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Value of Ecological Services of Exotic *Eucalyptus tereticornis* and Native *Dalbergia sissoo* Tree Plantations of North-Western India

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Abstract

Value assessment of exotic and native tree plantations based upon short-term gains from wood has suggested that exotic plantations are more profitable than native tree plantations. Such estimations have largely ignored the value of ecological services. This study estimates the ecological-economic value of forest floor vegetation, soil nutrients and return of nutrients from litter in exotic Eucalyptus tereticornis and native Dalbergia sissoo plantations in northwestern India. Two age groups of plantations, i.e. 6-8 years (young) and 19-21 years (old) were selected to compare net benefits as exotics deliver most of their benefits (especially wood) by eight years of age, while natives deliver benefits after 12-15 years of age. The diversity of plant species, nutrient content in soil and nutrient return through litter were greater in Dalbergia than in Eucalyptus plantations. A comparison of plantations at eight years suggested that the total monetary value of tangible (timber, fuel, fodder, eucalypt oil and ash) and ecological services (phytodiversity, soil nutrient content and nutrient return through litter) was 1.6 times greater in Eucalyptus than in Dalbergia plantations, chiefly because of timber. However, ecological benefits were 1.8 times greater in Dalbergia than in Eucalyptus plantations. At 19-21 years of age, Dalbergia supported 2.7 times more total benefits than Eucalyptus. Thus there seems to be a need to consider both tangible and intangible services over the long term and to carry out total value assessment of exotic and native tree plantations to design appropriate policy.

Keywords: *Eucalyptus tereticornis*, *Dalbergia sissoo*, monoculture plantations, ecological services.

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Introduction

PRE-1988 FOREST POLICIES in India promoted wide-scale plantations of exotic tree species such as *Populus deltoides*, *Acacia spp*., *Eucalyptus spp*., *Leucaena leucocephala* and *Prosopis juliflora* to meet the increasing industrial and fuelwood demands of the public (Bajaj 1997). *Eucalyptus tereticornis* was preferred to other exotic trees because of short-term visible gains for straight bole, fast growth rate, more productivity per unit area and least post-plantation care (Mathur et al. 1984; Kushalappa 1985; Rajan 1987; Sharma et al. 1988; Kapur and Dogra 1989; Chatha et al. 1991). But the scientific community, private growers and the public have been divided over the merits and demerits of *Eucalyptus* plantations for economic gains from wood, and for ecological functions such as water usage, understorey ground cover and allelopathic effects (Mathur and Soni 1983; Dabral and Raturi 1985; Shiva and Bandyopadhyay 1987; Bahuguna et al. 1990; Narain et al. 1990; Geetha et al. 1994; Jalota and Kohli 1996; Jalota 1997; Jalota et al. 2000; Sangha et al. 2000; Singh and Singh 2003).

The total value estimations based on monetary returns from wood in short rotation exotic plantations led to undervalue native trees such as *Dalbergia sissoo*, mainly due to their longer life span. Many native trees, e.g. *Dalbergia* have better timber quality than *Eucalyptus* (Shiva and Bandyopadhyay 1987) and are preferentially used for good quality furniture. The ecological services (shade, shelter, fodder and medicinal value) rendered by native trees are essential for the common man, especially in some rural communities of India, but the value of these 'unseen' ecological benefits is invariably ignored in our accounting system for forest resources. Moreover, the negative effects of exotic plantations, such as reduced plant diversity (Jalota 1997) are neglected in such an accounting system. Hence, they fail to provide an accurate estimate of costs and benefits of native or exotic plantations.

Most of the reports available to date (Bahuguna et al. 1990; Chatha et al. 1991; Kushalappa 1985; Mathur et al. 1983; Rajan 1987; Shiva and Bandyopadhyay 1987) have focused on either economic benefits from wood products or on the ecological aspects of exotic and native tree plantations, but none has integrated ecological and economic potential for tangible and intangible benefits. Jalota and Sangha (2000) compared the tangible benefits of *Dalbergia* and *Eucalyptus* plantations, and showed that over a short-term the tangible benefits from *Eucalyptus* were greater than *Dalbergia*, while these benefits were greater for *Dalbergia* if considered over 21 years of age. This led us to consider the importance of ecological services that are otherwise overlooked such as phytodiversity, nutrient return from litter and soil nutrients, and to rationally evaluate their ecological and economic potential in *Eucalyptus* and *Dalbergia* monoculture plantations for two age groups, i.e. young (6-8 year) and old (19-21 year). The monetary equivalence of ecological services is reported here in addition to tangible gains, to determine the total value of *Eucalyptus* and *Dalbergia* plantations from the ecological and economic perspectives.

Methods

Two sets of *Eucalyptus* and *Dalbergia* plantations, each 6-8 year (young) and 1921 year (old), in triplicate, were selected for the study during 1996-1999, in the territory of Chandigarh, in north-west India (30^{0} 42' N, 76^{0} 54' E 333) under similar edapho-climatic conditions.

The selection of these age groups was important as 6-8 years and 19-21 years represent the mature age in *Eucalyptus* and *Dalbergia* respectively. A representative area of 4 ha was marked at each site for various measurements.

Ground Vegetation

Species diversity and biomass productivity of various plants growing on the floor of *Eucalyptus* and *Dalbergia* plantations were measured during summer, autumn, winter and spring in three consecutive years following the quadrat method (Misra 1968). Ten 1 m x 1 m quadrats were laid randomly in each season at each of the sites. Indices of diversity, dominance, richness and evenness were computed using the statistical software ECOSTATS. The importance value index (IVI) (sum of relative values of density, frequency and dominance) was also calculated for each species. The formulae used to calculate density, frequency and dominance (Misra 1968) are as follows:

Density of a species = number of plants of a certain species/area Relative density = density of a species/total density of all species x 100 Frequency = number of quadrats of occurrence of a species/total quadrats sampled

Relative frequency = frequency of a species/total frequency of all species x 100

Dominance = basal area of a species/total area sampled

Relative dominance = basal area of a species/basal area of all the species x 100

The average value of the importance value index and the relative biomass of each species was calculated from the seasonal readings taken over a year.

The ground floor species contribute to the ecological sustainability of an ecosystem by contributing to soil stability, maintaining hydrological and nutrient balance. Some of these species are also used in food preparation. A review of the literature (Singh et al. 1983; Kamal 1988; Husain et al.,1992; Rastogi and Mehrotra 1993; CSIR 1994) and local surveys (conducted by the authors) revealed that the plant species found on the floors of *Eucalyptus* and *Dalbergia* had five main uses: food, fuel, fodder, medicine and soil stabilisation.

In the absence of local markets to capture the value of these usages, we opted for the ordinal analysis method (Henderson and Quandt 1980) for assigning monetary value to each component of ground-floor vegetation. The monetary equivalence for each plant species was estimated in relation to its use for the selected five categories: food, fuel, fodder, medicine and soil stabilisation. Each species was assigned scores based on the lifespan (longevity) and biomass production. On the basis of longevity, scores were assigned as 1 for annual, 2 for biennial and 3 for perennial life cycles, and for biomass production, scores were assigned according to the plant weight (1 for weight <10 g/plant, 2 for 10-100 g/plant and 3 for >100 g/plant).

The total scores for each species for all five categories were calculated in relation to their life cycle and biomass production as number of uses x (life cycle score + biomass score). For example, a plant with three uses (food, medicine and soil stabilisation) having a perennial life cycle and biomass > 100 g, was scored 18. In the absence of any information on a particular use of a species, its score was assigned the value zero. The function of soil stabilisation was considered in all species, so its value was counted for all species. A plant with all five uses, perennial life cycle and biomass productivity >100 g/plant, scored the maximum, i.e. 30. The total economic value was then computed for all the usages by applying the following method (Chopra et al. 1997 a and c):

Pt = Pi x Si / St

where

Pt = Total economic value for all the uses of a plant species;

Pi = Mean market price of a species per plant;

Si = Score obtained for the various uses of a plant;

St = Total maximum score for all the five uses.

The total monetary value of phytodiversity in *Eucalyptus* and *Dalbergia* plantations was calculated according to the total number of plants per hectare in each plantation. The total number of individuals of a species per hectare per year was calculated from the seasonal data collected over year (as mentioned earlier). The monetary value of each plant type was then multiplied with the number of plants per hectare of a species to estimate the total value per hectare.

While the utility and adequacy of this approach need to be confirmed by other studies, it is useful at the small scale (farm) to assess the value of various usages of plant diversity in the absence of any direct market value. A similar approach was used by Belal and Springuel (1996) to estimate the traditional value of particular uses of plants, however they did not calculate the monetary equivalence for a particular use of plant species. The present approach provides an estimate for use and ecosystem function for each plant species. This approach could be particularly useful in developing countries where people make use of wild plants/herbs in their daily diet and rely upon the natural diversity of these plants.

Soil

At each site, six litter-free soil samples were collected at the same time to a depth of 30 cm during summer, autumn, winter and spring for three consecutive years. The samples were air dried and sieved (0.2 mm mesh). The fresh and dry weights were also taken to determine soil moisture content. The samples were bulked for chemical analysis. The available content of phosphorus (Olsen et al. 1954), nitrogen (Kjeltec system I), potassium (flame photometer), organic carbon (Walkey and Black's titration method, Piper 1950) and micronutrients, viz. Cu, Zn, Fe and Mn (extraction with diethylene triamine penta acetic acid, using atomic absorption spectrophotometer) were analysed. The pH and electrical conductivity (EC) were measured with pH and EC meters. Data were analysed using Duncan's multiple range test (DMRT) (Duncan 1955).

The monetary value was assigned to nutrient content available at a site following the Surrogate Valuation Technique (Chopra et al. 1997b). It uses the information based on a marketable good to infer the value of an associated non-marketable good. This technique provides an economic measure to assign value for soil nutrients based upon the market value of fertilisers.

The value of soil nutrients was computed in relation to the market price of chemical fertilisers (see Chivaura-Mususa et al. (2000) and Guo et al. (2001) for similar approaches). Market surveys were conducted for price value of nitrogen, phosphorus, potassium, copper, zinc, iron and manganese. This helped to account for standing value of soil nutrients and assess it in relation to plantation type.

Soil pH, electrical conductivity (EC), moisture content and organic carbon hold no direct or indirect market value, hence these were evaluated on the basis of quantity and for their positive or negative importance in productivity. For example, soils were scored as -1 for pH < 6.0 (acidic), 2 for pH 6-8.5 (medium range, allows to grow most plant types), and -1 for > 8.5 (alkaline). Soil with EC < 0.8 (normal to grow most plants) was assigned 2 scores, with EC 0.8-1.6 (critical for salt sensitive crops) as -1, and for EC 1.6-2.5 (critical for salt-tolerant crops) as -2 scores. Moisture content was scored as 1 for low (0-3.5%) and 2 for > 3.5%. The content of organic carbon was scored as 1 for < 0.4% (low), 2 for 0.4-0.75% (medium), and 3 for > 0.75% (high).

Total soil value index (%) for pH, EC, moisture content and organic carbon (OC) was calculated according to the following formula:

Total Value Index: S score for soil pH, EC, moisture content and OC at a particular site/total score (i.e. 9) x 100.

Litter Production and Nutrient Release

The amount of litter production was quantified at regular three-month intervals for each season in a year from five permanent 1 m x 1 m quadrats. The measurements were taken only at old plantations of *Eucalyptus* and *Dalbergia*. Surface litter decomposition following the litter bag technique (Pauley and Little 1998), and annual release of nutrients (N, P and K) were studied. Nutrient loss over a one-year period of decomposition was computed in relation to the amount of litter produced at each site.

For monetary valuation, the release of nutrients from litter was considered as return of nutrients to the soil. The surrogate valuation technique (as applied for soil nutrients) was used to estimate the value of a particular nutrient. The monetary value of nutrient return calculated for 19-21 year old plantations was considered to be the same for 6-8 year old plantations in the absence of data from young plantations.

Results

Ground Vegetation

Ecological Evaluation

The density of plants (no. of plants per hectare) in young *Dalbergia* plantations was double that of same age *Eucalyptus* plantations and more than four times that of old *Eucalyptus* plantations [Table 1].Young and old *Eucalyptus* plantations had 17 and 18 ground species of plants respectively, whereas young and old *Dalbergia* plantations supported 34 and 28 plant species (Digital Appendix 1).

The plant species specific to *Eucalyptus* were few (three in young and six in old) compared to *Dalbergia* plantations (20 in young and 16 in old) (Digital Appendix 1). The importance value index was maximum for *Cynodon dactylon* in young plantations of *Dalbergia* and *Eucalyptus*. In old plantations, the importance value index was greatest for *Saccharum munja* in *Eucalyptus* and for *C.dactylon* in *Dalbergia* plantations (Digital Appendix 1).

The greater diversity of plant species on the floor of *Dalbergia* compared to *Eucalyptus* was clear from Shannon's index of diversity [Figure 1]. The indices of richness and evenness demonstrated uniform distribution of abundance of different plant species in *Dalbergia* compared to *Eucalyptus* plantations [Figure1].

Economic Evaluation

The number of plant species that have use value for food, fuel, fodder, medicine, and soil stabilisation was greater in *Dalbergia* compared to *Eucalyptus* plantations, regardless of plantation age [Table 1]. More plant species with annual and perennial life cycles were present in *Dalbergia* than in *Eucalyptus* plantations. The total biomass productivity of all plants was twice in younger, and more than three times greater in older plantations of *Dalbergia* compared to *Eucalyptus* plantations [Table 1].

Based on the criteria of biomass productivity and life cycle of a plant, the monetary equivalence was computed for the five selected uses of a species. In 6-8 year old plantations, C. *dactylon* had the maximum value among all plant species in *Eucalyptus* and *Dalbergia* plantations, but had 1.24 times greater value in *Dalbergia* than in *Eucalyptus* (Digital Appendix 2). In 19-21 year old plantations, *S. munja* had the maximum value followed by C. *dactylon* in *Eucalyptus* plantations; and *Cannabis sativa* followed by C. *dactylon* had maximum values in *Dalbergia* plantations. The total monetary equivalence for all plant species was 1.83 times and 5.78 times greater in respective young and old plantations of *Dalbergia* compared to *Eucalyptus* plantations (Digital Appendix 2).

Soil Nutrients

Ecological Evaluation

In both young and old plantations, the content of available N was in the soil was significantly greater in *Dalbergia* plantations (1332.95 kg/ha and 1774.57 kg/ha respectively) compared to that in respective young and old plantations of *Eucalyptus* (1112.8 kg/ha and 1520.74 kg/ha) [Table 2]. Similarly, the available content of K was significantly greater in *Dalbergia* plantations (1173.88 kg/ha at young and 703.75 kg/ha at old plantations) compared to that in respective young and old *Eucalyptus* plantations (935.15 kg/ha at young and 454.8kg/ha at old plantation soils). Available content of P did not differ between *Dalbergia* and *Eucalyptus* plantations of the same age group, but it was greater in soils of young plantations (18.51 kg/ha in *Dalbergia,* 17.71 kg/ha in *Eucalyptus)* compared to old plantations (16.09 kg/ha in *Dalbergia,* and 15.33 kg/ha in *Eucalyptus). Dalbergia* soils also had greater content of Fe and Mn compared to soils of *Eucalyptus*. Zn content did not show any difference at young age plantations, however, there was a greater content at old age in *Dalbergia* plantations. Only Cu content was greater in *Eucalyptus* than in *Dalbergia* soils [Table 2].

Soil organic carbon was maximum in old *Dalbergia* plantations (1.95%), and differed only with *Eucalyptus* at young age (0.69%) after applying DMRT (at 0.05% level) [Table 2]. Although soil pH and EC did not differ significantly between *Dalbergia* and *Eucalyptus* plantations, soil EC was more than double in *Eucalyptus* soils (0.87 dS/m in young and 0.89 dS/m in old plantations) than that in *Dalbergia* soils (0.31 dS/m in young and 0.42 dS/m in old plantations) which could adversely affect plant growth. Soil moisture content was greater in *Dalbergia* (6.32% at young and 5.88% at old plantation) plantations compared to *Eucalyptus* (1.86% at young and 3.66% at old) plantations [Table 2].

Economic Evaluation

The monetary equivalence for available N, K, Fe and Mn was greater in *Dalbergia* than in *Eucalyptus* plantations [Table 2]. *Eucalyptus* had greater monetary equivalence for Cu content than *Dalbergia*. Soil Zn content did not differ in its value in *Eucalyptus* and *Dalbergia* plantations, except old *Dalbergia* plantation, which had the maximum value [Table 2].

The total monetary equivalence for all the studied soil nutrients was 1.34 times greater in *Dalbergia* compared to *Eucalyptus* at both young and old age of plantations [Table 2]. *Dalbergia* soils had greater score for soil organic carbon and soil moisture than *Eucalyptus* soils. This led to a greater total soil value index in *Dalbergia* (100% in both young and old) compared to *Eucalyptus* soils (50% in young and 75% in old plantations) [Table 2].

Litter Production and Nutrient Return

The amount of litter produced in a year was 1.44 times greater in *Dalbergia* plantations (5698 kg/ha/yr) compared to *Eucalyptus* (3946 kg/ha/yr). The content of N, P and K was greater in litter collected from *Dalbergia* plantations compared to *Eucalyptus* plantations [Table 2], owing to their greater mass and concentration.

Value of Nutrient Return from Litter

The total monetary equivalence for the amount of nutrients released from litter in relation to the total amount of litter produced in *Dalbergia* plantations was 2.61 times greater (6709 Rs/ha) than that at *Eucalyptus* (2561 Rs/ha) [Table 2].

Total Benefits from Phytodiversity, Soil Nutrients and Litter

The ecological benefits represented only 0.09% proportion of total tangible benefits in young *Eucalyptus* and 0.39% of total tangible benefits in young *Dalbergia,* and 0.01% of total tangible benefits in both old *Eucalyptus* and *Dalbergia* plantations [Table 3], when counted only once. But, there is a continuum of benefits from these services over the age of a plantation. Therefore, the value of these services over the age of a plantation i.e. for 8 year and 21 year was calculated, which represented 0.27% of tangible benefits in young and 0.07% of tangible benefits in old *Eucalyptus;* and 1.38% in young *Dalbergia* and 0.12% of total tangible benefits in old *Dalbergia* plantations [Table 3]. Overall benefits from wood, non-wood products, plant diversity, soils and litter nutrient return (computed over the age of a plantation) were 1.6 times greater in *Eucalyptus* than *Dalbergia* at 8 year age of plantations [Table 3] and [Figure 2]. These were chiefly from timber in young *Eucalyptus* while *Dalbergia* had no timber value at this age, but *Dalbergia* supported 1.8 times greater value of ecological services than that of *Eucalyptus*. At 19-21 years of growth, *Dalbergia* supported 2.7 times more value for its tangible and ecological services than *Eucalyptus* plantations [Figure 2].

Increment in total benefits with age of plantation was more in *Dalbergia* (from 1,090,284 Rs/ha at young to 15,008,889 Rs/ha at old) than that in *Eucalyptus* (1,698,686 Rs/ha at young and 5,561,981 Rs/ha at old plantations) [Figure 2] and [Table 3].

Discussion

Native plantations of *Dalbergia* supported greater species diversity, soil nutrient content and litter production for more nutrient return than exotic plantations of *Eucalyptus*. The meagre understorey plant diversity in *Eucalyptus* plantations has been attributed to allelopathy (Kohli et al. 1990, Kohli and Singh 1991; Reid et al. 1992; Srivastava et al. 1994; Verma and Totey 1999) and/or the toxic effects of allelochemicals on soil micro-organisms (Dellacasa et al. 1989; Chander et al. 1995). Poor soil status in *Eucalyptus* plantations was also reported by Jha et al. (1999). Despite such evidence for the negative effects of eucalypts in monoculture plantations, it has been favoured over native trees due to the economic gains for wood (Shiva and Bandyopadhyay 1987; Jalota 1997). The ignorance of the costs associated with the negative effects of *Eucalyptus,* and the non-accounting of ecological services of native trees in total value assessment, resulted in the prediction of greater economic benefits for eucalypts over native trees.

Why are ecological services, such as species diversity or litter, so important? Tilman et al. (1997) report that diverse plants perform different ecosystem functions which contribute to the sustainability of an ecosystem. Ecosystem functions performed by one species may be complementary to the other species. Niche matching and the probability of presence of one species in promoting the existence of other species, are important mechanisms that determine species diversity in a sustainable ecosystem (Tilman 1999). According to the diversity-productivity hypothesis (Tilman et al. 1996; 1997), greater species diversity supports greater biomass productivity. Such a relationship was evident for plants growing under the canopy of *Dalbergia,* which showed greater total biomass compared to plants under *Eucalyptus* plantations, though there could be other factors such as soil nutrients that promote plant growth under the canopy of *Dalbergia*.

In addition to ecosystem functions of diverse plant species, various wild plants growing under native plantations are also important as medicine and food. The diversity and growth of plants are related to soil nutrient content and nutrient return from litter decomposition in an ecosystem. In *Eucalyptus* and *Dalbergia* monoculture plantations, the ground vegetation, soil nutrients and litter, which provide habitat for soil microorganisms, are important for ecosystem sustainability. Ground vegetation is also important to some extent to fulfil the needs of the local people. Therefore, the main ecological benefits from understorey plants in terms of food, fodder, fuel, medicine and soil stabilisation, from soil for major nutrients that support plant growth, and nutrient return from litter are considered in this study. There are many other ecological services e.g. carbon sequestration, aesthetic value of a plantation and the existence value of diverse plant species, which also contribute to the total value of an ecosystem, which are not accounted for in this study.

The study highlights the importance of native trees for their value of ecological services as the benefits were twice greater in *Dalbergia* than in *Eucalyptus* plantations, when calculated over the age of a plantation. Although at young age of these plantations, *Eucalyptus* scored over *Dalbergia* owing to its prominent timber gains, at 21 years of age, the total returns from *Dalbergia* were about thrice greater than from *Eucalyptus*. There was also a greater increase in benefits from 8 to 21 years of age in *Dalbergia* compared to that in *Eucalyptus*. It is important to note that in *Eucalyptus* (21 year-old plantation), tangible benefits (timber and other non-wood products) were calculated at a rotation of eight years over a 21-year time period (i.e. for 2.5 crops, as *Eucalyptus is* generally harvested at 8-10 years of age) (Jalota and Sangha 2000). Our earlier study (Jalota and Sangha 2000) reported the main tangible benefits from these two plantations, though at a young age the benefits were greater from *Eucalyptus,* but at an old age, *Dalbergia* performed better than *Eucalyptus*.

The present results further suggest that *Dalbergia* plantations are more profitable at 21 years of age with greater ecological services from understorey plant diversity, litter and soil nutrient content than *Eucalyptus* plantations. Moreover, over the period of growth for *Dalbergia* plantations, ecological services will be in a continuum to sustain the system over a longer time, whereas in *Eucalyptus* rotational harvest at every 8-year intervals will disturb the dynamics of ecological services.

The methodology used here to assign monetary value to intangible services would need further improvements but such a tool is appropriate in a developing country such as India where common herbs/plants are used in daily life. The application of standard techniques (Contingent Valuation Method (CVM), Choice Modelling (CM) Method, Contingent Ranking, Travel Cost Method (TCM), and so on) cannot be generalised as they largely depend upon the culture and financial status of a society (Sangha et al. 2000). Other methods based upon ecosystem functions have been proposed. Nunes et al. (2001) estimated the value of biodiversity at four levels, i.e. genes, species, ecosystems and functions, but they missed the social value attached to a particular usage which is important for people in developing countries.

Human interactions with environment are important when considering valuation of ecological services (Daily 1999). In developing countries, common valuation methods (CVM, CM or TCM) may not work due to regional variations and societal differences to use a plant species, to make aesthetic sense of a site or differences in cultural values. There is a lot of integration/cross-linkage of use and non-use benefits from forests, and their interaction with people; and this emphasises the need to develop some indigenous methods to evaluate ecological services. The methodology used in this paper was based on the actual use of plant species.

This paper emphasises the importance of ecological services in total value over the long term for fast-growing exotic and steady-growing indigenous trees in terms of all direct and indirect benefits before implementing any forest policies/decisions. The total value judgment over a long term could provide a better idea about the potential of a tree plantation. The development of indigenous methods to evaluate the use of indigenous plants by locals will help to assess their accurate value for future policy decisions.

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References

1. Bahuguna, V.K., J.D.S. Negi, S.R. Joshi and K.C. Naithani. 1990. Leaf litter decomposition and nutrient release in *Shorea robusta* and *Eucalyptus camaldulensis* plantations. *Indian Forester* 116:544-546.
2. Bajaj, M. 1997. Policy failure and Forestry Sector: A critique of Public Policy and Governmental Intervention in Forestry Sector. In: *The Challenge of the Balance, Proceedings of a National Environment and Economic Meeting* (ed. A. Agarwal), pp. 207-216. Published by Centre for Science and Environment, New Delhi.
3. Belal, A. E. and I. Springuel. 1996. Economic value of plant diversity in arid environments. *Nature and Resources* 32:33-39.
4. Chander, K., S. Goyal and K. Kapoor. 1995. Microbial biomass dynamics during decomposition of leaf litter of poplar and eucalypt in a sandy loam. *Biology and Fertility of Soils* 19:357-361.
5. Chatha, I.S., J. Singh and D. S. Sindhu. 1991. An economic analysis of *Eucalyptus* plantations in Punjab. In: *Proceedings of a Workshop on Socio-economic Aspects of Tree Growing by Farmers in South Asia,* held at the Institute of Rural Management, Anand, 11-15 March, pp. 24-34.
6. Chivaura-Masusa, C., B. Campbell and W. Kenyon. 2000. The value of mature trees in arable fields in smallholder sector, Zimbabwe. *Ecological Economics* 33:395400.
7. Chopra, K., M. Chauhan, S. Sharma and N. Sangeeta. 1997a. *Economic Valuation of Biodiversity Part -I*. A report by the Institute of Economic Growth, New Delhi, India.
8. Chopra, K., G. K. Kadekodi, S. Bathla, D. V. Subbarao, S. Sharma, P. Pandey, S. K. Andhikari and M. Agarwal. 1997b. *Natural resource accounting in Yamuna Basin: Accounting for Forest Resources*. A report by the Institute of Economic Growth, New Delhi, India.
9. Chopra, K., G. Kadekodi, M. Chauhan, S. Sharma and N. Sangeeta. 1997c. *Economic Valuation of Biodiversity Part -II*. A report by the Institute of Economic Growth, New Delhi, India.
10. CSIR. 1994. *The Useful Plants of India*. Council of Scientific and Industrial Research. CSIR publications, Delhi, India.

India. ↑

11. Dabral, B.G. and A. S. Raturi. 1985. Water consumption by *Eucalyptus* hybrid. *Indian Forester* 111:1053-1070. ↑
12. Daily, G. C. 1999. Developing a scientific basis for managing Earth's life support systems. *Conservation Ecology* 3:14-27. ↑
13. Dellacasa, E., P. Menedex, P. Moyna and P. Cerdeiras. 1989. Antimicrobial activity of *Eucalyptus* essential oils. *Fitterapia* 60:544-546. ↑
14. Duncan, D.B. 1955. Multiple range and multiple F tests. *Biometrics* 2-4:1-42. ↑
15. Geetha, C.K., K. Gopikumar and M. Arvindakshan. 1994. Comparative growth of multipurpose (indigenous v/s exotic) tree species in the warm humid tropics of Kerala. *Indian Journal of Forestry* 17:134-136. ↑
16. Guo, X., X. Xiao, Y. Gan and Y. Zheng. 2001. Ecosystem functions, services and their values - a case study in Xingshan country of China. *Ecological Economics* 38:141-154. ↑
17. Henderson, J. M. and R. E. Quandt. 1980. *Microeconomic Theory- A Mathematical Approach*. Mc Graw- Hill publishers, pp. 5-36. ↑
18. Husain, A., O. P. Virmani, S. P. Popli, L. N. Misra, M. M. Gupta, G. N. Srivastava, Z. Abraham and A. K. Singh. 1992. *Dictionary of Indian Medicinal Plants*. Published by Central Institute of Medicine and Aromatic Plants, Lucknow, India. ↑
19. Jalota, R. K. 1997. Comparison of Eco-physiological Functions of Mono-culture plantations of Exotic *(Eucaluptus* L' Herit) to Indigenous Tree Species and Forest Ecosystems in Semi-arid Zone. Ph.D. Thesis. Panjab University, Chandigarh, India. ↑
20. Jalota, R. K. and R. K. Kohli. 1996. Status of Floor Vegetation Under Exotic and Indigenous Tree Plantations in Semi-arid Zone of North India. In: *Proceedings of IUFRO-DNAES International Meet on Resource Inventory Techniques to Support Agroforestry and Environment* (eds. R. K. Kohli and K. S. Arya), pp. 291-296, conference held on 1-3 Oct., Chandigarh, India. ↑
21. Jalota, R.K. and K. K. Sangha. 2000. Comparative ecological-economic analysis of growth performance of exotic *Eucalyptus tereticornis* and indigenous *Dalbergia sissoo* in mono-culture plantations. *Ecological Economics* 33:487495. ↑
22. Jalota, R.K., K. K. Sangha and R. K. Kohli. 2000. Under-storey vegetation of forest plantations in N-W India - An ecological economic assessment. *Journal of Tropical Medicinal Plants* 1:115-124. ↑
23. Jha, M. N., M. K. Gupta and B. M. Dimri. 1999. Soil organic matter status under different social forestry plantations. *Indian Forester* 125:883-890. ↑
24. Kamal, R. 1988. *Economy of Plants in the Vedas*. Commonwealth Publishers, Delhi, pp. 138. ↑
25. Kapur, S. K. and A. S. Dogra. 1989. Fast growing species for meeting rural and industrial needs of Punjab present status and future needs. *Indian Forester* 115:201-208. ↑
26. Kohli, R. K. and D. Singh. 1991. Allelopathic impact of volatile components from *Eucalytptus* on crop plantations. *Biologia Plantarum* 36:475-483. ↑
27. Kohli, R.K., D. Singh and R.C. Verma. 1990. Influence of eucalyptus shelterbelt on winter season agro-ecosystems. *Agriculture, Ecology and Environment* 33:23-31. ↑
28. Kushalappa, K.A. 1985. Economics of *Eucalyptus* hybrid and *Casurina* plantations under farm forestry in Karnatka. *Van-Vigyan 23 (1& 2)*. ↑
29. Mathur, H.N. and P. Soni. 1983. Comparative account of undergrowth under Eucalyptus and Sal in three different localities of Dun Valley. *Indian Forester* 109:882-890. ↑
30. Mathur, H.N., H. Francis, S. Raj and S. Naithani. 1984. Ground water quality (pH) under different vegetative covers at Osamund (Nilgiri hills). *Indian Forester* 10:110-115. ↑
31. Misra, B. 1968. *Ecology Work Book*. Published by Oxford and IBH Co., New Delhi. ↑
32. Narain, P., R. Singh and K. Singh. 1990. Influence of forest cover and site characteristics in Doon Valley. *Indian Forester* 116:901-916. ↑
33. Nunes, Paulo A. L. D. and Jeroen C. J. M. van den Bergh. 2001. Economic valuation of biodiversity: sense or nonsense? *Ecological Economics* 39:203-222. ↑
34. Olsen, S.R., C. V. Cole, S. Watanabe and L. A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S Department of Agriculture, Washington, DC, Circular no. 939. ↑
35. Pauley, T. K. and M. Little. 1998. A new technique to monitor larval and juvenile salamanders in stream habitats. *Banisteria* 12:32-36. ↑
36. Piper, C.S. (ed.). 1950. *Soil and Plant Analysis*. University of Adelaide, SA, Australia. ↑
37. Rajan, B.K.N. (ed.). 1987. *Versatile Eucalyptus*. Diana Publications, Nandiding Extn., Bengalore, India. ↑
38. Rastogi, R. P. and B. N. Mehrotra (eds.). 1993. *Compendium of Indian Medicinal Plants Volumes I and II*. Central Drug Research Institute, Lucknow, and Publications and Information Directorate, Delhi. ↑
39. Reid, W., C. Barber and K. Miller (eds.). 1992. *Global Biodiversity Strategy* Guidelines for Action to Save, Study and Use Earth and Biotic Wealth Sustainably and Equitably. Published by WRI, IUCN and UNEP in association with FAO and UNESCO. ↑
40. Sangha, K.K., R. K. Jalota and R. K. Kohli. 2000. Ecological- Economic Assessment of Plant Diversity in Mono-cultures of *Eucalyptus tereticornis* and *Dalbergia sissoo* Plantations. In: *Proceedings of International Symposium on Tropical Forestry Research: Challenges in the New Millenium* (eds. R. V. Verma, K. V. Bhat, E. M. Muralidharan and J. K. Sharma), held at Peechi, India., on 2-4 August, pp. 120-126. ↑
41. Sharma, S.K., R. M. Singhal, J. S. Samra, S. P. Banerjee, K. Singh and S. D. Sharma. 1988. Studies of some difficult sites of Shivalik Forest Division with respect to their management. *Van - Vigyan* 26 (1& 2). ↑
42. Shiva, V. and J. Bandyopadhyay. 1987. *Ecological Audit of Eucalyptus Cultivation*. Publication of Research Foundation for Science, Techonology and Ecology, Dehradun, India. ↑
43. Singh, U., A. M. Wadwani and B. M. Johri (eds.). 1983. *Dictionary of Economic plants in India*. Indian Council Agriculture Research, Delhi. ↑
44. Singh, T. A. and Y. Singh. 2003. *Eucalyptus:* an ecological monster for Punjab. *Ecology, Environment and Conservation* 9:477-478. ↑
45. Srivastava, K.K., V. J. Zacharias, A. K. Bhardwaj, J. Augustine and S. Joseph. 1994. A preliminary study on the

grasslands of Periyar Tiger Reserve, Kerala. *Indian Forester* 120:898-907.
46. Tilman, D. 1999. Diversity and production in European grasslands. *Science* 286:10991100.
47. Tilman, D., J. Knops, D. Wedin, P. Reich, M. Ritchie and E. Siemann. 1997. The influence of functional diversity and composition on ecosystem processes. *Science* 277:1300-1302.
48. Tilman, D., D. Wedlin and K. Johannes. 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. *Nature* 379:718-720.
49. Verma, R. K. and N. G. Totey. 1999. Biological diversity, medicinal potential of ground flora and improvement in soil quality under plantations raised on degraded bhata land. *Advances in Forestry Research in India* 20:37-69.

Figures

[Figure 1], [Figure 2]

Tables

[Table 1], [Table 2], [Table 3]

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