COLLEGE OF FORESTRY

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FAST-GROWING SPECIES PLANTATIONS – Myths & Realities AND THEIR EFFECT ON SPECIES DIVERSITY

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ABSTRACT:

Plantation is neither inherently good nor inherently bad. It is a neutral technology which, when poorly planned and executed, can cause grave problems; and when well done, can deliver not just large quantities of wood, but a range of environmental and social benefits. Obviously, If, plantations replace natural forest, or take over lands previously used by farmers, they might be considered a bad thing. If, on the other hand, they are sensitively sited on degraded lands and managed by local communities, the opposite will hold true (Cossalter and Pye-Smith, 2003).

There have been certain possibilities to achieve species diversity on degraded lands by afforestation of fast-growing tree species. All tested species of Acacia, Teak and Eucalyptus seem to be the favorable tree for the growth of the ground vegetation. Species diversity indices of their ground flora vegetation showed higher values than those of open control area. Diversity index (H) was 3.795 under *A.catechu*, 3.595 under *T. grandis* and 3.173 in open bhata land, species richness (SR) was 22, 20 & 15, respectively (Verma 2000); *Eucalyptus tereticornis* suported the maximum species richness (36), followed by *Acacia auriculiformis* (26), then *Tectona grandis* (20) and the lowest was recorded for open area (15) (Thapliyal, et al., 2002). Maximum species was recorded in rainy season and minimum in summer under *E.tereticornis* (Bahar and Jain, 2002). Under Poplar plantation, Lodhiyal (2001) found the short-lived species with maximum H in older stand (9-yr old) and lower H in the younger stands. This is due to lower nutrient levels in older stands and a higher level in the youngers.

On *imperrata*-grasslands, fast-growing species plantations of *G. arborea*, *A. mangium* and *A. crassicarpa* in *Imperata* grassland had early significantly suppressed the development of *Imperata cylidrica* (reduced dry biomass) and favored the development of other grasses and shrubs, viz., *Chromolaena odorata* and *Clibadium surinamense*. There is a significant linear correlation existed in regression analysis between distance of planted trees and grass biomass for four tested tree species *A.mangium* ($y= 1.547x-1.426$, $r^2= 0.95$), *A. crassicarpa* ($y= 2.083x-0.669$, $r^2= 0.97$), *Gmelina arborea* ($y= 0.926x- 0.886$, $r^2= 0.75$) and *Paraserianthes falcataria* ($y= 2.926x- 2.696$, $r^2= 0.96$) (Otsamo, 2002).

INTRODUCTION.

Establishing plantations might sound like a laudable activity. Trees, after all, have many virtues. They convert water, sunlight and carbon dioxide into wood and oxygen, and it is frequently claimed that they regulate the water cycle, stabilize steep slopes against erosion and prevent flooding. Trees also provide a habitat for countless creatures and micro-organisms, and hundreds of millions of people rely on them for timber, firewood, fruit, nuts, resins and other products. Appropriate monoculture plantation of fast-growing species like Acacia, Teak, Poplar, etc., has proved to be one of applicable approach for afforestation programs, both in economical and ecological purposes, particularly, the only effective choice to initially reforest the degraded areas, then to transform into permanent forest (Apel, 2004). During recent years the planting of large areas of fast growing trees has sparked off much controversy, especially in the developing world. Critics of these “fast-wood” plantations include environmentalists, who argue that they are replacing natural forests and causing harm to wildlife, water resources and the soil, and local communities, who complain that plantations are taking over land which previously provided them with the means to feed themselves and earn a living (Cossalter and Pye-Smith, 2003). This has become a major issue, particularly where "fast-wood" plantations are a significant land use.

100 years have seen a major reduction in global forest cover, especially in the tropics. Natural forests have been replaced by a variety of simple agricultural monocultures such as rice or industrial forest monocultures made up of fast- growing exotic species such as *Pinus, Eucalyptus, Acacia* or *Tectona* (Lamb, 2003). Around the world, biological communities that took millions of years to develop are being devastated (Sharma, 2003). About 20 per cent of all species are expected to be lost within 30 years and 50 per cent or more by the end of 21st century (Myers, 1993; Sharma, 2004). The current decline in biodiversity is largely the result of human activities from habitat destruction, over-harvesting, pollution and inappropriate introduction of exotic plants and animals. The diversity of natural ecological communities has never been more valued than they are now, as they become increasingly threatened by the environment crises. Efforts are, therefore, needed to conserver biological resources and utilize them on sustainable basic and maintain genes, species and ecosystems (Verma, 2000).

In the past, studies on biological diversity have been concentrated on higher spatial scales, e.g. regional and global (May, 1988; Raven, 1987; Daily, 1995; Groombridge, 1992; Sharma, 2004). A great deal of time and expertise has been expended, but our understanding of the structure and functioning of communities has been meager. The current focus of ecological studies, therefore, is shifting from the higher scale to locally manageable scale (Rickklef and Shluter, 1993; Nagendra and Gadgil, 1999; Negi, 1999; Sharma, 2004). This paper is aiming to make a review on fast-growing plantations, their development & argumentation, on methods and findings, how effects of fast-growing tree species plantations on their species diversity of ground flora vegetation.

RELEVANT TERMINOLOGIES

Plantation definitions:

Fast-growing species:

According to Dwivedi (1993), fast-growing species are those which yield a minimum of 10 cubic meters of wood per hectare per annum. In case of younger plantation, a height increment of 60 cm per annum is considered necessary for fast growing species. This concept of fast growth in forestry is relative and it depends upon several factors like locality, age, management objective.

Plantation:

There are various definitions of what constitutes a plantation or man-made forest; one is that a plantation is "a forest crop or stand raised artificially, either by sowing or planting" (Ford-Robertson, 1971). According to Nambiar, (1989), Plantation is treated as crop, usually monocultures and even-aged in nature, managed either for wood or biomass production or for improving the environment. Such crops may be raised at sites where forests may or may not have existed in the part, or they may be naturally regenerated stands managed in such a way that they have the essential characteristics of plantation. Plantations are established for a variety of reasons and they vary in composition and structure, as well as in the intensity of management (Cossalter and Pye-Smith, 2003).

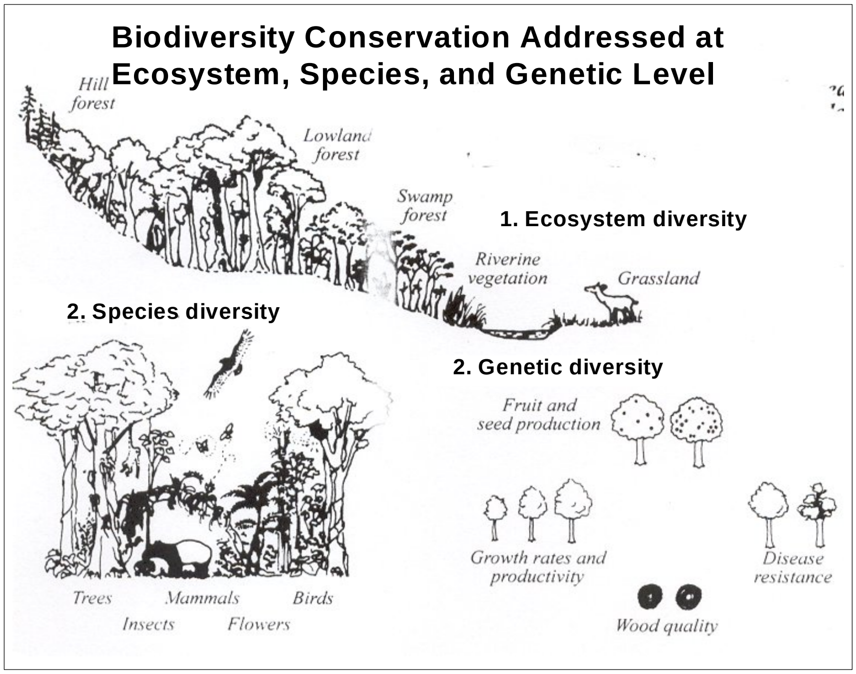
Fast- wood plantations:

Fast-wood plantation are those which are intensively managed for commercial plantation, set in blocks of a single species, which produce industrial round wood at high growth rates (mean annual increment of no less than 15 m^3 per ha) and which are harvested in less than 20-year rotation (Cossalter and Pye-Smith, 2003). The sole purpose of fast-wood plantations, in contrast to plantation, is to produce large volume of small-diameter logs at competitive prices as quick as possible supplied as raw material for the pulping and paper industries.

Fast-wood plantations can be large-scale estates owned by companies or concentration of a large number of small- to medium –scale commercial woodlots owned by smallholders. The tropics and subtropics are not the only regions where fast-wood plantations occur. Poplar is a good example of a genus almost entirely confined to temperate regions. They are managed as fast-wood plantations in many farms in southern Europe, North America and northern China with rotations of 20 years or less and growth rates above $20m^3$ per ha per year. And not all fast-growing species make fast- wood plantations. The genus of *Paulownia* is widely distributed in East Asia, in temperate, subtropical and tropical areas. *P. tomentosa* is the best-known species and is planted in northern China for its high quality timber, high growth rate on fertile soil, but not treated as fast- wood plantation (not in block planting).

Biological Diversity in general:

According to the US office of Technology Assessment (1987), biological diversity is "the variety and variability among living organisms and the ecological complexes in which they occur" (Sharma, 2003). Biological diversity is therefore occurring at three levels: genetic diversity, species diversity and ecosystem diversity as showed in following figure.



Genetic diversity: At finer levels of organization, biodiversity includes the genetic variation within species, both among geographically separated populations and among individuals within single population.

Species diversity: Biodiversity at its most basic level includes the full range of species on earth, from microorganisms such as virus, bacteria and protists through the multi-cellular kingdoms of plants, animals and fungi.

Community/Ecosystem diversity: On a wider scale, biodiversity includes variations in the biological communities in which species live, the ecosystem in which communities exist, and the interactions among these levels.

Species biodiversity measurement and indices:

Alpha, beta and gamma diversity:

Whittaker (1975) distinguished three different kinds of species diversity, that he called alpha, beta and gamma diversity. Alpha diversity refers to he number of species within a sample area (e.g. a single 20x50m quadrat). Beta diversity describes the differences in species composition between two adjacent sample areas along a transect (e.g. beta diversity is low when the overlap between the species composition of two quadrats is high, and is highest when the samples have no species in common at all). Gamma diversity describes regional differences in species composition (e.g. the difference in botanical composition between comparable habitats on two adjacent mountain ranges).

Species Richness:

At its simplest level, diversity can be defined as the number of species found in a community, a measure known as Species Richness. Diversity is “a single statistic in which the number of species and evenness are compounded. Many methods for calculation of diversity have been proposed that combine these two types of information. The most successful method being based on the information theory equation of Shannon and Weaver (1963) as defined as follows.

The Diversity Index (H):

$$H = \sum_{i=1}^{s} \{Ni/N\} \log_2 \{Ni/N\}$$

Where: H = Shannon- Wiener index of Species Diversity and in this case,

Ni = Number of individuals (or Importance Value Index- IVI) of the species i.

N = Total number of individuals (or IVI) of all the species in site.

The Diversity Index (H) must have not only a variety component but also an equitability component; it must account for the distribution of individuals among the species present. In table 1, each community has a total of five species and 100 individuals, but the distribution of individuals among the species is different. Community A has the most equitable distribution possible, then therefore has highest H while Community C has the least equitability, then therefore, has lowest H among the three communities. In other word, it is said that, information content is maximum if each individual belongs to a different species (probabilities to represent of individuals in all species are equal), and minimum if all belong to the same species (Rolan, 1973).

Table 1: Species diversity of three hypothetical communities

Species	n_1	n_2	n_3	n_4	n_5	**n**	$s/\sqrt{n}$	**H**
Community								
A	20	20	20	20	20	100	0.50	2.32
B	50	35	7	5	3	100	0.50	1.67
C	96	1	1	1	1	100	0.50	0.32

Source: Wilhm, 1969; Rolan, 1973)

The concentration of dominance (Cd):

It is determined by using Simpson’s index (Simpson 1949) as:

$$Cd = \sum_{i=1}^{s} \{Ni/N\}^2$$

Where Ni and N were the same as those of Shannon- Wiener Information Index mentioned above.

In other cases of study, the Diversity Index (H) and concentration of Dominance (Cd) might be calculated on the basis of Biomass (W) or Importance Value (IV) (Xu, et al., 2001) instead of number of individuals and IVI. This aspect will be further discussed in the methodological section.

Other indices and concepts:

Importance Value Index (IVI):

In order to express the dominance and biological success of any species with a single value, the concept of Importance Value Index (IVI) has been developed as per Curtis and Mclntosh (1950); Phillips (1959); and Mishra (1968); who have reported the IVI as a better expression of relative ecological importance of the species than the single absolute measure like frequency, density and basal cover, etc. Therefore, Importance Value Index (IVI) of each species was calculated by summing up the three relative values viz., relative density, relative frequency and relative dominance, following Curtis (1959).

The Niche concept:

The Niche is a multidimensional description of a species' resource needs, habitat requirements and environmental tolerances (Hutchinson, 1957; Crawley, 1997). The niche concept serves as a shorthand summary of a species' complex suit of ecological attributes, including its abiotic tolerances, its maximum relative growth rate, its phenology, its susceptibilities to various enemies and its relative competitive abilities with other plant species.

Niche space partitioning and resource sharing:

Species-rich communities may be composed of (i) species with narrower niches (ii)species with more broadly overlapping niches; (iii) habitats providing "longer" niche axes or (iv) a combination of these. Dominance Diversity (D-D) curves are drawn to ascertain resource apportionment by the components in the various sites for herbaceous species, wherein the IVI was used as an expressive measure of the Niche of species/ resource apportionment. This is based on the assumption that there is some correspondence between the share of community resource and community space utilized by a species (Whittaker 1975, Pandey 2002). Degree of resource apportionment is considered a measure of resource conservation (Pandey 2002).

REVIEW METHODS ON VEGETATION & SPECIES DIVERSITY ANALYSIS

Materials and Data analysis:

Monoculture forest plantation of species Acacia, Eucalyptus, Teak and Poplar were used for the study objectives. Study sites, experimental designs and implementation were taken different plantation ages ranging from one to nine years, different planting densities (2m x 1.5m; 2m x 2m; 3m x 1.5m; 3m x 3m and more spacing) and different seasons in to consideration. The comparisons for different species diversity indices, their interaction correlations and effects were made among the studied species & their ground-growth components and also made between studied sites with these species and open site as control.

Some packaged software programs were used for calculation of biodiversity indices (SPDIVERS.BAS and SUDIST.BAS) (Ludwig & Reynolds, 1988; Khopai, et al., 2003). Software packages of SYSTAT (SYSTAT, 1996), ANOVA, Linear Regression Co-relation Analysis (Excel 5.0, 2001) was used for statistical data analysis for significances, interaction effects, and correlations.

Vegetation study and analysis:

Most Phyto-sociological studies were conducted by applying Quadrat Method (Mishra, 1968; Rastogi, 1999 and Sharma, 2003) or sampling plot method . **Quadrat** is a sampling unit, an area of definite size with different shape like circular, rectangular or square, use the kinds of list, count and chart for plant community structure studying. Since plant community is usually heterogeneous, the determination of size and number of quadrats necessary for adequate sampling is prerequisite. Quadrats with size of 1m x 1m were used for herbaceous species and laid down randomly in study sites of plantation and open site for control. In each quadrat, data of number of individual plant, diameters and covers for different species present was collected for analyzing quantitative characters of frequency, density, cover area and basal area.

Density:

Density denotes average number of individuals of a given species out of the total of samples examined in a study area however the species may or may not occur in all the quadrats. (Oosting, 1958, Rastogi, 1999, Sharma, 2003).

$$\text{Density} = \frac{\text{Total number of plants of individual species in all quadrats}}{\text{Total number of quadrats studied}}$$

$$\text{Relative Density (RD) (\%)} = \frac{\text{Density of individual species}}{\text{Total density of all species}} \times 100$$

Frequency:

Frequency indicates the number of sampling units in which a given species occurs. In this no counting is involved, just a record of species presence or absence is made (Raunkiaer, 1934, Rastogi, 1999, Sharma, 2003).

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats with the individual species}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Relative frequency (RF)(\%)} = \frac{\text{Frequency of any species}}{\text{Total frequency of all species}} \times 100$$

Basal Areas:

The basal area is one of the chief characteristics determining dominance and the nature of the community. It refers to the ground actually penetrated by the stems (Honson and Churchbill 1961, Rastogi, 1999, Sharma, 2003).

$$\text{BA (spm.)} = \pi r^2 \text{ or } \frac{3.1416 \times (\text{diameter})^2}{4} \text{ or}$$

$$\text{Relative Basal Area (RBA) (\%)} = \frac{\text{BA. of individual species}}{\text{Total BA of all species}} \times 100$$

Values of abundance was calculated following Curtis and Mclntosh (1950)

$$\text{Abundance} = \frac{\text{Total number of plants of individual species in all quadrats}}{\text{No. of quadrats in which the species occurred}}$$

The ratio of abundance to frequency for different species was determined for eliciting the distributional pattern. The ratio indicates regular (<0.025), random if it lies in between 0.025- 0.05 and contagious distribution if it higher 0.05 (Curtis and Cottam, 1956).

Measurement of Cover:

Usually cover is defined as the vertical projection of the crown or shoot area of a species to the ground surface, expressed as a fraction or percentage of a species to the ground surface expressed as a fraction or percentage of a reference area.

$$\text{Relative Cover (RC) (\%)} = \frac{\text{Cover of species A}}{\text{Total cover of all species}} \times 100$$

Table 2: Modified Scale for Measurement of Crown:

Scale Value	Range of Cover (%)	Mid-point of Cover (%)
1	0-1	0.5
2	1-5	3.0
3	5-15	10.0
4	15-30	22.0
5	30-45	37.0
6	45-65	55.0
7	65-80	72.0
8	80-90	85.0
9	90-100	95.0
10	100	100.0

Plant crown covers were measured by some ways. One of which is applying a visual estimate, in which, a suitable scale of value was developed and applied for small plots of study sites (table 2). Average cover for a species was estimated by assigning the mid-point of cover to each plot with a given scale value and then averaging the mid-point values for all plots. Plots from which the species was absent were included in the average with a value of zero (Rastogi, 1999). The seedlings were considered as herbs, while saplings as shrubs (Pandey, et al. 2002).

Other method of ground vegetation cover measurement was applied by Otsamo (2002), in which the sampling plot was divided into 20 sub-plots, each representing 5% of the quadrat. Sub-plot with presence of herbs will be counted as 5% cover.

Importance Value Index (IVI):

The synthetic value was obtained by summing the three relative values as follows:

- IVI = RD + RF + RC (Rastogi, 1999 and Sharma, 2003), or
- IVI = RD + RF + RBA (Mishra, 1968)

Calculation of Diversity Indices:

Shannon-Wiener Diversity (H):

The Diversity Index (H) might be calculated on the basis of number of individuals (Shannon and Weaver, 1949; Rolan, 1973; Pielou, 1975; Pandey, et al. 2002), or on the basis of biomass (Rolan, 1973) and on the basis of IVI (Shannon and Weaver, 1963; Verma, 2000) or Importance Value (IV) (Pielou, 1975, Xu et al., 2001). These formulas are as follows:

- $H = \sum_{i=1}^{s} (Ni/N) \log_2 (Ni/N)$

Where: H = Shannon- Wiener index of Species Diversity

Ni = Number of individuals (or Importance Value Index- IVI) of the i^{th} species.

N = Total number of individuals (or IVI) of all the species in site.

s

- $H = \sum_{i=1} (Wi/W) \log_2 (Wi/W)$

  Where: H = Shannon- Wiener index of Species Diversity,

  Wi = Biomass of the i^{th} species.

  W = Total biomass of all species collected in site.

- $H = \sum_{i=1}^{s} (p_i \log_2 p_i)$

  Where: H = Shannon- Wiener index of Species Diversity,

  p_i = IV = Importance Value of the i^{th} species.

  IV (%) = (RBA + RD)/2 (Basnet, 1992)

  RBA (%) = Relative Basal Area

  RD (%) = Relative Density

Concentration of dominance (Cd):

Similar ways of calculation were also applied to calculate the Concentration of dominance (Cd) by Simpson's index (Simpson, 1949).

$$Cd = \sum_{i=1}^{s} (Ni/N)^2$$

Where Ni and N were the same as those of Shannon- Wiener Information Index.

Hill's numbers of N1 & N2:

Further more, Khopai (2003) used **Hill's numbers of N1 & N2** to discuss species diversity of ground flora under effects of afforestation activity in Thailand,

$N1 = e^{H}$
$N2 = 1/Cd$,
where: N1 = number of abundant species in the sample
N2 = number of very abundant species in the sample
H = Shannon- Wiener index of Species Diversity
Cd = Simpson's index

Index of similarity (Sorensen's Index- SI) (β- Diversity):

SI = 2C/ (A+B)

Where: C = number of species common to both communities

A = total number of species in community A

B = total number of species in community B

Dominance- Diversity (D-D) curve:

To analyze species dominance and ascertain the resource apportionment among the species at various sites, Dominance- Diversity (D-D) curves were developed. The IVI was used as expressive measure of niche of species, thus treated as an expression of the relative niche size (Whittaker 1975, Pandey 2002).

FINDINGS AND DISCUSSIONS

Plantations: History and Development:

The practice of planting trees goes back to ancient times, and many economically important species have been widely planted outside their natural range of distribution for thousands of years. Prior to 1900, low population density and the widespread availability of natural forests meant that there was no need to plant trees extensively as an industrial resource. However, some nations became progressively more concerned about their lack of natural forests, and in the first half of 20th century tree planting began in earnest in western Europe, the united state, Australia, New Zealand, South Africa and a small number of developing countries such as India, Chile, Indonesia and Brazil. Later, in the 1950s, Japan, Korea and China embarked on massive reforestation programs.

The 1960s saw the launching of large-scale plantation programs in many tropical countries, and between 1965 and 1980 the area devoted to tropical plantations trebled. During this period the United Nations of Food and Agriculture Organization (FAO) played an important role by disseminating technical information and promoting plantations. In most cases, plantations were established with financial supports from foreign donors or with soft loans. Plantations often benefited from direct subsidies and they were mostly managed by state organizations. Poor marketing and a failure to establish viable links between plantations and industrial consumers of wood products meant that many trees-planting activities came to an end when external support ceased. Nevertheless, the area under plantations continued to expand at a rapid rate. According to the Global Forest Resource Assessment 2002, conducted by FAO, the global plantation estate increased from 17.8 million hectares in 1980 to 43.6 million hectares in 1990 and 187 million hectares in 2000 (Cossalter and Pye-Smith, 2003). A third of today’s plantations are found in the tropics and two- thirds in temperate and boreal zones. A relative small number of countries dominate the plantation business, with five, each possessing over 10 million hectares of plantations, accounting for 65% of the world’s plantations. These are China, the United States, the Russian Federation, India and Japan. However, few of their plantations could be classified as fast wood.

The FAO assessment estimates the global rate of new planting at 4.5 million hectares a year, with Asia accounting for 79 per cent and South America 11 per cent. There was a significant increase between 1991 and 2000 in the area of plantations established for industrial purpose, this includes all fast-wood plantation- as a result of increased private-sector involvement. FAO's figures make no distinction between fast-wood and other types of industrial plantation. Attempts have been done to establish as thorough a picture as possible of today's fast-wood estate. The result in table 3 presents the key characteristics of the main types of fast-wood plantation, together with their extent and distribution. The key players are Brazil, Indonesia, China, India, South Africa, Thailand, Vietnam, Malaysia, Venezuela as far as tropical and subtropical species are concerned, and China, Chile, Portugal, Spain, Argentina, Uruguay, South Africa and Australia for the temperate species (Cossalter and Pye-Smith, 2003).

Table 3: Fast-growing species plantations: main species and countries involved

Species	Mean annual increment (m^3/ha/year)	Time to reach maturity (years)	Estimated extent fast-wood plantations only (1,000 ha)	Main countries (in decreasing order of importance)
Eucalyptus grandis and various eucalypt hybrids(1)	15-40	5-15	± 3,700	Brazil, South Africa, Uruguay, India, Congo, Zimbabwe
Other tropical eucalypts(2)	10-20	5-10	± 1,550	China, India, Thailand, Vietnam, Madagascar, Myanmar
Temperate eucalypts(3)	5-18	10-15	± 1,900	Chile, Portugal, north-west Spain, Argentina, Uruguay, South Africa, Australia
Tropical acacias(4)	15-30	7-10	± 1,400	Indonesia, China, Malaysia, Vietnam, India, Philippines, Thailand
Caribbean pines	8-20	10-18	± 300	Venezuela
Pinus patula and *P. elliotii*	15-25	15-18	± 100	Swaziland
Gmelina arborea	15-35	12-20	± 100	Costa Rica, Malaysia, Solomon islands
Paraserianthes falcataria	15-35	12-20	± 200	Indonesia, Malaysia, Philippines

Poplars	11-30	7-15	± 900	China, India, USA, central & western Europe, Turkey

(1) Mainly hybrids involving: *E. grandis, E. urophilla, E. tereticornis, E. camaldulensis, E. pillita*
(2) Mainly *E. camaldulensis*, *E. tereticornis*, *E. urophilla*, *E. robusta, E. pillita, E. deglupta* .
(3) Essentially *E. globulus*, but also several frost-resistant species (mainly *E. nitens)* .
(4) Essentially *Acacia mangium,* but also *A. auriculiformis* and *A. crassicarpa*.

The reason for the rapid expansion of fast-wood plantations is purely economic. Fast-wood plantations can produce one and a half to two times more wood per ha per year, and reach maturity two to three times faster, than longer- rotation soft-wood plantations.

With their cheap land, low labor costs and potential for higher tree growth rates, developing countries located in the tropics and subtropics have advantage over cooler, temperate regions when it comes to producing plantation wood. However, large investors are interested in other factors too, and have so far concentrated on a limited number of developing countries, only a handful of which are in the tropics. The risk of land appropriation, concern about the lack of legal and commercial structures and a lack of good infrastructure are likely to deter some investors.

Plantations and the argumentation of their environmental issues:

Much of the opposition to fast-wood plantations is based on the belief that they have a damaging impact on the environment. They are seen, most notably, as a threat to biodiversity, to water resources and to soil fertility. Many environmental groups also fear that the planting of genetically modified tree crops will lead to problems in the future. There are, too concerns about the spread of pests and diseases in the single-species tree plantations. The ability of trees to remove carbon dioxide from the atmosphere has encouraged some governments and organizations to advocate planting fast-growing trees to counter the thread of global warming. However, many environmentalists are opposed to such a move, in part because they believe developed countries should reduce their carbon emissions at source, in part because they consider the plantations to be environmentally and socially harmful.

Plantations and Biodiversity:

If large swathe of natural forest is cleared to make way for a fast-wood plantation, there will be a loss of biodiversity. The same applies when a natural savanna ecosystem is replaced by a plantation of alien species, as has frequently happened in South Africa, Uruguay and Argentina. Yet a similar plantation, established on degraded land, might bring about an increase in biodiversity. In other word, *the impact of plantations on biodiversity will be a* *function of what they replace*. Other factors of importance include the location of the plantation, its size, length of rotation and species composition. The issue of contiguity is also important. If new plantations are sited close to existing natural forests, they may benefit from their biodiversity: animals, birds and insects will be readily available to invade the new plantations. However, if no such reservoir of biodiversity exists, then the chance of the plantations being invaded by wildlife from outside, and providing a new habitat, becomes more remote.

Recent figures provided by FAO suggest that natural forests in the tropics are being converted to other land uses at an alarming rate, with an area half the size of Finland being lost every year. Conversion to forestry plantations accounts for 6-7 per cent of these losses. The remaining 93-94 per cent is lost to agriculture and industrial development. Indonesia is witnessed with massive conversion of natural forests to fast-growing plantations. By the end of 2001, it had 1.4 million hectares of industrial pulpwood plantation, approximately half of which had been established on land cleared of natural closed forest during the previous 20 years (accounted for 5-7% of total losses of natural forests in Indonesia). Natural forests have been cleared to make way for plantations in other parts of the world too. But in some countries, Brazil for example, significant areas of fast-wood plantations have been established on land that had already been cleared of natural forests by farmers and others.

When new fast-growing plantations are established, the existing vegetation - closed forest, scrubland, grassland or whatever - must be removed, and before a single tree is planted the vast majority of mammals, birds and other creatures will be forced to flee. Furthermore, the building of new roads by plantation companies will bring about the surrounding natural forests to be more vulnerable to illegal logging and damaging. In the humid tropics, the larger the area of natural forest converted to new plantation, the greater the number of species that will be effected. A recent study in East- Kalimantan, Indonesia revealed that, 1-ha plot contained 200 species of trees, while a 5-ha plot contained doubled that amount and a 10-ha plot over 500 species. This means that the larger a plantation, the greater will be its impact on biodiversity if it replaces pristine forests (Sist and Saridan, 1999; Cossalter and Pye-Smith, 2003).

However, there are two sides to this story. In some situations, fast-growing plantations may have a positive impact on biodiversity. When the natural vegetation has already been destroyed or seriously declined- for example, by logging, unsustainable agriculture or overgrazing- plantations may help to restore some biodiversity. In many parts of China and

India, plantations have been established on barren lands or abandoned agricultural land. On the whole, this has been good for biodiversity. In the People's Republic of Congo, eucalypt plantations established on savannas seldom colonized by forest species- annual fires destroy the tree seedlings- have acted as a nurse crop for species invading from nearby natural forests. This phenomenon of plantations "catalysing" natural forest restoration on degraded land has been documented for several types of plantation, including fast-wood, in many countries (Parrotta and Turnbull, 1997; Cossalter and Pye-Smith, 2003). Some plantations will support more biodiversity than others, and the same species will invariably shelter and attract more wildlife in its natural habitat than outside its distributed range as an exotic. Native Australian eucalypt forests, for example, support a rich diversity of animals and plants, but not when planted as a monoculture in other parts of the tropics.

Water Matters:

The effects of plantations on water yields and flooding have been the subject of much myth-making. Almost invariably, whenever there is a major flood in the cry goes up that it has been caused by deforestation. And this is generally accompanied by the claim that the obvious way to prevent a recurrence is to plant trees in the water catchment, the idea being that they will soak up excess water. There are often good reasons for planting trees, but plantations can seldom guarantee an even flow of water, whatever the climatic conditions.

The sites most commonly targeted for fast-wood plantations tend to be those with plentiful rainfall, as promotes the highest growth rates. However, some fast-wood plantations and many other types of plantations are established where water is in limited supply, at least during the dry season. Environmentalists frequently criticize large-scale plantations on the grounds that they reduce the amount of water that flows through the water catchment. According to the World Rainforest Movement (WRM), fast-growing eucalypt and pine plantations have led to water shortages in Espirit Santo state of Brazil, in South Africa, southern Chile, north-east Thailand and many other places. These shortages, are said to have led to the abandonment of farmland, a decline in fish catches, the depletion of groundwater reserves and the drying up of steams and wells.

When a plantation is established, there will inevitably be a change in the water cycle. The nature of the change will depend on what sort of habitat the plantation replaces. When a natural forest is converted into a plantation, the greatest changes will occur during the first few years following clearance and planting. In contrast, when plantations are developed on grassland, the initial change in hydrology will be slight, but will become progressively more pronounced as the plantation approach maturity (Nambia and Brown, 1997). According to a study in French Guiana, when eucalypts were established following clearance of primary forest, runoff increased by over 60 per cent in the first year. Thereafter it declined, and by year six, run-off was some 10 per cent less than it had been under primary forest. When forest was replaced by *Digitaria* grassland, run-off increased by over 100 per cent in the first year, and was still some 30 per cent higher than under primary forest after five years. This could suggest that water run-off increased when grassland replaces trees in wet tropical environment like French Guiana: clear-cutting leads to more water downstream, not less. Run-off also increases dramatically when new plantations are established after clear-cutting, but plantations, especially those consisting of fast-growing trees, soon retain more water than primary forest, thus reducing the water available to those living downstream. This suggests that WRM's criticism of plantations – that they deprive downstream users of water- is valid in certain situations.

Climatic conditions also play a significant role in determining the precise impact of new plantation on water flows. Studies indicated that, in very wet and very dry climates, forested areas will experience lower levels of water run-off than un-forested areas. The water retention by fast-growing plantations can cause serious problems for users downstream, especially when the plantations replace the grassland. In South Africa, large areas of riversides were planted with eucalypts, black wattle and pine during 1950's and 60's, and these led to a dramatic decline in the water available to users downstream. As a result, in the mid -1990s, the South African government hired many thousands of people to remove the offending trees. Nowadays, obtaining a "water license" from the Department of Water Affairs and Forestry is prerequisite to plantation development. Silvicultural measures- choosing species that use less water, thinning heavily are also being encouraged.

It is frequently said that trees can regulate water flow by retaining water during wet season and releasing it slowly during dry season. After all, root activity leads to better soil structure and increases the capacity of the soil to store water. However, this is rarely born out by empirical analyses, and what little evidence exists to support this view is anecdotal. The importance is that we need to make a distinction between the way forests and plantations deal with modest amount s of water, and the way they behave during extreme events, when massive quantities of water fall over a very short period of time (Cossalter and Pye-Smith, 2003). It is little or no evidence to suggest that forests or plantations can prevent flooding when an area is deluged with large amounts of rain.

A failure to understand the relationship between trees and water has resulted in the misuse of both land and money. Investing millions of dollars on plantations that use more water than the vegetation they replace is senseless if water is already in limited supply for downstream communities. In other situations, a decrease in dry season stream flow, as a result of the increased demand for water in fast growing plantations, may not cause significant water problems to other users. It is impossible to make generalizations about the relationship between fast- plantations and water flows, and each plantation, each plan for a new plantation, should be assessed individually (Cossalter and Pye-Smith, 2003).

Plantations and the Soil:

Soil degradation has become an increasingly serious problem, especially in the tropics and subtropics, where soils are inherently poor and at high risk of erosion. The main causes of soil degradation are poor agricultural practices, deforestation and overgrazing, and fast-growing plantations can also result in soil degradation if they are poorly planned & managed. As a rule, erosion tends to increase during site preparation and early years of growth, when the soils are exposed to wind and water. Once the trees are established, erosion may still be an issue, especially where there is little ground cover, on sloping and in plantation where leaf size encourages the creation of large water drops. Short rotation plantations experience more erosion than longer rotation crops with identical conditions.

Nutrient losses are generally at their most significant during site preparation and harvesting. Some nutrient losses also occur as a result of erosion. Burning between rotation of plantations has been responsible, in part, for site degradation and subsequent decline in yields. The concept of site management with uses of tree residues during and between rotations, after harvesting has been accepted to restore the soil fertility, site productivity and sustain the yields. As general principle, short rotation fast- wood plantation will have a more significant impact on soil fertility than longer rotation plantation, but fast-wood plantations are generally much less degrading to the soil than many commercial agricultural crops, e.g. nitrogen removed by a cereal crop was two and half time or more , and fifteen time more with phosphorus as compared to those removed by eucalypt plantation (FAO, 2000). On soils that are naturally poor in nutrients- low phosphorus availability is one of the main factors limiting forest productivity- the use of fertiliser is essential.

However, on degraded lands plantations can help to reduce and control erosion and they are some time established precisely for that purpose. For example, in New Zealand, radiata pines have been planted on degraded farmland to reduce erosion. A study revealed that, on sites with either no trees or trees of less than one year old, more than 20 per cent of surface area was disturbed by cyclone, as the age of plantations increased, the amount of disturbance declined and at nine year- age or more, disturbance was only 0.2 per cent or less of the area (Challenge Forest, 1989).

Although fast-growth plantations are more prone to increased rates of erosion and decline in fertility, when compared to longer rotation plantations, they can in certain circumstances have a beneficial influence on the soil and prevent or reduce erosion. Plantations of eucalypts in Congo cover some 45,00 ha of very poor sandy soils. They have replaced degraded savanna grassland that was little use, either for grazing or hunting. Studies showed that these plantations have improved the soil by building up organic matter (Loumeto and Bernhard-Reversal, 2001). They have also encouraged the return of natural vegetation and wildlife (Loumeto and Huttel, 1997).

Plantations and Pests:

There are some views that hold that exotics are at less risk of pest outbreaks than native trees, at least for a long initial period after their introduction. It contended that the safe period is generally long enough to justify their commercial exploitation. The plantation may eventually be attacked by pests, but the lack of pests in the early stages of introduction means that they may be much more productive than native species (Cossalter and Pye-Smith, 2003). The recent study for pest outbreaks in tropical forest plantation conducted by CIFOR raised the question that, is there a greater risk for exotic tree species than for indigenous tree species? The answer of K.S.S Nair was that “No generalization is possible for exotics as a group, but more species seem to be at lesser risk, at least for a long , though uncertain, period of time after introduction”. Intriguingly, he found that the common belief that pest problems are less severe among indigenous species than exotic plantation- the theory being that specialized natural enemies of the pest are already present in indigenous stands of trees- does not necessarily hold true. Although natural enemies play important role to control the increase of pest population, but the outbreaks also occur in natural forests and in plantation of native species. The factors that involved in the likelihood of pest outbreaks may be the distance between the original locality and introduced plantation, appropriation of site- species matching & selection, silvicultural practice and the area under plantation.

For better approach of pest control and prevention, much greater attention should be paid to find the tree species and provenances that best suit particular sites and their chosen is not only for their growth potential but also their ability to resist pest attacks.

Genetically Modified Trees: Opportunity or Threat?

One of the fiercest debates in recent years has concerned the use of genetically modified organisms (GMOs). It has opened up a whole new world of possibilities. However, it is a relatively new field and many believe that it possesses a threat to both human and nature. The first genetically modified trees were produced in 1987 and by 1998 there were at least 116 confirmed GM tree trials around the world. The main reasons for that they develop GM trees are firstly to improve growth rates of plantation crops, secondly to reduce the lignin contents in wood, thirdly to produce tree crops with weed resistance and finally the desired tree species with pest insect resistance. The allegation for that is therefore also good for environment issues because of reducing hazards on chemical process of lignin removing in pulping industry and reducing the use of chemicals for weed and pest controls.

Those opposed to the development and use of GMOs are particularly concerned about the possibility of engineered genes escaping into the wild, where they might become established in natural populations of closely related species. They also concerned that, reducing lignin contents could make trees more susceptible to pest attacks, and insects pests might develop a resistance to the transgenic trees and become more difficult to control. In fact in agricultural pests, many have mutated to become resistant to spray used on cotton, coffee and a range of other crops.

A WWF scoping study surmises that the main impact of transgenic trees might not be genetic pollution, or the creation of "super weeds" but the contribution to make unsustainable land use (Asante-Owusu, 1999). The study suggests that trees engineered for enhanced growth will generally be voracious consumers of water and nutrients, and thus will have the potential to degrade land. Nevertheless, it is true that genetically improved or modified trees will fulfill their true potential only when the right growing conditions are provided. They must be planted in suitable climates with adequate water and nearly always require the use of fertilizers, other intensive tending techniques are also required.

Plantations and Global Warming:

We are all very concerned about the problem of global warming that caused by carbon dioxide emission released by burning of fossil fuels. There is about one fifth of carbon emission come from the felling and burning of forests. One of the ways that involved in plantation forests for contribution to tackle global warming is to slow down the rate of deforestation and use the biomass of fast-growing trees as substitution for fossil fuels. The theory is that biomass plantations will sequester the amount of carbon released by burning biomass fuels.

Trees convert carbon dioxide into solid carbon, in the form of wood, and they do so especially effectively when they grow rapidly. Huge amounts of carbon are stored in natural forests, but as they grow at a slower rate than plantations, they do not actively sequester as much carbon per unit area. The Kyoto-Protocol and the term of Clean Development Mechanism (CDM) are aiming to use plantation projects funded by carbon-released companies to offset their carbon pollution as carbon credits for control greenhouse gases emission into the air. But environmentalists opposed the projects of plantations in the CDM with complains that these projects will exclude poor people from the land and cause the sorts of environmental problems that already discussed in previous sections.

Obviously, the nature of plantation, it ownership and the uses to which its timber are put will determine whether or not it is beneficial from an environmental and social point of view. CIFOR, WWF, IUCN and Forest Trends have consistently maintained that whatever arrangements are made under the CDM, local communities should always be consulted when plantation projects are being considered. Ideally, they should be involved in the management and they should derive a range of benefits from the new plantations viz., animal fodder, firewood, timber. However, if this is to happen their nature and species composition will be very different from conventional fast-wood plantations.

One estimate suggests that, if 100 millions ha of additional plantations were to be established- this is likely maximum over the next 50 years- the annual carbon fix would amount to 0.4GT, or approximately 2 per cent of the annual carbon loading into the atmosphere (Harcastle, 1999). This suggests that the planting of industrial fast-wood plantation will do little to counter the problem of global warming.

Fast-growing plantations: possibility to achieve species diversity on degraded lands?

IVI, distribution and species diversity indices of ground flora species under Teak, Acacia and Eucalyptus plantations:

IVI & Distribution: According to Verma (2000), the number of ground flora species under *Tectona grandis Acacia catechu* plantation were 20 and 22, respectively, whereas, in open bhata land, it was 15. In Tectona plantation, *Hyptis suaveolens* recorded dominant species with maximum IVI of 62.66, it followed by *Cassia mimosoides* (47.39), *Cassia absus* (41.27). The minimum IVI of 1.20 was noted for *Alysicarpus monilifer* (table 3). Under

Acacia catechu plantation, *Cassia mimosoides* was dominant species with maximum IVI of 54.44, followed by *Spermacoce pusilla* (40.55), and *Rungia pectinata* (25.66). *Merremia tridentata* recorded the minimum IVI value of 2.12 (table 4).

Table 3: Distribution of ground flora under *Tectona grandis* plantation

Species	Density (m^{-2})	Frequency (%)	Abundance (m^{-2})	A/F	IVI
Hyptis suaveolens (L.) Poit.	8.3	90	9.22	0.102	62.66
Cassia mimosoides L.	26.1	100	26.10	0.261	47.39
Cassia absus L.	16.7	100	16.70	0.167	41.27
Alysicarpus tetragonolobus Edgew.	9.7	80	12.12	0.151	23.71
Triumfetta rhomboidea Jacq.	6.8	70	9.71	0.138	22.98
Branchiaria ramosa (L.) Stapf.	6.8	90	7.55	0.083	17.06
Euphobia hirta L.	2.4	70	3.42	0.048	11.72
Chorchorus aestuans L.	5.4	30	18.00	0.600	10.89
Heteropogon contorus (L.) P.Beauv.	3.4	50	6.80	0.136	10.29
Melochia corchorifolia L.	2.8	60	4.66	0.077	9.82
Impomoea sindica Stapf	3.1	60	5.16	0.086	9.60
Spermacoce pusilla Wall.	2.2	40	5.50	0.137	6.78
Merremia tridentata (L.) Hall.	1.4	50	2.80	0.056	6.60
Rungia pectinata (L.) Nees.	1.0	50	2.00	0.040	6.05
Evolvulus alsinoides (L.) L.	1.1	40	2.75	0.068	5.32
Tridax procumbens L.	0.3	20	1.50	0.075	2.54
Evolvulus nummularius (L.) L.	0.3	10	3.00	0.300	1.32
Sida acuta Burm.f.	0.2	10	2.00	0.200	1.27
Waltheria indica L.	0.1	10	1.00	0.100	1.23
Alyscicarpus monilifer (L.) DC.	0.2	10	2.00	0.200	1.20
Total: 20 species					**300**

Source: R.K. Verma, 2000

Table 4: Distribution of ground flora under *Acacia catechu* plantation

Species	Density (m^{-2})	Frequency (%)	Abundance (m^{-2})	A/F	IVI
Cassia mimosoides L.	30.7	100	30.70	0.307	54.44
Spermacoce pusilla Wall.	17.5	90	19.44	0.216	40.55
Acacia catechu (L.f.) Wild.	23.4	100	23.40	0.234	38.95
Rungia pectinata (L.) Nees.	14.4	80	18.00	0.225	25.66
Hyptis suaveolens (L.) Poit.	3.7	100	3.70	0.037	22.77
Heteropogon contorus (L.) P.Beauv.	4.6	70	6.57	0.093	20.37
Lindernia crustacea (L.) F.V. Muell.	8.1	70	11.57	0.165	18.36
Branchiaria ramosa (L.) Stapf.	4.3	60	7.16	0.119	10.96
Justicia spp.	2.7	70	3.85	0.055	9.86
Evolvulus nummularius (L.) L.	2.5	50	5.00	0.100	8.27
Alysicarpus tetragonolobus Edgew.	2.0	20	10.00	0.500	7.12

Alyscicarpus monilifer (L.) DC.	1.5	50	3.00	0.060	6.64
Evolvulus alsinoides (L.) L.	1.7	40	4.25	0.106	6.17
Polygala chinensis L.	0.9	30	3.00	0.100	5.12
Pennisetum pedicellatum Trin.	0.9	20	4.50	0.225	4.74
Euphobia hirta L.	1.3	20	6.50	0.325	4.06
Triumfetta rhomboidea Jacq.	0.8	20	4.00	0.200	3.66
Cryptolepsis buchananii Roem. & Schultes.	0.3	20	1.50	0.075	2.93
Phyllanthus virgatus Forst. F.	0.5	20	2.50	0.125	2.47
Impomoea sindica Stapf	0.4	20	2.00	0.100	2.33
Zorina gibbosa Span.	0.3	20	1.50	0.075	2.26
Merremia tridentata (L.) Hall.	0.2	20	1.00	0.050	2.12
Total: 22 species					**300**

Source: R.K. Verma, 2000

It is evident that, all the ground flora species, exept *Rungia pectinata* and *Euphobia hirta* under Tectona plantation and *Hyptis suaveolens* and *Merremia tridentata* under *Acacia catechu* plantation have the ratio of abundance to frequency (A/F) higher than 0.05 (table 3), their distributions were contagious. The contagious distribution is the most common pattern in nature, the random pattern happened only in site where environment conditions are un-uniform and the pattern of regular is found in site with severe competition among individuals (Odum, 1971, Verma, 2000).

In open bhata land, the distribution pattern wad also contagious except for *Evolvulus alsinoides*. Species of *Indigofera linnaei* was dominant with maximum IVI of 60.27, followed by *Euphobia hirta* (41.30), *Dactyloctonim aegyptium* (41.18). *Digitaria bicornis* was recorded with minimum IVI of 3.14 (table 5).

Table 5: Distribution of ground flora in open bhata land

Species	Density (m^{-2})	Frequency (%)	Abundance (m^{-2})	A/F	IVI
Indigofera linnaei Ali	14.9	100	14.90	0.149	60.27
Euphobia hirta L.	15.0	90	16.66	0.185	41.30
Dactyloctonium aegyptium (L.) Wild.	17.6	100	17.60	0.176	41.18
Eragrostis ciliaris (L.) R.Br.	5.7	100	5.70	0.057	27.17
Alyscicarpus monilifer (L.) DC.	5.2	90	5.77	0.064	24.66
Desmodium triflorum (L.) DC.	7.5	80	9.37	0.117	19.85
Cyperus niveus Retz.	7.4	60	12.33	0.205	17.64
Melanocenchris jacquemontii Jaub. & Spach	6.2	50	12.40	0.248	14.74
Spermacoce pusilla Wall.	3.7	70	5.28	0.075	12.94
Lindernia ciliata (Colsm.) Pennel	3.9	40	9.75	0.243	10.96

Evolvulus alsinoides (L.) L.	2.0	70	2.85	0.040	10.72
Zorina gibbosa Span.	1.5	50	3.00	0.060	7.77
Mollungo pentalhylla L.	0.8	30	2.66	0.088	4.32
Branchiaria ramosa (L.) Stapf.	0.8	20	4.00	0.200	3.29
Digitaria bicornis (Lam.) Roem & Chultes ex. Loud.	0.7	20	3.50	0.175	3.14
Total: 15 species					**300**

Source: R.K. Verma, 2000

Regarding the Diversity Indices, in the table 6 values showed that, concentration of dominance (Cd.) of ground flora was lower and index of diversity (H) was higher under both the plantations than that of open bhata land. The lower value of dominance is shared by many species.

The index of diversity of ground flora under *Acacia catechu* was much more (3.795) than *Tectona grandis* (3.595) and open bhata land (3.173). Species diversity index is depended upon species component and evenness to represent of individuals all species. For a specific site, the lower value of concentration of dominance it has, the higher value of diversity index it contains.

Table 6: Species Richness (SR), Concentration of dominance (Cd.) and index of diversity (H) of ground flora under *Acacia catechu*, *Tectona grandis* plantations and open bhata land.

Plantation/Area	SR	Cd.	H
Acacia catechu	22	0.095	3.795
Tectona grandis	20	0.110	3.595
Open bhata land	15	0.180	3.173

Source: R.K. Verma, 2000

Table 7: Index of similarity (Sorensen's Index- SI) between different sites understudy.

Plantation/Area	*Acacia catechu*	*Tectona grandis*	Open bhata land
Acacia catechu	1.00	0.68	0.33
Tectona grandis		1.00	0.29
Open bhata land			1.00

Index of similarity between *Acacia catechu* and open bhata land was 0.33 (dissimilarity 0.67), between *Tectona grandis* and open bhata land was 0.29 (dissimilarity 0.71). This indicates that, there is remarkable degree of dissimilarity of ground flora species under plantations in comparison with open bhata land. The index of similarity between two plantations was 0.68 (dissimilarity 0.32) indicating more similarity of species between two plantations. It seems that not only macro-environment but also the nature of tree species planted change the micro-climate and soil properties which in turn may affect the species diversity (Pandey et al., 1988; Verma, 2000).

In other study of ground flora species under *Tectona grandis, Acacia auriculiformis and Eucalyptus tereticornis* plantations in Kerala (Thapliyal, et al., 2002), it revealed that, *Eucalyptus tereticornis* suported the maximum species richness (36), followed by *Acacia auriculiformis* (26), then *Tectona grandis* (20) and lowest species number of 15 was recorded for open area (control). It was seen that more number of species were found in older plantation, like Eucalyptus (4 years 10 months) had 36, Acacia (3 years 10 months) housed 26, while Teak was 4 years & 5 months, but it housed only 20 species (table 7). It was explained that the tending operations of the Teak plantation were frequent and its canopy is quite dense which did not allow the adequate sunlight to reach to the ground, thus hampering the establishment and growth of the ground flora species (Bhaskar and Dasappa, 1983; Thapliyal, et al., 2002). The canopy of Acacia and Eucalyptus stands were open to allow enough light to reach the ground so vegetation was not affected much because of light.

The density of ground plants per m^2 was highest in open area (66), followed by *Eucalyptus tereticornis* (59), *Tectona grandis* (48) and lowest in *Acacia auriculiformis* with only 39 plants The lowest value of density under *Acacia auriculiformis* plantation among all might be attributed to the fact that the plantation had accumulated a lot of leaf litter which had some allelopathic effects on the seed germination of the species (Jadhav & Gavna, 1992; Dhawan et al., 1995; Barman et al., 1997; Bora et al., 1999; John & Nair, 1999; Thapliyal et al., 2002). *Eucalyptus tereticornis* stands had slight crown which allow sufficient light radiation reach to ground floor and had accumulated little leaf litter, hence any allelopathic effect on the ground flora was not apparent.

Table 8: Species richness and plant density of ground flora species under diff. monoculture plantations

	A. auriculiformis	*E. tereticortis*	*T. grandis*	Control
Ages of plantation	3 yrs. 10 months	4 yrs. 10 months	4 yrs. 5 months	
Spacing	2.0 x 1.5 m	3.0 x 1.5 m	2.0 x 2.0 m	
No. of ground flora species	26	36	20	15
Density: total plants/m^2	39	59	48	66

Source: Manisha Thapliyal et al., 2002

The spacing space at this stage, did not have a bearing on the number of ground flora species although it did seem to improve the density of ground vegetation as more growing space is made available and the root competition is minimized (Thapliyal et al., 2002).

In this case of the study, it did not support the view that Eucalyptus plantations have adverse effects on the undergrowth as concluded by Bhaska and Dasappa (1986). The weed menace was not that severe in Eucalyptus as in Casuarina in which the undergrowth appeared as a pure stand of *Chromalaena odorata* Fabaceae, Verbenaceae and Malvaceae were the most represented families. The dominant species were *Chromalaena odorata* ,*Hemidesmus indicua*, *Ageratum conyzoides* and *Mimosa pudica* which were common to all the stands and open ground as well. According to Bahar & Jain (2002), the composition of ground flora species under *Eucalyptus tereticornis* plantation was dominated by *Cannabis sativa* and *Ageratum conyzoides* at all their studied sites. The species richness in Eucalyptus was of the same magnitude as in other plantations and the study supports the findings of Mathur and Soni (1983) Rajvanshi et al., (1983) and Hossain et al., (1998) that Eucalyptus supports luxuriant undergrowth and if not greater then equally better species diversity as in other plantations (Thapliyal et al., 2002).

The ***study* of Otsamo** (2002) on early effect of four fast-growing species on ground vegetation in *Imperata* grassland showed all tested species except *P. falcataria* had significantly suppressed the development of *Imperata cylidrica* (dry biomass t ha^{-1} order: *G. arborea* (0.2) ≤ *A. mangium* (0.5) ≤ *A. crassicarpa* (2.2) ≤ *Paraserianthes falcataria* (6.0) ≤ open area (11.4) and favored the development of other grasses and shrubs, viz., *Chromolaena odorata* and *Clibadium surinamense*.

Table 7: Mean cover and above ground dry biomass of ground vegetation under four plantation tree species at 3x3 m spacing two years after planting and one year after weeding, and on an open area (control) at an *Imperata cylindrica* dominated site in South Kalimantan, Indonesia. Means followed by the same letter do not differ significantly (α= 0.05)

	Imperata cylindrica		*Chromolaena odorata*		*Clibadium surinamense*	
Tree species	**Cover** *(%)*	**Biomass** *(t ha^{-1})*	**Cover** *(%)*	**Biomass** *(t ha^{-1})*	**Cover** *(%)*	**Biomass** *(t ha^{-1})*
G. arborea	15c	0.2c	4c	<0.05b	5	<0.05b
A. mangium	22c	0.5c	13c	0.5a	13	0.5ab
A. crassicarpa	58b	2.2c	17ab	0.9a	28	1.1ab
P. falcataria	84a	6.0b	40a	2.4b	23	1.4a

Open area	93a	11.4a	-	-	-	-
F	68.719	50.672	12.774	17.417	3.187	5.578

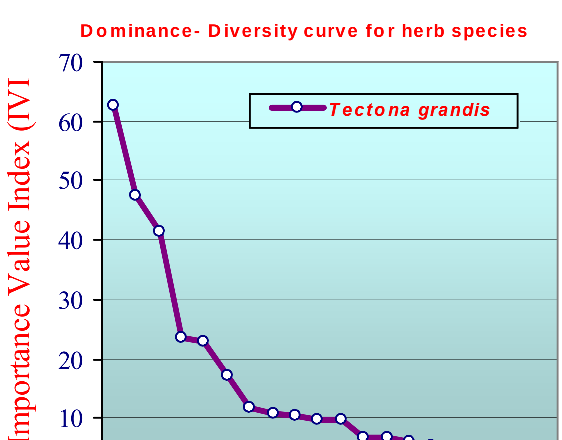
There was a highly significant positive correlation (r = 0.842) between the grass and shrub biomasses. This means that high shrub biomass did not affect grass growth, but that both shrubs and grass were growing vigorously in the same plots, suggesting that environment stimuli for both growth forms were similar.

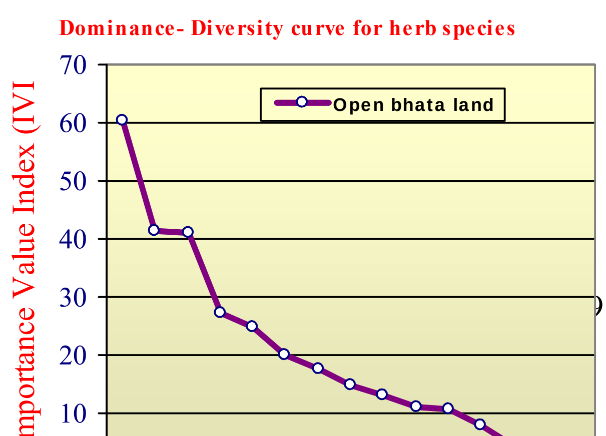
Dominance Diversity (D-D) curves:

Regarding ***Resource Sharing and Niche Space Apportionment***, Dominance Diversity (D-D) curves are drawn to ascertain resource apportionment by the components in the various sites for ground flora species, wherein the IVI was used as an expressive measure of the Niche of species/ resource apportionment. This is based on the assumption that there is some correspondence between the share of community resource and community space utilized by a species (Whittaker 1975, Pandey 2002). Degree of resource apportionment is considered a measure of resource conservation (Pandey 2002).

According to Verma (2000), the D-D curves for ground flora species under plantations of *A. catechu* & *Tectona grandis* and open bhata land were developed in Figure 2. They showed the approach to log-normal distribution series of Preston (1948), which could indicate that the sites had less number of species in higher IVI range, high competition among the species, high diversity and efficient utilization of resource (Verma, 2000; Pandey 2002). Naturally, the D-D curves for ground flora species have tendency to approach log-normal distribution model, thus they could play an important role in the resource conservation (Pandey, et al., 2002). In *A. catechu* & *Tectona grandis* and open bhata land the top niche was occupied by *Hyptis suaveolens, Cassia mimosoides* and *Indigofera linnei*, respectively. *Cassia mimosoides* and *Cassia abssia* in *Tectona grandis*, *Spermacoce pusilla* and *A. catechu* regeneration in *A. catechu* plantation and *Euphorbia hirta, Dactyloctonium agyptium* in open bhata land occupied the intermediate niche. In both the plantations and the open bhata land, remaining species shared the lower niche (Verma, 2000).

Figure 2 (a, b & c): Dominance- Divesity curve of ground flora species in diiferent sites.





Effect of seasonal and plantation age aspects on species diversity indices of ground flora:

Seasonal floristic composition under *Eucalyptus tereticornis* plantation has been recorded for different sites in upper Gangatic plain (site I- Hardwar; Site II- Deo-Band and site III- Shukratal) under study of Bahar and Jain (2002). The total number of species recorded 56, 39 and 32 in rainy, winter and summer seasons at site I. At site II, 40, 38 & 31 and at site III, 39, 31 & 26 plant species were found in rainy, winter and summer seasons, respectively. The maximum number of species was recorded for site I, followed by site II , then III. It can be attributed to the relatively less tree density at site I as compared to site II and site III. The maximum of species was recorded in rainy season, followed by winter and summer seasons at all studied sites. During rainy season, soil attains sufficient moisture for plant growth and development. The minimum number of species during summer season attributed to low soil moisture status, high temperature and biotic activities (Bahar and Jain, 2002). Similar observations were also reported by Misra and Das, 1960; Kumar and Joshi, 1972; Singh and Yadav, 1974; Mathur et al., 1980; Mathur and Joshi, 1983; Melkania and Joshi et al., 1999).

In the study of Lodhiyal (2001) on species diversity of short-lived species under Poplar plantation in Tarai region of central Himalaya, it reported that the value of Simpson's index (concentration of dominance) ranged from 0.227 (9-yr) to 0.566 (5-yr.) in rainy season, 0.324 (9-yr) to 0.688 (6-yr) in winter season and 0.186 (9-yr) to 0.776 (7-yr) in summer season. The diversity of short-lived species under Poplar plantation ranged from 1.523 (5-yr) to 2.499 (9-yr) in rainy season, 1.679 (6-yr) to 2.388 (7-yr) in winter and 0.634 (7-yr) to 2.620 (9-yr) in summer season (table 9). The diversity index value thus fall within the range reported for temperate forests (Braun, 1950; Mank, 1967; Rissar and Rice, 1971; Lodhiyal, 2001), but are markedly lower than those reported for tropical forests (Knight, 1975). This indicates that the lower nutrient concentration in soil prefer higher diversity of species. Species richness was maximum in 6 yr old plantation, while the species diversity was maximum in older stand (9 yr old) and it was lower in younger stands. This is due to lower nutrient levels in older stands and higher nutrients in the young stands (Lodhiyal, 2001).

Table 9: Species Richness (SR), concentration of dominance (Cd.) and diversity index (H) of short-lived species under poplar plantations of different ages.

Ages of plantation (year)	**Rainy season**			**Winter season**			**Summer season**		
	SR	**Cd.**	**H**	**SR**	**Cd.**	**H**	**SR**	**Cd.**	**H**
5	10	0.566	1.573	10	0.639	1.325	6	0.421	1.768
6	14	0.538	1.699	13	0.688	1.079	7	0.698	1.349
7	10	0.547	1.600	9	0.476	2.388	3	0.776	0.634
8	9	0.507	1.721	10	0.663	1.209	7	0.428	1.641
9	8	0.227	2.499	8	0.324	2.163	8	0.186	2.620

Effect of tree density on growth development and composition ground flora species:

According to Otsamo (2002), Regression analysis revealed a significant linear correlation between increasing distance between planted trees and grass biomass for four tested tree species of *A. mangium* and *A. crassicarpa, Gmelina arborea and Paraserianthes falcataria* (Figure 3). Corresponding results and statistics were also obtained for grass cover (figure 4). Of which, *P. falcataria* was lowest with its grass suppression capacity. The vegetation biomass under the plantation did not differ from that of the open area. This may be explained by the light canopy structure and small leaflet size of *P. falcataria*. Both *A. mangium* and *A. crassicarpa* highly suppressed ground vegetation. This was probably the result of their canopy structure. Thick canopies of Acacia – species with relatively larger leaflet size seemed to be more effective in shading. Factors other than light intensity may also have effects on ground vegetation development. Acacia-species have reported to bear allelopathic effect by their litter fall on ground vegetation (Gonzalez et al., 1995; Otsamo, 2002). The remarkable differences between tree species in their ability to compete with ground vegetation give new criteria for species selection in plantation programs (Otsamo, 2002).

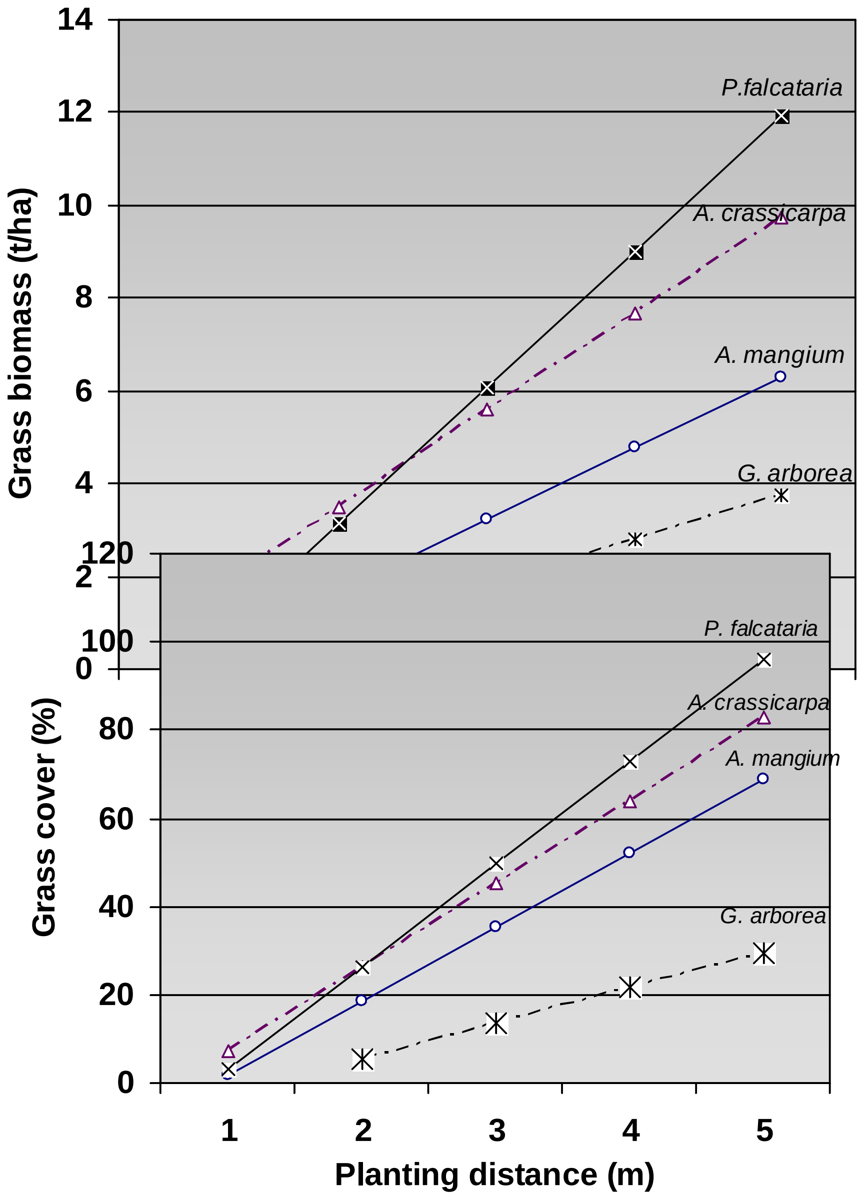


Figure 3: Effect of distance between planted trees (planting distance) of *Acacia mangium* ($y= 1.547x - 1.426$, $r^2= 0.95$), *A. crassicarpa* ($y= 2.083x - 0.669$, $r^2= 0.97$), *Gmelina arborea* ($y= 0.926x- 0.886$, $r^2= 0.75$) and *Paraserianthes falcataria* ($y= 2.926x- 2.696$, $r^2= 0.96$) on above ground dry grass biomass on an *Imperata cylindrica* dominated grassland site two years after planting and one year after last weeding in South Kalimantan, Indonesia.

Figure 4: Effect of distance between planted trees (planting distance) of *Acacia mangium* (y = 16.730x – 14.776, r^2 = 0.95), *A. crassicarpa* (y = 18.805x – 11.334, r^2 = 0.89), *Gmelina arborea* (y= 8.005x-10.447, r^2= 0.72) and *Paraserianthes falcataria* (y= 23.252x- 20.139, r^2= 0.95) on grass cover on an *Imperata cylindrica* dominated grassland site two years after planting and one year after last weeding in South Kalimantan, Indonesia.

CONCLUSIONS

1. Fast-growing plantation would be set to become one of the most important forms of industrial development over the coming decades. It is neither inherently good nor inherently bad. It is a neutral technology which, when poorly planned and executed, can cause grave problems; and which, when well planned and executed, can deliver not just large quantities of wood, but a range of environmental and social benefits. Obviously, If, plantations replace natural forest, or take over lands previously used by farmers, they might be considered a bad thing. If, on the other hand, they are sensitively sited on degraded lands and managed by local communities, the opposite will hold true. It is essential that, governments adopt a landscape approach to plantation development. A plantation project should not be allowed to implement, if it could not prove to supply with a full range of forest goods and services at landscape level and it would lead to the loss of primary forests or other important ecosystems. In any cases, local communities need to be involved in the earliest stage of planning and development.
2. These case studies are preliminary ones but shows that all tested species of Acacia, Teak and Eucalyptus seem to be the favorable tree for the growth of the ground vegetation. All the species diversity indices of their ground flora vegetation showed higher values than those of open control area. At this stage of the present studies, they do not support the allegation that Eucalyptus deters the growth of ground flora, probably long term monitoring needs to be done to come to any firm conclusion. If Eucalyptus are protected and managed they can provide sufficient protection to the ground surface.
3. Seasons and ages of plantation showed significant affects on species diversity of ground flora vegetation. In Eucalyptus, study showed the maximum number of species of ground flora in rainy season, followed by winter and summer season at all studied sites. In Poplar plantation, species richness was found to be maximum in 6 yr old plantation, while the species diversity was maximum in older stand (9 yr old) and it was lower in younger stands.

4. On *imperrata*-grasslands, fast-growing species plantations of *G. arborea*, *A. mangium* and *A. crassicarpa* in *Imperata* grassland had early significantly suppressed the development of *Imperata cylidrica* (reduced dry biomass) and favored the development of other grasses and shrubs, viz., *Chromolaena odorata* and *Clibadium surinamense*. The effects of these planting species and density on the ground vegetation development were so clear that they should be seriously considered in planning of plantation establishment on *imperrata*-grasslands, where the displacement of *Imperata cylidrica* and the favour of diversity are sought.

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Such species will need to follow their climatic envelopes by migrating to cooler and moister environments, usually uphill or southwards in the southern hemisphere. Marine species will also need to adapt to warmer ocean temperatures.Â Climate change is predicted to take place faster in the next century than at any time for at least the last 10,000 years.Â A diversity of species increases the ability of ecosystems to do things like hold soils together, maintain soil fertility, deliver clean water to streams and rivers, cycle nutrients, pollinate plants (including crops), and buffer against pests and diseasesâ€"these are sometimes called â€˜ecosystem functionsâ€™ or â€˜ecosystem servicesâ€™. Biodiversity or Biological diversity is a term that describes the variety of living beings on earth. In short, it is described as degree of variation of life. Biological diversity encompasses microorganism, plants, animals and ecosystems such as coral reefs, forests, rainforests , deserts etc. Biodiversity also refers to the number, or abundance of different species living within a particular region. It represents the wealth of biological resources available to us. With certain species of plants having a disadvantage with a warmer climate, their insect herbivores may also be taking a hit.[41] Temperature will directly affect diversity, persistence and survival in both the plants and their insect herbivores. As these insect herbivores decrease, so will the higher levels of species that eat those insects. This cascading event would be detrimental to our earth and how we view nature today. Challenges of modeling future impacts[edit]. Accurate predictions of the future impacts of climate change on plant diversity are critical to the development of conservati