Eucalyptus plantations are also seen increasingly in the states of West Bengal, India and Tamil Nadu, India.

Many farmers have become dye-hard eucalyptus supporters. Mishra (CSE, 1985 a) claims that in Uttar Pradesh, India, we even insist that 10 per cent of plantations should comprise of species other than eucalyptus. But farmers in western Uttar Pradesh want only eucalyptus. Shyamsundar (CSE, 1985 a) has stated Last year some 5 million seedlings (of other species) were wasted in our nurseries due to lack of demand.

Dinesh Kumar (CSE, 1985 e) argues that eucalyptus plantations have a definite role to play in agroforestry systems. Eucalyptus plantations in the midst of farmlands act as windbreaks, increase humidity and cut down radiation to increase photosynthetic activity in nearby agricultural crops. These advantages have resulted in 23% and 24% increase in the yields of wheat (Triticum vulgare) and mustard (Brassica sp.) respectively in Gujarat, India, and 40-43%, 39-47%, and 23-64% increases in yields of groundnuts (Arachis hypogia), pulses (Cajanus cajan) and millets (Panicum sp.) respectively in Andhra Pradesh, India. In Gujarat, India, where irrigated farm forestry is progressing in a big way many farmers have started taking intercrops with eucalyptus. Patel (CSE, 1985 e) has been experimenting with the possibility of taking grain and pulse crops. He already grows two species of fodder grassses.

Khoshoo (CSE, 1985 f) is of the opinion that eucalyptus can be a blessing in a captive plantation... eucalyptus plantation can be grown successfully on marginal or degraded land without any major disadvantage.
Concerned with the increasing criticism against eucalypts, the Government of Karnataka, India, had set up an expert committee called Environmental Planning Committee of Karnataka (EPCK) (CSE, 1985 b). After extensive deliberations the committee submitted a report which states, *inter alia*, that *if eucalyptus plantations under social forestry replace agricultural crops in drought-prone areas to a limited extent, that would be ecologically beneficial.*

According to Chaudhury (1986), eucalypts are the most suitable tree for farm forestry because of their fast growth, thin crown, straight bole and easily coppicing nature. Poore and Fries (1987) also consider eucalypts as ‘ideal genera’ for afforestation purposes, especially for the previously tree-less sites, because of their rapid growth rate and their ability to survive even on poor soils, in particular those deficient in phosphorous.

That eucalypts can grow well even on poor soil is substantiated by Saxena (1992). He has reported that eucalyptus has been grown in areas of low productivity surrounding the metropolitan town of Bangalore, Karnataka, India where eucalyptus logs and poles are bought by the paper mills and by construction companies. He has emphasized the fact that the area where eucalypts are grown is predominantly semi-arid with uncertain rainfall, and that eucalyptus has replaced an inferior food-grain, ragi (*Eleusine coracana*).

According to Rao (1995) eucalyptus were planted to check desertification in the Nile valley, indicating that the tree has the ability to grow under very adverse, desert-like conditions.

**Views against**

Kang (CSE, 1985 f) claims that many farmers have stopped growing eucalyptus along field boundaries because it depletes water on both sides of the boundaries. He had found that eucalyptus attracted crows which then damaged grain crops. Kang recommends that a legume like leucaena must be planted in between eucalyptus to preserve soil fertility. Bhumbla counters Kang's observation by saying (CSE, 1985 f) *it must be pretty bad agriculture to begin with which gives a 24 per cent increase in yield of wheat simply by planting eucalyptus along field boundaries.*

According to Krishnamurthy (CSE, 1985 a), foresters in Karnataka, India, who had felled natural forests in the Western Ghats for eucalyptus, now restrict its planting to lower rainfall zones of 500 mm to 1,125 mm. He also states *The depressing effect of drought on fields of rainfed crops (millets, pulses and oilseeds) coupled with the lack of remunerative price support for these crops, is driving the farmer to such frustration that opportunities offered by industrial interests for turning their lands into eucalyptus plantations are finding ready acceptance. And the forest department is encouraging the farmers to raise eucalyptus through the massive distribution of seedlings free of cost.*

Shiva and Bandyopadhyay (1987) strongly criticised the introduction of eucalypts in social forestry. According to them the choice of eucalypts in soical forestry is not apt *vis a vis* the needs of the common man whose priorities are fuel, fodder, green manure etc, rather than industrial products such as paper and rayon.
On balance
The gist of arguments for the use of eucalypts in social forestry are:
a) they are exceptionally productive and remunerative
b) they do not have any different (or particularly adverse) impact on environment than other trees used in social forestry.

The critics of eucalypts question both these assertions and declare that eucalypts should not be used in social forestry or for any other purpose.

In the following sections we have examined in detail the arguments and counter-arguments on all specific aspects of eucalypts - beginning with productivity. We have put particular emphasis on the evidence of quantitative and controlled experiments. On balance we find that even though there is no conclusive evidence in literature, there is stronger scientific evidence for eucalypts than against it - indicating that eucalypts can be gainfully used in social forestry provided certain precautions are taken, mainly the proper choice of species and proper manner of harvesting (to avoid overkill and thus safeguard against all such negative impacts on water and soil that overexploitation of any tree may cause). Our studies based on controlled experiments performed in undisturbed Euclayptus hybrid plantations, described later in this thesis, have established this fact beyond a shadow of doubt.

These points would become progressively clearer on perusal of the following sections of this chapter.

Productivity of Eucalyptus
The most basic and powerful argument in favour of using eucalyptus in social forestry has been based on the belief that the genus eucalyptus is one of the fastest growing trees in the world or, more precisely, one of the fastest growing trees which is also one of the easiest to grow.

All those who favour eucalyptus emphasize this argument again and again but those who are against eucalyptus have been challenging this belief.

Evidence that Eucalypts is exceptionally productive
Khan (1959) studied plantations of eucalyptus (Eucalyptus tereticornis - globulus), casuarina (Casuarina equisetifolia), and acacia (Acacia auriculiformis) raised in Sriharikota island, Andhra Pradesh, India. He acquired growth data from four-year plots and statistically analyzed the data. This revealed that eucalypts produced more woody biomass than the other species in identical period of time. Whereas eucalyptus plantation generated an average of 1.3 cubic feet of wood, acacia generated less than a fourth of it (0.34 cubic feet) and casuarina about 3% less (1 cubic feet).

Kawahara et al (1981) compared the growth rate of E. camaldulensis with other fast growing trees and concluded that the productivity of E. camaldulensis (17-59 tonnes/ha year) puts it in favourable light in comparison to the productivity of other trees (15-30 tonnes/ha year).

In 1983 Chaturvedi reported findings of an experiment conducted at Kanpur, India, specifically to decide which of the six fast-growing trees - Acacia auriculiformis, Albizia...
Lebbeck, Dalbergia sisso, Pongamya pinnata, Syzigium cumini and Eucalyptus hybrid were suitable for promotion in the social forestry programme in India. The studies were conducted under controlled conditions so as to eliminate extraneous factors (such as grazing) from influencing the productivity data. Their findings, summarized in Table 1, support the observations of earlier (and later) workers about the high productivity of eucalyptus.

In a plantation raised on silty clay loam soil, Gurumurti and Rawat (1989) observed that in *Acacia nilotica, Prosopis juliflora, Acacia tortilis* and *Cassia siamia* the ‘bole biomass’ (the woody portion) constituted only 30-40% of the total biomass, in *Eucalyptus hybrid* and *Casuarina equisetifolia* the bole biomass, but formed as much as 80% of the rest of the tree. From these observations the authors concluded that eucalyptus and casuarina are amenable to close cropping and are ideally suited as pole crops. Their observations also indicate that eucalyptus (and casuarina) generate much more quantities of profitably utilizable biomass than the other trees studied.

Somachai et al. (1990), recording the performance of eucalyptus in Japan, have observed that the tree yielded about 44.9 tonnes/ha year of biomass which was over 30% more than the yield from *Acacia mangium* plantation of identical age.

Bargali and Singh (1991) report that the net primary productivity of a eucalyptus plantation (23.4 tonnes/ha year) was similar to that of the *Populus deltoides* plantation (25 tonnes/ha year) and a natural sal forest (22 tonnes/ha year). However the net nutrient uptake of eucalyptus was lower than that of the populus plantation and the natural sal forest. This, the authors believe, gives eucalyptus a net advantage vis a vis productivity - soil nutrient ratio.

In a recent report from Neyveli Lignite Corporation (NLC), Tamil Nadu, India (Shankran, unpublished internal report, 1995), productivity of *Eucalyptus tereticornis* has been compared with *Acacia auriculaeformis* and *Leucaena leucocephala* grown within the NLC campus (Table 2). The study clearly reveals that *E. tereticornis* is by far the most productive of the three fast-growing trees studied.

**The counter arguments**

Shiva and Bandyopadhyay (1987) have stated, ‘having found that all recognised and established scientific information is illegitimating eucalyptus as a fast growing tree the forest establishment of the country stopped their dependence on these data and initiated their controlled experiment immediately after the domination of eucalyptus in the social forest programmes got challenged in 1981’. Their allusion is to the data reported by Chaturvedi (1983), summarized in Table 1, which they (Shiva and Bandyopadhyay) believe to be the only study of its type ever conducted. They have then gone on to blast the so-called ‘Kanpur experiment’ as the ‘only straw (available to the proponents of eucalyptus) to hold on to’.

Shiva and Bandyopadhyay (1987) have also quoted from Bhumla (1984) to say that there is no data available to prove that eucalypts produces more biomass than other indigenous trees. They have also quoted from Quereshi (1967) and have mentioned ‘a comparison of growth...
Table 1. Productivity of six trees explored for social forestry (Chaturvedi 1983); the data is for growth across one year span in trees of identical age

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Species</th>
<th>Shoots</th>
<th>Roots</th>
<th>Leaves</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><em>Acacia auriculiformis</em></td>
<td>1023.5</td>
<td>361.6</td>
<td>327.9</td>
<td>1713.0</td>
</tr>
<tr>
<td>2.</td>
<td><em>Albizia lebbeck</em></td>
<td>1132.4</td>
<td>085.6</td>
<td>136.8</td>
<td>2354.8</td>
</tr>
<tr>
<td>3.</td>
<td><em>Dalbergia sissoo</em></td>
<td>1129.3</td>
<td>775.5</td>
<td>99.7</td>
<td>2004.5</td>
</tr>
<tr>
<td>4.</td>
<td><em>Pongamia pinnata</em></td>
<td>168.0</td>
<td>274.7</td>
<td>77.5</td>
<td>519.7</td>
</tr>
<tr>
<td>5.</td>
<td><em>Syzigium cumini</em></td>
<td>1278.0</td>
<td>593.7</td>
<td>514.3</td>
<td>2386.0</td>
</tr>
<tr>
<td>6.</td>
<td><em>Eucalyptus hybrid</em></td>
<td>2519.8</td>
<td>2094.3</td>
<td>594.9</td>
<td>5209.0</td>
</tr>
<tr>
<td>Sl. No.</td>
<td>Tree species</td>
<td>Productivity</td>
<td>Rotation (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------</td>
<td>---------------------</td>
<td>------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td><em>Eucalyptus tereticornis</em></td>
<td>30-60Kg/tree</td>
<td>5-7 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td><em>Acacia auriculiformis</em></td>
<td>25-30Kg/tree</td>
<td>7 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td><em>Leucaena leucocephala</em></td>
<td>20-25Kg/tree</td>
<td>6 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
rate of ten species by the Gujarat Forest Department to say that eucalyptus is not one of the fastest growing but among the slowest of the faster growing trees.

On balance

Eventhough Shiva and Bandyopadhyay have used strong words to denounce eucalyptus, they give no hard data at all on any experiment done simultaneously on eucalyptus and other species to substantiate their arguments. Nor have we found in literature any such authentic data. On the other hand numerous authors from India as well as abroad have reported through independent experiments conducted under different regions and across a time span of several decades - summarized by us in the proceeding section - which indicate that eucalyptus is indeed one of the most productive trees and generally yields more valuable biomass than such other fast-growing trees as acacia, casuarina, leucaena, and cassia.

Eucalyptus and surface run-off

It has been alleged that the surface run-off is very high in eucalyptus plantations, because of scarce undergrowth and other adverse edaphic conditions created by the tree. It has also been alleged that this high surface run-off leads to soil nutrient deficit, besides adversely affecting groundwater recharge.

Views in favour of eucalypt

Chinnamani et al (1965) have observed that the proportion of run-off from the eucalyptus and acacia was similar to that from the shola forests. Similar results based on a three-year study have been reported by Samraj (1977).

According to Mathur et al (1980), the presence of excellent undergrowth which is generally allowed by an open canopy of eucalyptus actually reduces run-off, especially during rainy season. They have reported results of their experiments in support of this observation.

Poore and Fries (1987) have stated that eucalypts can be, and has been, used for erosion control. They suggest that even if surface run-off is noticed, it can be alleviated by terracing - a practice which is also beneficial for the establishment and growth of eucalyptus on steep dry sites. Earlier de le Lama (1984) had also suggested terracing to control soil erosion.

Views against

Stein (1952) has reported that in steep dry areas where E. globulus has been planted, understorey development and litter build-up were insufficient to prevent surface run-off. He believes that eventhough Eucalyptus globulus is a fast growing, heavy crowned tree which casts a dense shade, it gives little litter. This makes eucalyptus plantation susceptible for rapid surface run-off. He also had reported that in Southern India, where rainfall is less than 750 mm the failure of an understorey to develop coupled with a weekly developed forest floor, leaves the soil exposed to run-off under such condition.

Mathur et al (1976) and Balagopalan (1986) also have reported that eucalyptus plantations hasten soil loss.
According to Poore and Fries (1987), eventhough the presence of litter and ground vegetation greatly controls the amount of run-off, this would certainly vary according to the climate. The ground vegetation of eucalyptus forest is sparse in dry climates due to root competition and perhaps, allelopathic effects. But the situation would be different in less drier climates.

**On balance**

It appears that whether eucalyptus leads to an increase in water run-off and soil loss depends upon what it is replacing. If *Eucalyptus hybrid* is replacing a natural stratified forest then the water run-off and soil loss will be *relatively* increased. If, on the other hand, *Eucalyptus hybrid* is planted in agricultural land or degraded land devoid of tree cover - as envisaged in the government plans - then the water run-off and soil loss will decrease.

The intensity of surface run-off also greatly depends upon the type of soil as well as the species planted. It has been reported that in some species of eucalyptus the root-reticulation pattern is such that it binds the soil particles together, thereby the surface soil escapes from being eroded. Much also depends upon the rainfall regime of the area. If the intensity of rainfall is high the surface run-off also will be at the maximum. This condition can be noticed in almost all types of plantations. Hence selection of proper regime and right species would greatly control the soil loss in eucalyptus plantation. Selection of right species would also lead to an improvement in the undergrowth species development, which would also greatly control the surface run-off. The experiments of these authors, described later in this thesis, have provided strong evidence to support this contention. We have found that the diversity of undergrowth in the plantation of *Eucalyptus hybrid* is as good as in other monocultures or mixed cultures. There is thus as good protection against run-off and soil erosion in eucalyptus plantations (if proper species are used) as provided by other tree species.

**Eucalyptus and water uptake**

The most often - repeated allegation against eucalyptus is that it consumes large amounts of water thereby reducing soil moisture as also lowering the groundwater table.

**Views in favour of eucalypts**

According to Shyamsundar (1983 a) the criticism against eucalyptus that it lowers the groundwater table is baseless as the roots of the eucalypts rarely go lower than 3 - 4 meters, hence it could not tap subterranean water.

Lima and O’Loughlin (1984) support this view. They strongly oppose the statement that the shallow root system of eucalypts is the main cause for depleting the soil moisture. They are of the view that the lateral spreading and depth of penetration of the root system vary with species and this has to do with intensity of water uptake. Hence selection of right species will prevent the problem of high water uptake. They also report that the overall soil water regime of eucalyptus forests do not differ from that observed in pine plantations.

According to Foley and Bernard (1984) eucalypts roots can break up the soil structure or even a subterranean layer of impervious hard pan. Hence eucalypts can improve rain water
percolation, creating a net positive effect on the ground water level.

Dinesh Kumar (1984) states that several trials in Australia have proved that eucalyptus is the most efficient user of scarce water resources. He concludes that the species itself is a good drought resistant one.

As far as the possibility of eucalyptus plantations lowering the ground water table is concerned, the Economic and Planning Council of Karnataka (EPCK) report (CSE, 1985 b) argues that the roots of Eucalyptus hybrid rarely go lower than 3 meters to 4 meters deep and usually do not spread out (laterally) more than 1.5 metres. This means that Eucalyptus hybrid only consumes subsurface seepage water, and it cannot tap subterranean groundwater. This being so it is unlikely that Eucalyptus hybrid is responsible for wells running dry. The later phenomenon can be due to several other factors such as: enormous increase in the number of irrigation pumpsets; continuous drought for consecutive years; and very high density of tree planting. In Davanahalli and Hoskote taluks of Karnataka state, India, for instance the number of energised irrigation wells have doubled within six years. Similar intensity of exploiting underground water is visible in several parts of Kolar district, Karnataka, India. Chaturvedi (CSE, 1985 b) argues that the Terai region of Uttar Pradesh, India, where eucalyptus plantations have allegedly lowered the water table, is actually full of tubewells which might be the real culprits.

Ray (CSE, 1985 c) states that it is a fact that streams have dried up in Nilgiris after the removal of the original shola forests, but it is uncharitable to blame it on eucalyptus. The eucalyptus plantations would have helped in recuperating the subsoil water had the leaf litter been allowed to remain on the ground and get converted into humus. But all the leaves are removed for distilling eucalyptus oil. In the plains, the local people remove the leaves and twigs for cooking purposes. In such a situation the soil is not in a position to absorb water and recuperate the water table.

CSE (1985 c) has mentioned that the foresters repeatedly cite a 1972 study from the Nilgiris which reports that the annual transpiration of water in a Eucalyptus globulus plantation corresponds to a rainfall of 34.75 cm whereas potato fields use 65 cm of rainfall. The total rainfall in the area was 130 cm thus making available the balance 95.25 cm to cover interception loss, surface run-off, evaporation, deep percolation, water yield and soil moisture storage.

Mathur (CSE, 1985 c) believes that it is agriculture crops which are responsible for depletion of water resources and not eucalyptus plantations. Water use for some of the agricultural crops like wheat (Triticum vulgare), paddy (Oryza sativa), sugarcane (Saccharum sp.) and millet (Panicum sp.) is 38 cm, 104 cm, 163 cm and 64 cm respectively.

Patel (CSE, 1985 c), one of the first eucalyptus farmer of Gujarat, India, switched over to eucalyptus because there was not enough water to grow cotton, which is a heavy user of water. Now that he has been farming eucalyptus, he claims, the water table in the region has stabilised. Patel also claims that the plantation has improved the water absorption capacity of the land as
compared to neighbouring farms because eucalyptus roots break the soil and thus increase the seepage. During one night in 1976, water accumulated from 12 inches of rainfall, was absorbed within one hour on Patel's eucalyptus farm. On the contrary, the water on some of the neighbouring farms stood for three to four days after the rain.

Poore and Fries (1987) have quoted that drawing of soil moisture depends on stand density, and soil and environmental conditions. They have quoted from Lima and O'Loughlin (1984) and have summarised their findings to say that in alpine dry sclerophyll condition, soil water regime does not differ between eucalyptus forest, grassland, and herb field.

Poore and Fries (1987) have also reported that the effect of eucalyptus in reducing water yield is probably less than that of pine and greater than that of other broad-leaved species; but all species of trees reduce water yield compared with scrub or grass. The yield of eucalyptus timber (11.1 m³ mean annual increment) by far offsets the value of that part of the water losses that would have been added to the ground water. They are of the opinion that though the water-yield was reduced by about 20% compared with that from open ground, it is probable that a somewhat similar loss would have occurred under any other tree crop. They also have reported that the overall soil water regime of eucalyptus forest does not differ from that observed in pine plantations which is also a fast-growing tree.

According to Srivastav (1993), eucalyptus has high water holding capacity in the soil. According to his study conducted in the arid region in Surat District of Gujarat state, India, there was more soil moisture under eucalyptus than a nearby open area even after three consecutive drought years!

According to Rao (1995), the argument that eucalyptus absorbed as much as 60 gallons of water a day is not based on reality. For this, plantation area with eucalyptus planted two meters apart should receive nine cms of rain per day. Taking half of this as average, the yearly uptake of water should be 1642.5 cm which is unbelievably high. But no part in India where eucalyptus has been planted receives so much of rain. In fact eucalyptus grown in Nilgiri, Tamil Nadu, India, for over a century uses only 35 cms of the 135 cms of rainfall there.

Rao (1995) has also stated that the Eucalyptus hybrid adopted in the Indian subcontinent is not a wasteful consumer of water. But is, on the contrary, one of the most efficient utilizers of scarce water, producing more timber for water consumed than many other native species. He also states that scientists in Brazil (which have more than a million hectares of land under eucalyptus) confirm that eucalyptus plantations consume less water than the same area under natural forests.

**Views against**

Stein (1952) has stated that in closed plantations eucalyptus has a great water demand. This together with an extensive and dense root system enables it to compete successfully for available soil moisture, especially with smaller, shallow, rooted plants. Thus eucalyptus uses all the water available to the soil.
According to Heith and Karschon (1967), a study conducted in the central coastal plains of Israel (rainfall 600 mm, a dry period of 3 to 5 months) where eucalyptus plantation was compared with an open ground, showed that eucalyptus made use of all the water available to it.

Maheshwata Devi (1983) and Bahuguna (1984) also believe that eucalyptus consumes more water than other trees. According to them the streams feeding agricultural lands in the vicinity of eucalyptus plantations have gone dry. They also claim that in arid regions the high water uptake by eucalyptus interferes with processes which replenish soil moisture and recharge ground water leading to soil aridisation and ground water depletion.

Chaturvedi (CSE, 1985 b) says that in any area the same number of eucalyptus trees will consume more water than any other species during the same period.

Gupta (CSE, 1985 b) points out that in low rainfall areas, eucalypts roots form a dense network just below the soil surface to extract every bit of moisture.

The Economic and Planning Council of Karnataka (EPCK) report (CSE, 1985 b) agrees that eucalyptus plantations are heavy consumers of water on a per hectare basis. But, it argues that one has to look at the total water balance including the impact of transpiration losses and the extent of percolation into the soil.

The statement that eucalyptus is drought resistant is strongly questioned by Shiva and Bandyopadhyay (1987). According to them the shallow root system of eucalypts prevents it from surviving through permanent water scarcity, unlike the indigenous species that have been proved to be genuinely drought resistant. They also have mentioned a study conducted by the hydrological division of the CSIRO in Australia on the hydrological impact of eucalyptus on water resources to say that the efficiency of utilizing water by eucalyptus is greatly controlled by the rain-fall regime of the area. During years with precipitation less than 100 mms, deficits in soil moisture and ground water were created by eucalyptus. A permanent water deficit was avoided by significantly high rain fall of 1477 mms in one of the 5 years studied. Table 3 summarizes the results of the long term hydrological study showing that when rain fall is of the order of 1000 mms or less, eucalyptus plantations create deficits both in the soil moisture and ground water.

The accusation of Shiva and Bandyopadhyay (1987) against eucalyptus is that its fast growth requires excessive water and its lateral roots are spread in such a way that recharge of water through percolation becomes impossible. Hence, ground water does not get recharged. Also the vast network of root system just below the soil surface extracts every bit of moisture made available to the soil by precipitation. They also question the statement that the roots of eucalypts rarely go lower than 3-4 meters and that it cannot tap subterranean water. According to them the talk of the tapping of the underground water resources through the tap root as the only process of depleting ground water by the trees is either sheer illiteracy of elementary arithmetic and biology or it is a calculated attempt in misinforming the lay public and non-specialists in the decision -making bodies. Shyamsunder (1983 b) also have expressed similar view. Little
Table 3. Changes in soil moisture and ground water in eucalyptus catchment (mms)

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Year</th>
<th>Precipitation</th>
<th>Soil Moisture</th>
<th>Ground water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1975</td>
<td>1477</td>
<td>+29</td>
<td>+27</td>
</tr>
<tr>
<td>2.</td>
<td>1975</td>
<td>914</td>
<td>-87</td>
<td>-14</td>
</tr>
<tr>
<td>3.</td>
<td>1976</td>
<td>883</td>
<td>-49</td>
<td>-33</td>
</tr>
<tr>
<td>4.</td>
<td>1977</td>
<td>983</td>
<td>+49</td>
<td>-12</td>
</tr>
<tr>
<td>5.</td>
<td>1978</td>
<td>900</td>
<td>+30</td>
<td>-19</td>
</tr>
</tbody>
</table>
Evidence has been found of the water consumption of eucalyptus under natural conditions of unlimited water during the summer months or data comparing eucalyptus with other tree species under such conditions.

**On balance**

The evidence discussed above has sought to answer two key questions: do eucalypts use more water or have a greater effect on the water regime than other trees and are eucalypts more efficient in their use of water than other trees?

One conclusion can be clearly drawn, as pointed out by Poore and Fries (1987), that depending upon circumstances, eucalyptus has been used from time to time to lower water-tables in swampy areas either to dry out the soils or to control mosquitoes. Here, the effects clearly accomplish their purpose and are beneficial. If, however, eucalyptus lead to the reduction in volume of an aquifer which is used downstream for domestic water supply or for irrigation water, the effects are likely to be considered harmful. In all such cases it is important to consider the purpose of planting (fuelwood, shade, shelter, poles etc), the various uses that might be made of the water, and the total benefits and costs in the local socio-economic context.

According to Foley and Bernard (1984), whether a eucalyptus plantation will affect the water table depends greatly on the hydrological and physical properties of the soil. It is also determined by what kind of vegetation it replaces. If the previous crop was a water hungry one, the water table may well rise. If the eucalyptus are being planted to replace slow-growing scrub, on the other hand, in an area with a sensitive hydrology, it is quite possible that the water table might fall. The effects can only be predicted through a careful site survey. Further, as in the case of other aspects of eucalyptus controversy, the strong views for or against eucalypts invariably emanate from piece-meal observations made without due consideration of the context or the setting under which certain positive or negative impacts of eucalypts were observed. There is also the recurring theme of blaming the entire genus of eucalyptus for the adverse impact of one or two of its species.

Our experiments, reported later in this thesis, have established that *Eucalyptus hybrid* plantations do not deplete soil moisture and their performance in this report always compared favourably with plantations of other tree species.

**Eucalyptus and rate of transpiration**

It has been alleged that transpiration losses - loss of water from the surface of the leaves - is very high in eucalyptus tree genus. It has been said that this is due to the fact that eucalypts do not have the mechanism to control transpiration.

**Views in favour of eucalypts**

Dinesh Kumar (1984) has refuted the allegation that eucalyptus has a high transpiration rate. According to him eucalyptus being a xerophyte has a low transpiration rate and it controls stomatal openings according to water availability without serious reduction in biomass production. Similar findings have been reported by Brown *et al* (1976), Ackerson (1980) and

According to Poore and Fries (1987), majority of eucalyptus species do have some control over the rate of transpiration, which helps them to survive drought stress during some part of most years, and which is apparently related to the rainfall regimes of their natural habitats. They also have reported that average annual evapotranspiration in pine plantations is in the same order of magnitude as that observed in eucalyptus forests.

**Views against**

Pryor (1976) has reported that the transpiration rate of eucalyptus remain high even when the water supply from the soil has dwindled.

High transpiration rate by eucalyptus has also been alleged by Shiva and Bandyopadhyay (1987). They have listed in Table 4 the transpiration rate of Eucalyptus and other tree species to show that eucalyptus shows high transpiration rate compared to other such trees.

**On balance**

As in other aspects of eucalyptus controversy, the stress has been on the 'black' or 'white' areas with little regard to the 'grey' areas in between. There is as much hard data suggesting that eucalyptus causes heavy transpiration losses as there is evidence that eucalyptus does not. Several species of eucalyptus have the ability to adjust to different ranges of habitats. If eucalypts are grown in an area where there is surplus ground water, they would make use of the water for their growth. At the same time if they are grown on moisture-lean soils, they adopt themselves to that habitat. This can be possible only if they have some mechanism to control their water usage, including rate of transpiration. Or else it would be impossible for them to survive in drought-like conditions.

In the present study it has been established that the *Eucalyptus hybrid* plantations were not wasteful utilizers of water resources and their effects on the soil moisture were always comparable with other tree plantations advocated as being ecologically superior to eucalyptus by a section of environmentalists.

**Eucalyptus and soil nutrients**

A number of possible effects of planting eucalyptus on the nutrient balance have been suggested. One of the criticisms against eucalypts is that they may deplete the nutrients of the site, particularly if they are grown and cropped for several rotations.

**Views in favour of Eucalypts**

Attwill (1966) in his study under mature *E. obliqua* forest in the great dividing range of south-eastern Australia reports that eucalyptus does enrich soil nutrients and the principal contribution is made by leaching nutrients from the leaves.

George (1979) has estimated the nutrients contained in the rainfall, stemflow and throughfall in a plantation of *Eucalyptus hybrid* at Dehra Dun, India. The data on concentration of nutrients is presented in Table 5 and total yields (in kg/ha year) in Table 6. It is seen that concentration of salts in stemflow and to a lesser extent in throughfall are greater than in the rainwater.
Table 4  Transpiration of eucalyptus and other tree species (in mm)

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Species</th>
<th>Transpiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Eucalyptus</td>
<td>1200</td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>1248</td>
</tr>
<tr>
<td>3</td>
<td>&quot;</td>
<td>1136</td>
</tr>
<tr>
<td>4</td>
<td>&quot;</td>
<td>5526</td>
</tr>
<tr>
<td>5</td>
<td>&quot;</td>
<td>1255</td>
</tr>
<tr>
<td>6</td>
<td>Mixed Forest</td>
<td>140</td>
</tr>
<tr>
<td>7</td>
<td>Mountain Rain Forest</td>
<td>870</td>
</tr>
<tr>
<td>8</td>
<td>Birch</td>
<td>564</td>
</tr>
<tr>
<td>9</td>
<td>Beech</td>
<td>456</td>
</tr>
<tr>
<td>10</td>
<td>Spruce</td>
<td>516</td>
</tr>
<tr>
<td>11</td>
<td>Pine</td>
<td>282</td>
</tr>
</tbody>
</table>
Table 5. Concentration of nutrients in stemflow, throughfall and rainwater

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Nutrients (ppm)</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>N</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Stemflow</td>
<td></td>
<td>3.07</td>
<td>3.01</td>
<td>0.19</td>
<td>0.18</td>
<td>0.17</td>
</tr>
<tr>
<td>2. Throughfall</td>
<td></td>
<td>0.70</td>
<td>0.65</td>
<td>0.15</td>
<td>0.15</td>
<td>0.01</td>
</tr>
<tr>
<td>3. Rainwater</td>
<td></td>
<td>0.31</td>
<td>0.35</td>
<td>0.15</td>
<td>0.10</td>
<td>0.01</td>
</tr>
</tbody>
</table>
### Table 6 Nutrient return through stemflow, throughfall and rainwater (Kg/ha Year)

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Nutrients</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>N</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stemflow</td>
<td>39</td>
<td>38</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>Throughfall</td>
<td>94</td>
<td>88</td>
<td>2.0</td>
<td>2.0</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>133</td>
<td>126</td>
<td>2.2</td>
<td>2.2</td>
<td>0.2</td>
</tr>
<tr>
<td>3</td>
<td>Rain water</td>
<td>52</td>
<td>59</td>
<td>2.5</td>
<td>1.7</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Grand Total</td>
<td>185</td>
<td>185</td>
<td>4.7</td>
<td>3.9</td>
<td>0.4</td>
</tr>
</tbody>
</table>
However, it is unclear whether these additional amounts come from leaching of the foliage or by washing aerosols and dust from the leaves.

Raison and Crane (1981), experimentally found greater rates of phosphorus removal when harvesting *Pinus radiata* compared with *E. delegatensis* (Table 7).


Lima and O’Loughlin (1984) have presented an interesting evidence of the interaction of rainfall with the forest canopy. They compared the nutrient contents of rainfall, through directfall and stemflow in four different kinds of eucalyptus forest. It was seen that there is a consistent enrichment of rainwater after it passed through the canopy, especially in terms of sodium and potassium. The leached sodium was about two times as much as is found in the litter fall and potassium 1-3 times (Table 8). These experiments indicates that in an eucalyptus plantation, soil nutrient enrichment also occurs through the rain water intercepted by eucalyptus trees. There has been no report contradictory to the findings of Lima and O’Loughlin.

According to Foley and Bernard (1984) the allegation that eucalypts extracts all the nutrients available in the soil is not just. They are of the view that all plants extract nutrients from the soil. When the plants are harvested and biomass is removed, the soil nutrients are bound to be lost from the plantation. This could happen with any tree species. The rate of loss of nutrients is dictated by the rate at which biomass is removed. If under such circumstances a high yielding tree genus like eucalyptus reduces soil nutrients, so will other plants like rice, sugarcane, leucaena, prosopis or any other fast growing tree.

Foley and Bernard (1984) report that the rate at which the depletion of soil nutrients occur, and the nature of the problem that arise from it, depends to a large extent on the type of soil and its physical structure rather than the tree species. Soils which are inherently fertile can support high yielding crops for many years without the productivity declining. Others may be depleted very quickly. But the case against eucalyptus is no different from that which might be made against any other crop.

The report of the expert committee, set up by Government of Karnataka, India (EPCK), to examine the ecological impacts of eucalyptus (CSE, 1985 d) has noted that the question of whether Eucalyptus hybrid enriches the soil also depends on what Eucalyptus hybrid replaces and on the planting density. If Eucalyptus hybrid replaces a tropical rain forest then it will return less nutrients to the soil than the rain forest. But eucalyptus will enrich the soil in the case of marginal agricultural land or unwooded or degraded areas.

The report has further noted that the impact of *Eucalyptus hybrid* on the soil depends on the planting density. It appears that if the planting density increases above 10,000 trees per hectare, nitrogen and phosphorous deficiency may result. In the state of Karnataka, India, the planting density is about 3,000 trees per hectare, at these low densities, there is no evidence that eucalypts
Table 7. Quantities of rates of phosphorous exported from the forest when harvesting \textit{E. delegatensis} and \textit{P. radiata} on short and long rotation

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameter</th>
<th>\textit{Eucalyptus} (\textit{E. delegatensis})</th>
<th>\textit{Pine} (\textit{P. radiata})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tree rotation (yr)</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>57</td>
<td>40 #</td>
</tr>
<tr>
<td>2.</td>
<td>P exported (Kg P/ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>in stemwood</td>
<td>9</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>in bark</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>in bole</td>
<td>13</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>80</td>
</tr>
<tr>
<td>3.</td>
<td>Rates of P harvested</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>in boles</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>as per wood(q Pt/Wood)</td>
<td>97</td>
<td>258</td>
</tr>
<tr>
<td></td>
<td>as per time(Kg P/ha.yr)</td>
<td>0.73</td>
<td>1.97</td>
</tr>
<tr>
<td></td>
<td></td>
<td>51</td>
<td>169</td>
</tr>
</tbody>
</table>

#includes 4 commercial thinning at ages 16, 22, 28, and 34 prior to clearfelling at age 40
Table 8. Leaching of nutrients from eucalyptus forests canopy by rainfall

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Species</th>
<th>Process</th>
<th>Kg/ha year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>K</td>
</tr>
<tr>
<td>1</td>
<td><em>E. signata-E. umbra</em></td>
<td>P</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S</td>
<td>0.9</td>
</tr>
<tr>
<td>2</td>
<td><em>E. nilanophloia</em></td>
<td>P</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T</td>
<td>22.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S</td>
<td>0.7</td>
</tr>
<tr>
<td>3</td>
<td><em>E. obliqua</em></td>
<td>P</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T</td>
<td>15.4</td>
</tr>
<tr>
<td>4</td>
<td><em>E. obliqua</em></td>
<td>P</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T</td>
<td>13.4</td>
</tr>
</tbody>
</table>

P = Rainfall  
T = Throughfall  
S = Stemflow
pletes the soil. Indeed, by withdrawing the nutrients from the lower levels in the soil and depositing them on the surface, the nutrient status of the top soil is enhanced in eucalyptus plantations. To sum up, the report says, although natural forests should not be replaced with *Eucalyptus hybrid* monoculture, there are no compelling and perceived grounds for discouraging eucalyptus cultivation in marginal agricultural or degraded lands, from the viewpoint of nutritional adequacy. The report stresses the fact that if proper management practices in eucalyptus plantations are not adopted, quick rotations of eucalyptus may definitely affect the nutrient levels in the soil.

Chaturvedi (CSE, 1985 d) states that there are genuine cases of 'second rotation decline'. He believes that eucalypts grow fast and are generally harvested at short rotations in commercial farming. Their demand for moisture and nutrients cannot keep pace with felling in such cases. It may, therefore, be necessary to rotate eucalyptus with other species. These species should be nitrogen fixing, shallow-rooted and deciduous. Research for the choice of such species and their cycle of planting is needed.

Patel (CSE, 1985 b) argues that eucalyptus leaf litter builds up rapidly in the soil. He also emphasizes that, because of little sunlight that reaches, and heavy shade, it also decays very quickly, thus enriching the soil.

Kushalappa (1984) has reported an improvement in organic carbon, phosphorus, and potassium contents in the soil in eucalyptus plantations thus providing a strong evidence that eucalyptus monocultures are not detrimental to soil fertility.

Poore and Fries (1987) believe that eucalypts may improve soil characteristics when planted on degraded or deforested sites by improving the structure of the surface soil, by penetrating relatively impermeable layers of sub-soil, and by drawing up nutrients from depth. These authors have also quoted from Singhal *et al* (1975) and Singhal (1984) mentioning experimental results to show that humification is faster under eucalyptus. They also report that because of this reason the chances of loss of organic matter from the soil is also reduced. According to them the humification is brought about by eucalyptus debris, which produce humic acid, increase the polysaccharides, and hastens the rate of polymerisation with reduction in dispersion, thus enhancing the fertility of the soil. Jamet (1975) and Jha and Pande (1984) have stated similar views.

The natural eucalyptus forest appears to control the leaching and run-off of nutrients slightly better than other natural forests (Poore and Fries, 1987). The effects of evercropped eucalyptus on soil depends upon the state of the soil in which the trees are planted; beneficial in degraded sites, probably not so when replacing indigenous forests. When eucalypts are planted in bare sites, there is an accumulation and incorporation of organic matter.

In a recent study Pal and Ratwri (1991) have shown that even as biomass is removed from a eucalyptus plantation, no significant nutrient deficit is created. They explain that generally, the utilizable biomass of a large eucalyptus tree genus has larger proportion of wood, and
comparatively lesser bark and branches. Since bark and branches generally store higher amount of nutrients than rest of the tree, more nutrients are lost when trees with larger proportion of bark and branches are harvested than the ones, like eucalypts, of smaller ones.

George and Varghese (1991) report that only certain species of eucalyptus are high extractors of soil nutrients and that entire genus should not be blamed on this count. Their experiments reveal that E. globulus takes up 184 Kg/ha year of NPK and returns as much as 102 Kg/ha year to the soil while E. hybrid takes up 113 Kg/ha year of NPK and returns only 31 Kg/ha year to the soil. In other words only certain and not all species of eucalyptus cause nutrient stress on the soil.

In Zimbabwe, Sanginga et al (1991) found no evidence that eucalyptus is nutritionally more demanding than Leucaena leucocephala and Casuarina cunninghamiana.

Views against

Pryor (1976) has observed that in Australia eucalypts are seen to thrive only on soils which are moderately deficient in nutrients. In highly deficient soils, according to Pryor, eucalypts do not grow.

Balagopalan (1986) states that eucalyptus plantation decreases organic carbon and other soil nutrients thus affecting the chemical and physical properties of soil.

Shiva and Bandyopadhyay (1987) claim that since eucalyptus genus is a fast growing tree, its nutrient requirements are excessively high and create a nutrient deficit since eucalypts return only a small quantity of nutrient through its litter compared to its high uptake. They have quoted from Singh (1984) to buttress their argument (Table 9). Shiva and Bandyopadhyay (1987) also claim that eucalypts when planted on fertile agricultural land and harvested at short rotations, creates heavy nutrient deficits, destroying conditions of biological productivity.

Bahugana et al (CSE, 1985 b) is of the opinion that leaves of eucalypts that fall to the ground do not retain any moisture; the leaves group themselves into heaps and remain in a dry state whatever be the intensity of rainfall. There is no mulching; and there are no dung droppings of any sort. As a result there is no decomposition of organic matter, vegetable or animal, no absorption of nutrients by the soils and no humus formation.

On balance

It can be said that the nutrient uptake is a universal occurrence that can be made about all fast growing tree crops (Prasad et al. 1985). Moreover there is also no scientific evidence that eucalyptus have any special demands in this respect.

There are a large number of reports, augmented by hard data, from workers studying eucalypts across the world that supports the view that eucalyptus is no different than other fast-growing trees, perhaps better than many, in its impact on soil nutrients. In comparison there are lesser number of reports that accuse eucalypts of depleting soil nutrients and several of such reports are based on hastily arrived conclusions based on fleeting observations rather than rigorous and controlled experiments.
### Table 9. Nutrient deficit created by *Eucalyptus hybrid* plantations (Kg/ha year)

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>Calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalyptus requires</td>
<td>217</td>
<td>100</td>
<td>1594</td>
</tr>
<tr>
<td>Eucalyptus returns</td>
<td>35</td>
<td>14</td>
<td>335</td>
</tr>
<tr>
<td>Annual nutrient deficit</td>
<td>182</td>
<td>86</td>
<td>1260</td>
</tr>
<tr>
<td>Deficit after 2nd rotation (20 yrs)</td>
<td>3640</td>
<td>1720</td>
<td>25200</td>
</tr>
</tbody>
</table>
We feel that any fast-growing crop if harvested repeatedly in short rotations would deplete soil nutrients and eucalypts are not any worse than other trees in this respect. Frequent disturbance in the plantations such as brooming of leaf litter may substantially increase the potential for associated loss of organic matter and nutrients from the plantation.

The studies presented in this thesis have provided a firm footing to the arguments mentioned above. As the experiments conducted by us cover a large number of undisturbed plantations, studied over a large time-span, our findings can be taken as evidence sufficiently strong enough to settle this argument.

**Allelopathic effects of eucalyptus and undergrowth**

Allelopathy is the deleterious effect of one plant on another through the production of chemical retardants that escape into the environment. The allelochemical and toxic effects of eucalyptus have been scientifically recorded and studied both in India and abroad. The report of Rice (1979), implicating *E. camaldulensis, E. baxteri* and *E. globulus* embodies one such study.

**Views in favour of eucalypts**

Mathur *et al* (1980) compared plantations of *E. camaldulensis* and *E. grandis* with sal forest and secondary brushwood resulting 14 years after clearing of sal forest. Both the number of species and the vegetation cover were greater in the eucalyptus plantations and lesser in the sal forest. So were the amounts of litter, above ground phytomass, and below ground phytomass. The crown canopy (a measure of shading) were recorded as: eucalyptus 74.7%, brushwood 53.79% and sal 36.29%. These suggest better and richer vegetation under the eucalyptus. Further comparisons by Mathur and Soni (1983) and Rajvanshi *et al* (1983) between sal and eucalyptus have led to similar conclusions.

According to the Forest Department, Government of Karnataka, India (CSE, 1985 d), eucalyptus does not prevent undergrowth. Where rainfall and soil conditions are better, profuse regeneration of native trees, shrubs and grasses can be seen inside eucalyptus plantations. The lack of undergrowth in the arid areas is on account of already degraded soil, overgrazing, and removal of the leaf litter by the villagers.

According to Rajan (CSE, 1985 d), the lateral roots of *Eucalyptus hybrid* ramify and occupy the top soil up to about 20 cm from the ground surface. Certain grasses grow well under eucalyptus plantations.

A study by the Central Arid Zone Research Institute at Jodhpur (CSE, 1985 g) points out that eucalyptus plants exploit subsurface moisture for their growth, leaving the surface moisture for undergrowth or other short duration crops. Another study reports that in areas which had only a coarse grass cover prior to planting of eucalyptus, the ground cover gradually changed to evergreen species.

According to Evens (1982), not all species of eucalyptus suppress other vegetation; under some species of 'lightly crowned eucalyptus,' much undergrowth can be seen. It all depends upon the selection of right species of eucalyptus. This view is also supported by the present
work.

Poore and Fries (1987) point out that the effects of eucalyptus on ground vegetation depend very much upon climate, this is mostly because of competition for water. The effects of reduced light created by eucalyptus trees are probably less than that are caused by other broad leaved trees like pines. Ground vegetation is less affected in wet conditions than in dry.

Williams (1990) argues that the seedling mortality which is reported to be high in eucalyptus plantation is not caused by the litter of eucalyptus alone. He is of the opinion that apart from competition, grazing and climatic condition are the prime factors responsible for seedling mortality. Hence, he feels, putting the blame solely on eucalyptus for its allelopathic effect is not fair. But if eucalyptus is grown in degraded and unwooded lands, undergrowth can occur provided the planting densities are low and of the order of a few thousand per hectare. Typically, there are other reasons for the absence of undergrowth such as excessive grazing, fires, fuelwood collection and soil erosion.

**Views against**

Story (1967), reported that some chemical exudates produced by eucalyptus were probably responsible for the allelopathic effect.

Del Moral and Muller (1969 & 1970) have reported allelopathic effect in eucalyptus plantation resulting in the absence of undergrowth.

Al. Mousawi and Al. Naib (1975) have also reported paucity of herbaceous plants in eucalyptus plantations in Iraq.

In India Swami Rao *et al* (1984) were one of the first to report the allelopathic effect of eucalyptus. They found volatile and water soluble growth inhibitors in the leaf litter which did not encourage the germination and growth of other plants in the vicinity of eucalyptus.

Eucalyptus has been alleged to discourage undergrowth for reasons other than allelopathy. For example, according to Gupta (CSE, 1985 d) the heavy demand for water by eucalyptus prevents undergrowth.

Rajan (CSE, 1985 e) points out that since lateral roots of *Eucalyptus hybrid* and their ramifications occupy a large portion of the top layer of soil, leucaena remains stunted if grown near old *Eucalyptus hybrid* trees.

Shiva and Bandyopadhyay (1987) state that in arid regions, eucalyptus inhibits the germination and growth of other plants through allelopathy thus posing a threat to food production.

Wilson and Zammit (1992), based on their experimental study at Brindabella Range, 30 km West of Canberra, Australia, report that eucalyptus litter limits germination and has the potential to limit distribution of understorey vegetation.

Rao (1995) has quoted from Bahuguna to say that planting eucalyptus in Uttarakhand area in the foot-hills of Himalayas has been mainly responsible for the stunting of fodder growth. According to Rao (1995) not even grass grows near eucalyptus.
On balance
All-in-all, we conclude, there is no strong evidence that all species of eucalyptus have allelopathic effect; indeed most do not have.

From the foregoing discussion it is obvious that even though certain species of eucalyptus has been reported to produce toxins inhibiting the growth of other vegetation in the vicinity, not all eucalyptus species are known to produce toxins.

There is another phenomena which may create an illusion of allelopathy. This is absence of certain undergrowth species around a supposedly allelopathic tree not because of the repulsion caused by the tree but due to the soil type and other ecological factors which, rather than the tree, may disfavour the presence of certain species of vegetation. Differences in soil type correspond to distinct floristic and structural formations within the forest or woodland. The understorey communities are correlated with soil properties as well. The casual factor in these relationships is unclear and requires experimental investigations.

The findings described in this thesis establish the fact that if a species of eucalyptus, which does not have allelopathic effect (such as Eucalyptus hybrid) is chosen for ecorestoration or social forestry, no adverse impacts on undergrowth or other nearby vegetation are evidenced.

Eucalyptus and wild life
There are several published studies on the behaviour of wild life in eucalyptus plantations, from Australia, Brazil, Malawi and South Africa. Two different kinds of comparisons are involved: between regions where eucalyptus is indigenous and the ones where it is an exotic, and between natural forests and plantations.

Views in favour of eucalypts
Comparison of natural (non-eucalypts) forest with plantations of eucalypts and of araucaria
Three papers cover this. Dietz et al (1975) compared two areas of mixed natural forest with a 10-year old plantation of E. Saligna and a 31 year old plantation of Araucaria angustifolia, a species native to Brazil. The two areas had once been indigenous evergreen tropical rain forest and were recovering from complete devastation, one 15 years ago and the other 52. Populations of small mammals were sampled by trapping in all four forests. Five species of mammals were involved (Orzymys nigripes, Monodelphis americana, Marmosa sp., Akodon arvalisides and Blarinomys breviceps). The highest relative densities of small mammals were found in the araucaria plantation, the lowest in the eucalypts plantation. Densities in the two natural forests were statistically the same and lay between the two plantations. The diversity of captured species was highest in the natural forests and least in the homogeneous plantations.

Jocque (1981) compared the density of webs and the weight of the individuals of the large spider Nephila sp. in eleven plots each of 7 X 7 m in eucalypts plantation and in Brachystegia woodland. The density of webs, and average weight of spiders, was significantly higher in the latter, 950:200 webs per hectare and 958:770 mg weight. He concluded that this is due to insufficient food in the plantation and surmises that the spider would disappear in large pure
eucalypt plantations. The activity of termites was also significantly lower in the plantation. Steyn (1977) made a qualitative comparison of the bird populations between eucalyptus plantations (mainly of *E. grandis*) which cover over 25,000 ha in north easternTransvaal and the natural lowveld (*Lowveld Sour Bushveld*) containing strips of trees and shrubs along watercourse.

He studied the following aspects:

a) those birds that use the eucalyptus plantation and which feed in the plantations;
b) those that use the understory of the older plantations for breeding and hunting for food;
c) those that breed in the plantations and feed elsewhere; and
d) those that use eucalyptus plantations for feeding only.

Some lowveld birds also made irregular invasions into the plantations, particularly during a winter drought in 1969/70.

Steyn also identified some niches which were filled by specialised birds in Australia but which were not yet filled by indigenous species in South Africa.

He concluded that eucalyptus plantations were not as sterile and unsuitable for bird life as they were often accused of being. Some less adaptable species had been driven out, and plantations were unsuited to the way of life of some species - for example the purple crested louries (*Gallirix porphyreolophus*), which is a fruit-eater and widow birds, bishop birds and some larks and pipits which prefer open country.

*Comparison on indigenous eucalyptus forests with eucalyptus plantations*

Woinarski (1979) compared the birds of a 25 year old plantation of *E. botryoides* with those of an adjacent natural forest of mixed age *E. dives* with an open, moderately tall canopy and a varied shrub and grass understory. The site was close to Melbourne, Australia. He found that six species were significantly more common in the plantation and nine species in the natural forest. The diversity of bird species was slightly higher in natural forest. There were more hawking species, fewer species that gleaned food from bark and branches, and fewer that ate seeds, fruit and nectar. Some species were common in the interior of the plantations than at the edges.

*Comparison of indigenous eucalyptus forests with forests of Pinus radiata*

Two comparison of this kind have been made. One, by Friend (1982) who worked at Gippsland, Victoria and compared mammals; the other by Neumann (1979) whose studies were based on beetles of North-east Victoria.

In case of mammals, the richness in species was lower and the proportion of introduced species was higher in eucalyptus plantations, particularly in the younger stands where no overstory vegetation existed. Certain small ground-dwelling species were favoured in such plantations (of particular ages), depending on their requirements for food and refuge. Larger ground-dwelling herbivores and carnivores were common in the pine forests, although feeding areas for herbivores were restricted in middle-aged trees to the edges of compartments or to
tracks. Most arboreal herbivores, nectivores and users of tree hollows were uncommon in the plantations, where they were restricted to remnants of native forest. Their long-term survival in the plantations was considered questionable. Some arboreal species with relatively broad requirements for food and refuge were able to exist within older plantation compartments which supported some understroey shrubs.

In pine forests the number of mammal species was greatest near edges adjacent to native forest, and where there was a mosaic of remnants of native forest and pine stands of various ages.

The findings of Neumann (1979) on beetles were similar. The diversity of communities of beetles was found to be significantly higher in mature eucalyptus than in the older stands of pine because, in the eucalyptus, there was a more even distribution of individuals among species and a greater richness of species. In both, the range of species was greater during the spring and summer than during the autumn and winter.

Negminal (1980) described the effects of progressive reafforestation since 1958 of secondary grassland in the Ranibennur Blackbuck Sanctuary of 119 km² in Karnataka, India. This resulted in the recovery of populations of the blackbuck (Antilope cervicapra), Indian bustard (Chloris gliriceps) and wolf (Canis lupus) that were nearly extinct. He considered it doubtful whether this trend would be maintained if the remaining open areas were planted.

Karanth and Singh (1983) report that in Karnataka, India, population of black bucks have increased significantly since eucalyptus plantation work started. There has been a marked increase in the population of Great Indian Bustard as well.

Kondas (1986) has reported that arboreal and ground birds are as abundant in eucalyptus plantations as in scrub lands.

**Views against**

According to Foley and Bernard (1984), eucalypts is a threat to ecological stability. He is of the opinion that as they are often cultivated in large monocultural stand, the land in and around a eucalyptus plantation becomes almost devoid of local fauna.

Gupta (1986) has observed that eucalyptus flowers are not eaten by animals or birds as well as its thin canopy crown does not harbour birds or butterfly population. Hence he is of the opinion that the possibilities of these fauna’s visit in eucalyptus plantation does not even arise at all.

According to Shiva and Bandyopadhyay (1987), eucalypts destroys the environment for soil fauna which are important “factories” for producing soil fertility and efficient “machines” for maintaining soil structure. They claim that scanty leaf litter of eucalypts is not effectively transformed into organic matter because eucalyptus is toxic to soil organisms constituting decomposer-food-chains. The earthworm *Lanipita mauriti* which is responsible for decomposition of leaf litter is found to be absent in eucalyptus plantations. Shiva and Bandyopadhyay also allege that eucalypts does not allow the presence of micro and macro
avifauna because of its allelopathic effect.

On balance
Whereas reports of systematic long-term experiments are available (as detailed in last but one section) to suggest that eucalypts are no more hostile to wildlife than other monocultures, similar reports of controlled experiments are not found to substantiate the case against eucalypts. Those who have written about unsuitability of eucalyptus to wild life have based their reports on visual observations made in heavily disturbed plantations. Further they seemed to have looked for the kind of biodiversity one finds in natural forests and, when not finding it in eucalyptus monocultures, have derided the latter without having checked how other monocultures perform in this respect.

The studies described in the last but one section bring forth the following observations:

a) that plantations have a less diverse flora and fauna than indigenous forests;
b) that plantations of exotics have a less diverse flora and fauna than plantations of indigenous species;
c) that plantations can be made into more favourable habitats for animals and plants by appropriate management which provides suitable habitats for the species one wishes to attract, leaving patches or corridors of indigenous vegetation helps greatly in this;
d) limited planting in treeless areas and the shelter that these provide can be beneficial to populations of wildlife.

In conclusion it may be pertinent to quote from Budowski (1984). As to ecological deserts, it all depends on with what a eucalyptus plantation is compared. If it is with a nearby natural mixed forest, there is no doubt that the latter is much richer in fauna but if such a plantation is compared with a nearby scarcely covered slope as for instance a burnt over savanna, then it is highly probable that there is more animal life including nesting birds in the eucalyptus stand.

In the present work several species of wild birds were spotted in the plantations of Eucalyptus hybrid.

Eucalyptus as shelter belts or wind - breaks
Among the numerous uses to which eucalyptus has been put, is planting them to protect crops against strong winds.

Jenson (1983) report that they could not find any evidence to suggest that eucalypts differ in their effects as shelter-belts from any other trees.

Poore and Fries (1987) state that eucalypts are frequently planted as shelter belts and therefore provide some protection against wind erosion. However, they maintain, this is strictly a physical phenomenon, its effects depend solely upon the physical characteristics of the site and of the shelter belts. The species used has no influence on the result except of course different species have different physical characteristics.

There are no specific adverse reports against the use of eucalyptus as shelter belts except that, indirectly, they might harm the crops via their alleged allelopathic effects. The aspect of
allelopathy has been discussed earlier and it can be safely concluded that all species of eucalyptus, except the few which have recognized allelopathic effects, would make as good trees for shelter beds as any.

**WHO IS LOBBYING FOR EUCALYPTUS?**

Those who write or speak against eucalyptus often mention the 'eucalyptus lobby' and the 'conspiracy of the vested interests to hoist eucalyptus upon Indian lands'.

What is this lobby? What are its vested interests?

Eucalyptus is not a patented product; no single agency or group of agencies have ownership rights over eucalyptus. Eucalyptus is different from such mass consumption items as pesticides, fertilizers, and medicines which one or other capitalist country could be allegedly manufacturing with the intention of marketing in India and amassing unholy fortune.

Then why someone would like to promote eucalyptus, less so thrust it, if one is aware of the so-called ecological dangers posed by eucalyptus?

After scanning through a vast body of anti-eucalyptus literature one is able to find only two arguments in which some specific reason is given for the predispositions towards eucalyptus; these arguments are:

a) Foresters who are employed with the government support eucalypts because the genera is easier to tend and grow than other tree species proposed for social forestry. Eucalypts are far less favoured by cattle for browsing than other trees. This attribute as also the general hardiness of eucalypts makes it easier to raise them; in other words foresters get better results for their labours with eucalypts. There is also this hint that as foresters have to work less hard to establish eucalyptus; the tree provides 'an easy way out' for the allegedly lazy government employees.

b) Industrialists need eucalyptus so they pressurise the government which in turn orders the forestry officials to promote eucalyptus.

In both the above-mentioned arguments, it appears, there are attempts to make flaws out of a virtue. That eucalyptus saplings are less prone to damage by cattle than other trees ought to be deemed as an added advantage and not the sole advantage.

As for the industrialist - government - forestry official nexus for promoting eucalypts it is a conjecture, though not a wholly unlikely one. But the point not to be overlooked is that as long as there are no unassailable grounds to shun eucalypts why the parties concerned should not promote it given its remunerativeness (which in turn is governed by market forces)? Even when there is no pressure from any government agency to plant eucalypts farmers go for them, even when other tree species are made available by social forestry initiatives, farmers prefer eucalypts.