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RESEARCH NOTES

Environmental Implications of Converting Natural Grassland into Eucalyptus Plantations in Hydro Power Catchments in Nilgiris, Tamil Nadu: An Economic Analysis

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I

INTRODUCTION

In India plantations of exotic tree species like *populous debtoides, Acacia spp., Eucalyptus spp*., *Laucaena leucocephala* and *Prosopis juliflora etc. were promoted* to meet the increasing industrial and fuel wood demand (Bajaj, 1997). Eucalyptus was preferred to other exotic trees because of short term visible gains for straight pole, fast growth rate, higher productivity per unit area and least post-plantation management (Mathur *et al.*, 1984, Kapur and Dogra, 1989). However, the economic gains of these trees has yet to be ascertained for wood and for ecological functions such as water usage, undersurface ground cover and allopathic effects (Mathur and Sonin, 1983, Dabral and Raturi, 1985, Shiva and Bandhyopadhyay, 1987, Bahuguna *et al.,* 1990, Nariman *et al.,* 1990; Jalota and Kohli, 1996; Jalota *et al.,* 1997; Jalota *et al.,* 2000 and Sajha *et al.,* 2001; Singh and Singh, 2003). In most cases ecological services (shade, shelter, fodder and medicinal value of the native species) 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. Hence, they fail to provide an accurate estimate of the costs and benefits of these species. Many studies conducted in India and abroad have focused either on the economic benefits from wood products or on the ecological aspects of exotic and native tree plantations, but the ecological and economic potential for tangible and intangible benefits have not been correlated so far (Kamaljit *et al.,* 2005). The exotic acacia and eucalyptus were introduced in Nilgiris Hills in 1858 where E. globules was planted along with E. Robusta. At present eucalyptus plantations in India occupy about 8 per cent area of the world.

Environmentalists in India have also raised alarm against the expansion of eucalyptus monoculture in the arid and semi-arid regions. The protests gained such momentum that in 1983, farmers of Karnataka uprooted the eucalyptus from the forest nurseries. During 1988, farmers in Thailand protested an eucalyptus tree

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planting project. In 1990, the Chipko activists in northern India were arrested for doing what their counterparts did in Karnataka. According to Krishnamurthy and Anon (1985), foresters in Karnataka, who had felled natural forests in the Western Ghats for eucalyptus, have now restricted its planting to lower rainfall zones of 500 mm to 1125 mm. The Economic and Planning Council of Karnataka (EPCK) report (1985) agrees that eucalyptus plantations consumes lots of water on per hectare basis and similar opinions were expressed by Shiva and Bandhyopadhyay, 1987 and Gupta, 1986. Pryor (1976) has reported that the transpiration rate of eucalyptus remains high even when the water supply from the soil has dwindled. Sanginga *et al.* 1991 in Zimbabwe found no evidence that eucalyptus is nutritionally more demanding than L*eucaena leucophela* and Casuarina cumminghamiana. Balagopalan (1986) stated that eucalyptus plantation decrease organic carbon and other soil nutrients thus affecting the chemical and physical properties of soil. AI Mousawi and AI Naib (1975) have also reported paucity of herbaceous plant in eucalyptus plantation in Iraq. Shiva and Bandhyopadhyay, 1987 have stated that in the arid regions, eucalyptus inhibits the germination and growth of other plants through *allelopathy* thus posing a threat to food security. Bernard (1984) stated that eucalyptus plantation is a threat to ecological stability. A concern has arisen in many parts of the world over the environmental effects of large scale planting of Eucalyptus as it is suspected to have adverse effects on soil and water resources and environment (Calder, 1993). The study of Jayakumar *et al.,* (1983), found that in Nilgiris, reduction of water yield by about 12 per cent due to change of land use pattern from mixed land use of grasslands and natural S*hola* (Natural) forest to fast growing species of *Acacia mearnsii* and *Eucalyptus globules.* Sharda *et al.* (1988) studied the hydrological behaviour of Nilgiris sub-watersheds as affected by bluegum plantations and concluded that during the first rotation of 10 years, bluegum brings a statistically significant reduction in the total water yield amounting to 867.7mm or 87mm yr^{-1}. Therefore, these environmental concerns are of special interest to the Nilgiris which forms a substantial part of the catchment to a number of hydroelectric reservoirs in Tamil Nadu. It has been amply demonstrated and documented based on watershed study by the Central Soil and Water Conservation Research & Training Institute Research Centre, Nilgiris that the conversion of grassland into *Eucalyptus globulus* (bluegum) plantation decreased the average annual water yield by 16 and 25.4 per cent during the first and second rotation, respectively, apart from drastically reducing the lean or dry season flow (Sharda *et al.,* 1998; Sikka *et al.,* 1998, Table 1). On the other hand it is debated that there are good economic returns from the bluegum plantation. But this economic return must be weighed keeping in view the environmental effects on soil and water resources, loss of power generation and environment. In view of the above facts, it was aimed to study the impact of converting grasslands into bluegum plantation by considering its impact in terms of water yield, grass/fodder yield and soil loss during the first and second rotation in the Nilgiris watershed.

II

DATA AND METHODOLOGY

At the Glenmorgan Research farm of the Central Soil and Water Conservation Research and Training Institute, Research Centre, Udhagamandalam in the Nilgiris, South India, two adjacent watersheds A and B, about 32 ha. each having identical physiographic characteristics were selected for the hydrological study in 1964 (Table 1). The study is located about 24 km away from the Udhagamandalam on the Udhagamadalam – Mysore national highway at latitude and longitude of $11^0$28'10" N$76^0$37'14" E, respectively, in Wenlock Downs forest reserves in the Nilgiris district of Tamil Nadu State. The region experiences a montane temperate humid climate with an average annual rainfall of 1380 mm, most of which is received from the south-west and north-east monsoons. The temperatures are mild with a maximum value of 26^0C during April and May (Anonymous, 1987). The soils are lateritic and derived from Charnckites with texture varying from sandy loam to sandy clay loam. The field capacity, wilting point and bulk density have been reported as 28.6 per cent, 18 per cent and 1.33g.cm-3, respectively. For recording of run-off, the automatic stage level recorders with 2:1 broad crested triangular weir were installed at the outlet of the both the watersheds, A and B. A small meteorological laboratory was established near the ridge, demarcating the boundary of the two watersheds, to record various climatologically parameters like rainfall, temperature, open pan evaporation, etc. After a calibration of 4 years (1968-71), Bluegum (Eucalyptus globules) was planted at a spacing of 2X2 m in one of the watershed (B) during July, 1972 above frost line covering an area of 18.76 ha (59 per cent). The rest of the area (41 per cent) in watershed B and the entire watershed A were kept under natural conditions of grasslands (grazed) and savanna vegetation 'Shola'. The silvicultural management practices consisted of felling and coppicing of the trees at 10 years rotation and replanting after fourth rotation.

TABLE 1. PHYSICAL FEATURES OF WATERSHED A AND B TAKEN UNDER THE STUDY

Characteristics	Watershed No.	
	A	B
(1)	(2)	(2)
Area (ha)	33.18	31.89
Shape index	2.22	1.03
Max. length of stream (m)	450	380
Stream density (km/km2)	1.36	1.19
Average slope (per cent)	21	17
Mean elevation (m)	2166	2166
Watershed relief (m)	55	61
Time of concentration (mts)	10.30	9.10
Perimeter (m)	2315	2214
Form factor	0.41	0.49
Compactness co-efficient	1.13	1.11

The soil moisture measurement was taken at weekly intervals at 0.5 m and 1.0 m sampling depths in both the rotations. The fluctuations in ground water level were recorded in the swamps through pipe well installed at a depth of 1.25m and along the slope through piezometric well installed at a depth of 5.0 m. The observation on height, growth, biomass (grasses) produced under the trees and in other watersheds, tree diameter at breast height (DBH) of bluegum were recorded regularly during the first and second rotation. Based on the run-off data collected during the calibration period, regression equations were developed for total run-off, surface run-off and base flow in watershed A and B (Samraj *et al.,* 1988,) and same equations were used to quantify the effect of bluegum plantations on water yield. The benefit stream largely included income from pulpwood, leaves, rejects and opportunity cost of grass lost due to eucalyptus plantations from the first and second rotation. Eucalyptus had five main uses, i.e., food, fuel, fodder, medicine and soil stabilisation. In the absence of local market to capture the value of these usages, this study opted for the ordinal analysis methods for assigning monetary values. The cost and benefit streams were worked out as given below.

Cost Stream

The value of water lost as a result of converting grassland into bluegum plantation has been related to the use to which it is being put by assuming different scenarios such as domestic use, industrial use and non-domestic use. The quantum of water lost per annum was 276.16 ha.cm and 299.44 ha.cm for the 1st and 2nd rotation, respectively (Sikka *et al.,* 1998). The per gallon water charges were taken as Rs. 0.50, Rs. 1.0 and Rs. 1.5 for the first rotation and Rs. 2.0, Rs. 4.0 and Rs. 6.0 for the second rotation, respectively. These prices of water were collected from Muncipality Water Supply Authority of the Nilgiris, Tamil Nadu for the reported period. The value of lost grass was evaluated in terms of its fodder value as per prevailing market price for the first and second rotation. Apart from this, the cost of land preparation, planting material, gap filling, watering and weeding, fencing, watch and ward and miscellaneous expenses were taken into account to generate the cost stream.

Benefits Stream

To evaluate all the possible benefits from the bluegum plantation, the returns from pulpwood, rejects, leaves and twigs were considered. The prevailing price of each item during the period reported upon was taken into consideration to convert all the benefits into monetary terms. Since, no difference was recorded in the sediment yield from grassland watershed with and without bluegum plantation, the benefits of the sediment yield reduction as a result of bluegum plantation was not taken into account.

Analytical Procedure

Discounting procedure was adapted to carry out the economic analysis. The discount rate of 10 per cent was used to calculate the Benefit Cost Ratio (BCR), and Net Present Worth (NPW). While calculating the BCR, NPW and Internal Rate of Return (IRR) all the possible costs including opportunity cost and benefits were taken into account.

The mathematical form of the discounting measures used is given below.

1. PVB $= \delta_t (\sum B_t)$
   PVC $= \delta_t (\sum C_t + \sum E_t)$
   NPW $= \delta_t (\sum B_t \; - (\sum C_t - \sum E_t))$

2. $$\text{BCR} = \frac{\delta_t (\sum B_t)}{\delta_t (\sum C_t \sum E_t)}$$

3. IRR is the discount rate which makes PVB= PVC

Where,

PVB = present value of benefits,
PVC = present value of cost,
δ_t = discount rate,
B_t = benefits from the eucalyptus plantation,
C_t = cost involved in the eucalyptus plantation,
E_t = Environmental cost,
T = Time period.

III

RESULTS AND DISCUSSION

The reduction in total water yield due to bluegum plantations during the first and second rotations was worked out. The mean annual reduction was found to be statistically significant in both the rotations amounting to 16 and 25.4 per cent, respectively, of the expected run-off under natural grasslands and 'shola'. The average annual rainfall of first rotation (1569mm) was 14 per cent higher than the long term average annual rainfall (1380mm) whereas in the second rotation (1309 mm), it was closer to long term average being lower by only 5 per cent. However, a higher average annual reduction of 7 per cent of rainfall was observed in total run-off during the second rotation as compared with 5.6 per cent during the first rotation. Stein (1952) had reported that in steep dry areas where E. globules has been planted, under storey development and litter build up were insufficient to prevent surface run-off. He believes that even though *eucalyptus globulus* is fast growing, heavy crowned tree which casts a dense shade, it gives little litter. He also reported that in Southern India, where rainfall is less than 750mm, the failure of an under storey to develop coupled with a weakly developed forest floor, leaves the soil exposed to run-off under such condition. Mathur *et al.,* 1976 and Balagopalan, 1986 also have reported that eucalyptus plantation hasten soil loss. Even though the presence of litter and ground vegetation greatly controls the amount of run-off, this would certainly vary according to the climate. The ground vegetation of eucalyptus forest is sparse in dry climate due to root competition and perhaps, *allelopathic* effects.

According to Heith and Karschon, 1967, a study in the central coastal plains of Israel (rainfall 600mm, a dry period of 3 to 5 months) where eucalyptus plantation was compared with an open ground, showed that eucalyptus used up all the water available to it. Mahashweta Devei, 1983 and Bahuguna, 1984 also believe that eucalyptus consumes more water than other trees. They also claim that in arid regions high water uptake by eucalyptus interferes with the process which replenish soil moisture and recharge ground water leading to soil aridisation and ground water depletion. Chaturvedi, 1976 and Anon, 1985 stated that in any area the same number of eucalyptus trees will consume more water than other species during the same period. Gupta, 1985 pointed out in low rainfall areas, eucalyptus roots forms a dense network just below the soil surface to extract every bit of moisture.

*Findings of First Rotation***:** The eucalyptus plantation after 10 years (1972-81), was felled during 1982 at the 30 cm height above the ground level, retaining all the shoots of coppice growth. The analysis of run-off data during the first rotation of 10 years revealed that bluegum brought a significant ($\acute{\alpha}$= 0.01) reduction of about 16 per cent in the total expected water yield from natural grass lands. On an average, the expected total flow and base flow under natural conditions of grasslands and ‘shola’ were 31 per cent and 23 per cent, respectively, of the expected rainfall of the region. Maximum month wise reduction both in total flow and base flow as a result of the bluegum plantations occurs during July-November corresponding to the maximum rainfall period. During the dry season months (January–April), the reduction base flow was 23 per cent at 50 per cent probability and is very crucial for sustaining dry weather flow in the hydro electric reservoirs. No adverse effect of bluegum plantations on soil erosion was visible and the water remained as clear as in the open grasslands. The moisture monitoring at 0.5 and 1.0m sampling depths inferred that the bluegum extracted most of the moisture from the upper soil layers but the deeper soil layers were not tapped. The bluegum interaction with the ground water table was insignificant and the roots remained well above the *phreatic* surface.

The benefit-cost analysis of bluegum plantation with and without environmental consideration was carried out and the same is presented in Table 2. It reveals that without considering the environmental factors bluegum plantation has given positive NPW at 10 per cent discount rates. Similarly, the BCR was found to be positive 4:1 at 10 per cent discount rate. This suggests that bluegum plantation is economical and viable forest species to meet the demand of growing population. Further, IRR was found to be 31.66 per cent suggesting that in the first rotation (1972-81) itself bluegum plantation is economical. However, considering the environmental damages and opportunity costs of eucalyptus cultivation the NPW for alternate use of water like domestic use has emerged negative at 15 per cent with negative BCR indicating that eucalyptus plantation is uneconomical whereas IRR resulted in 11.99 per cent and was found to be uneconomical. If similar quantity of water is used for industrial use and non-domestic use, the economic returns from bluegum plantation turned out to be uneconomical and negative. This indicates that returns from bluegum plantation in first rotation itself is uneconomical with consideration of environmental/social cost. Further, the benefits from this plantation is less than the cost of cultivation including environmental damage. Thus, the species replaced in natural agro ecosystem may be given due consideration from the environmental point of view.

TABLE 2. BCR, NPW, AND IRR OF PROJECT-FIRST ROTATION (1972-81)

Particulars	Discount rate (10 per cent) BCR	Discount rate (10 per cent) NPW	IRR (per cent)
(1)	(2)	(3)	(4)
WITH CONSIDERATIONS OF ENVIRONMENTAL FACTORS			
Domestic use	1.12	22185	11.99
Industrial use	0.77	-63054	5.06
Non-domestic use	0.48	-233530	0
WITHOUT CONSIDERATIONS OF ENVIRONMENTAL FACTORS			
Eucalyptus plantation	4.0	160828	31.66

Finding of Second Rotation: The coppiced shoots of bluegum retained after the harvest of first rotation were allowed to grow during the second rotation (1982-92). The regression equations developed during the calibration period (1968-71) were used to compute the values of total run-off, surface run-off and base flow for the watershed planted with bluegum (B). The harvesting of the second rotation was undertaken during 1992. The analysis revealed that the coppiced bluegum significantly (ά= 0.01) reduced total run-off by 25.4 per cent (937.8 mm) compromising a 10 per cent (184.0 mm) reduction in surface run-off and a 27 per cent (415.3) reduction in base flow. The highest computed run-off (756.7 mm) and the corresponding reduction in water yield (210.9 mm) was observed during the highest rainfall (1898.2) year of 1991.

The economic analysis for the second rotation of bluegum plantation with and without environmental consideration is presented in Table 3. The findings reveals that without environmental consideration bluegum plantation in highly economical in the second rotation. It is due to the fact that coppiced eucalyptus produced more biomass in terms of wood, twigs and leaves. Thus, eucalyptus plantation in the second rotation turned to be highly remunerative. On the other hand, when environmental/ social cost is considered while calculating the economics of bluegum plantation, it outweighs the added returns. It was found that if the shadow price of depleted water had been used for domestic purposes, the NPW, BCR and IRR were Rs. 8350693, 2.98 and 33 per cent at 10 per cent discount rate, respectively. Further, these measures tend to decrease as the discount rates increases. In terms of the use of this quantum of water for industrial and domestic purposes while calculating economics with alternate use of water it was found that NPW, BCR and IRR were decreasing significantly. In the case of water used for industrial purpose NPW and BCR were positive only up to 15 per cent discount rate. While for non-domestic use these measures were positive less than 15 per cent discount rate also. The IRR was found to be 12 per cent which is lesser than desirable discount rates. Though without considering the environmental damages eucalyptus plantation in the second rotation is highly economical where as with environmental effects it turned out to be uneconomical. Therefore, the species may be selected for the hilly areas having such agro-eco conditions in view of environmental consequences. Further, the data were pooled together for both the rotations (1972 to 1990) and economic analysis was carried out by considering the project life for 20 years. The economic evaluation suggests that with environmental consideration, BCR and NPW were positive. For domestic use and industrial use where BCR was 1.94:1 at 15 per cent discount rate indicating low returns from bluegum plantation (Table 4). In the case of non-domestic use BCR and NPW both were negative with 6.69 IRR, suggesting uneconomical returns were highly economical if we do not take into account the environmental considerations. But the profits are lower than the damages caused due to depletion of water, while considering the environmental factors. Further, it can be inferred from the results that eucalyptus plantation by converting the natural grass lands is not an economical proposition in Nilgiris.

TABLE 3. BCR, NPW AND IRR OF PROJECT-SECOND ROTATION (1982-91)

Particulars	Discount rate (10 per cent)		IRR (per cent)
	BCR	NPW	
(1)	(2)	(3)	(4)
WITH CONSIDERATIONS OF ENVIRONMENTAL FACTORS			
Domestic use	2.98	832069	32.80
Industrial use	1.59	463717	19.65
Non-domestic use	1.08	95364	11.67
WITHOUT CONSIDERATIONS OF ENVIRONMENTAL FACTORS			
Eucalyptus plantation	94.83	1238499	>100

TABLE 4. BCR, NPW AND IRR FOR 20 YEARS PROJECT PERIOD (1972-91)

Particulars	Discount rate 10 per cent		IRR per cent
	BCR	NPW (Rs.)	
(1)	(2)	(3)	(4)
WITH ENVIRONMENTAL CONSIDERATIONS			
Domestic use	1.94	337827	19.38
Industrial use	1.19	110559	12.82
Non-domestic Use	0.78	-201946	6.69
WITHOUT ENVIRONMENTAL CONSIDERATIONS			
Eucalyptus plantation	11.89	637838	34.48

IV

CONCLUSIONS AND POLICY IMPLICATIONS

The results of this study clearly demonstrate that the cost of environmental damage if worked out in terms of the environmental economics, outweighs the returns from bluegum plantation without considering environmental factors. On an overall basis considering both the first and second rotation, the IRR with environmental consideration comes to the level which is not economical. However, if the value of water as a resource is related to the highly subsidised domestic use, the IRR comes close to the acceptable economic level. Therefore, in the sloppy areas where natural vegetation is so important to control soil and water erosion, forest may be recommended to grow species with due consideration of environmental and social costs. The water use by eucalyptus exceeded the input supply of water from rainfall, albeit over a drier than average. This result generated considerable concern regarding the long term sustainability of such plantations and the water resource implications of such a high water use and rationing rainfall. The continuously increasing soil moisture deficits observed beneath the eucalyptus indicate that the possibility of the soil returning to field capacity within the monsoon season to allow matrix to flow through the profile to recharge the groundwater reservoir would be remote. The lessons learnt from the study are that future management and intervention in reservoir catchments have to be along with environment and social considerations for long term sustainability. The policy makers and researchers may consider the environmental and social costs of such plantations while working out the economics of eucalyptus (bluegum) plantation. Further, this study has been a useful policy instrument for the government and has resulted in the ban on block plantations of eucalyptus in Nilgiris, Tamil Nadu.

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