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STUDIES ON HYDROLOGICAL IMPACT OF CONVERSION OF NATURAL GRASSLANDS INTO BLUEGUM PLANTATIONS(EUCALYPTUS GLOBLUS) IN THE NILGIRI HILLS

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ABSTRACT

The Nilgiris disrict is drained by the rivers Moyar and Bhavani and their innumerable tributaries which are harnessed for Irrigation and generation of electricity. The natural vegetation comprised of vast stretches of grasslands interspersed with pockets of 'Sholas'. Out of many useful alien trees introduced in the District, bluegum has been extensively used for afforestation by the Tamil Nadu Governments over the past three decades due to its high rate of biomass production, coppicing capacity, shorter rotation and high economic returns.

The Central Soil and Water Conservation Research and Training Institute, Research Centre, Udhagamandalam initiated catchment studies during 1968 to quantify the effect of conversion of natural grasslands into bluegum plantations on water yields in the Nilgiri hills through paired watershed technique. The study area located at an average elevation of 2200 metres above sea level experiences an average annual rainfall of 1490 mm, 80% of which is contributed by south west and north east monsoons. Runoff was measured over 2:1 trangular weirs with stage level recorders. After the initial calibration of the watersheds under natural cover of grassland, 'Shola' and swamps, one of the watersheds was planted with Eucalyptus in July,1972. At the end of the first rotation of 10 years, the trees were felled during 1982 and during this period the average annual reduction in total runoff due to conversion of grasslands into bluegum was to the tune of 16%. During the first half of the second rotation, the reduction in total flow has further increased to about 20%. The seasonal distribution of total flow especially during the dry period which is mostly baseflow is drastically reduced to 50%. The data on consumptive use by Eucalyptus as a function of age and annual rainfall, five yearly trends in annual and seasonal runoff ratios for the period 1968 to 1986, the implications of reduced inflows into the hydro-electric reservoirs affecting power production,the policy decisions to be taken by the Government to sustain the hydel power based industries and wood based industries are discussed in this paper together with environmental impact.

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INTRODUCTION

The Nilgiris plateau forms a strategic part of the catchment of the rivers Moyar and Bhavani. These rivers and their tributaries have been harnessed for hydro electricity and irrigation projects. Nearly 40 percent of the hydro-electric power generation in Tamil Nadu is contributed by the reservoirs located in the Nilgiris district. Large scale planting of bluegum trees were taken up in the catchments of these rivers in different five year plans by the Tamil Nadu State Government for production of fuel, industrial raw material, etc. The vast grassy hill slopes which form the catchment area of these storage reservoirs were planted with bluegum. The State Electricity Department objected this large scale conversion of grassland into bluegum plantation contending that this afforestation will deplete the runoff and effect the discharge to the reservoirs located in this region. The Forest Department countered this contention with the argument that the tree cover established will contribute to the development of springs and consequent sustained all season flow into the reservoirs and the storage will not be affected. To answer this controversy, the Central Soil Conservation Research Centre, Udhagamandalam has taken up studies to get some authentic data on runoff, stream flow, soil erosion, etc. The Centre selected a truly representative area of 65 hectaresin the drainage basin of the Glenmorgan storage reservoir feeding the Pyakara hydro-electric project. The actual studies were initiated from the year 1968.

GENERAL DESCRIPTION OF THE STUDY AREA

The Soil Conservation Research Centre, Udhagamandalam selected a truly representative area of 65 hectares comprising of two, more or less identical sub-catchments of almost equal area, lying side by side in the drainage basin of the Glenmorgan storage reservoir feeding the Pykara hydro-electric project. This area is situated 24 Km away from Udhagamandalam-Mysore State Highway at latitutde and longitude of 11°28'10' N and 76°37'14'E respectively in Wenlock downs forest reserve, Nilgiri District, Tamil Nadu, The area experiences a montane temperate humid climate and is situated in the tropics. Mean annual rainfall of 1490 mm spread over 141 rainfall events is mostly contributed by the South West monsoon occurring from June to August and North-East monsoon from September to November. The air temperates goes as high as 27°C during April-May and as low as 0°C during December-January. Severe ground frost occurs from November to February. Himidity is high.

PHYSIOGRAPHY

The project area is located in the Western ghats at an elevation of 2200 metres above M.S.L. The physiography of the area is undulating. The area comprises of two catchments separated by a central ridge running in an East-West direction. The two catchments have more or less identical slope soil and vegetation and the entire area is representative of 'Wenlock Downs' reserve. The slopes range from 0-10% under ill drained swamps and 16-50% in grasslands and 10-75% in 'Shola' forest. The maximum elevation difference is only 61 m. Stream gradients vary from 3 to 5%. The watershed drains into Moyar Basin, Pykara tributary ultimately draining into the River Moyar.

SOILS

The soils encountered in the plateau are lateritic and derived from Charnockites. The soils are mostly clayey except concretion layer which have less clay percentage and more sand percentage. The parent materials have usually more silt content than clay and the pH values range from 4.5 to 5.8, The field capacity and wilting point values are 28.6% and 18.0% respectively and the bulk density value being 1.33 gm/cc. The infiltration rates at the end of 3 hours under 'Shola' and grass covers in the research watersheds range from 15 to 38 cm/hour and 0.3 to 0.6 cm/hour respectively. The lower rates of infiltration under the grass cover is attributed to moderate grazing activity by the Toda buffaloes throughout the year. The high rates of infiltration for prolonged time in 'Sholas' and other profile characteristics are responsible for perennial sources of water supply.

GEOLOGY

The data collected on geology indicate that the total thickness of over burden varies from 20 m to 90 m. In the catchment area, the bed rock slopes gently down from west to east at the rate of 1 in 12 and tends to rise in the Eastern part. The weathering is deep on the southern section of the area where the bed rock slopes down steeply towards south. For all practical purposes of hydrological studies, this constitutes the impervious strata so far as movement of ground water is concerned.

VEGETATION

Vegetation of the study watersheds can be classified as natural 'Shola', natural grassland and natural swamps.

NATURAL 'SHOLA'

It occupies a predominent area (7.86 ha) in both the watersheds. They are old, well established with well developed top canopy, under wood, under growth, leaf litter, humus, lianes, eriphytes, parasites and saprophytes. The soil humus and leaf litter is rich in micro and macro fauna and flora.

NATURAL GRASSLAND

The grassland is grazed by Toda semi wild buffaloes and is infested with weeds such as *Eupatorium glandulosum*, *Hypericum mysorensis* etc. The dominant species of grass is *Chrysopogon Zeylanicus*. The introduced grass Kikuya (*Pennisetum clandestinum*) has run wild. The natural and introduced legumes exist in these grasslands.

NATURAL SWAMPS

The swamps exist in both the watersheds. The swampy vegetation occur in both the sides of the streams as well as on swamps which have high water table ranging from 0 to 3 metres.

METHODS AND MATERIALS

Two watersheds A and B having an extent of 33.18 and 31. 89 ha respectively separated by a common ridge and having identical slope, soil, geology and land use were selected for the hydrological studies. The initial topographic, soil and vegetation surveys were conducted and gauging stations were established across the streams originating from the individual watersheds. A meteorological observatory to record daily rainfall and its intensity, maximum and minimum temperature and also open pan evaporation was set up on the ridge demarcating the two watersheds. At the time of initiation of the hydrological studies, the research watersheds. A and B were having 15.67% and 8.34% area under 'Shola' forest, 76.8% and 84.14% area under grassland while the remaining area of 7.53% and 7.52% was under swamps respectively. The important characteristics of both the watersheds are given below (Table No. 1).

Table No. 1

Topographical characteristics of the Watersheds

Characteristics	Watershed No.	
	A	B
Area (ha)	33.18	31.89
Shape index	2.22	1.03
Max.length of stream (m)	450	380
Stream density (KM/KM^2)	1.36	1.19
Average slope (%)	21	17
Mean elevation (m)	2266	2216
Watershed Relief (m)	55	61
Time of Concentration (minutes)	10.30	9.10
Perimeter (m)	2315	2214
Form factor	0.41	0.49
Compactness coefficient	1.13	1.11

Data on total monthly discharge were collected for four years viz., 1968-69 to 1971-72 (calibration period) from both watersheds A and B in its original condition, under natural grassland and 'Shola'. In one of the watersheds (B), bluegum was raised in part of the area above the frost line during July, 1972. The rest of the area in watershed 'B' and the entire watershed 'A' was maintained in its original condition under natural grassland and 'shola'. The stream gauging was done with the help of 2:1 broadcrested masonary weir with autbmatic stage level récorders during calibration period and post calibration period. At the end of 10 years (1982) rotation, the bluegum was felled under coppice system and the data analysed. In both the watersheds, one with coppiced E. globulus and the other with natural vegetation, studies have been carried out from 1983 to find out the effect of coppiced E. globulus on water yield. In order the quantify the effect of conversion of natural grasslands with bluegum plantation on water yields in the Nilgiris, the paired watershed technique was adopted.

RESULTS AND DISCUSSION

Negligible difference was observed in the total monthly discharge from both the watersheds during the calibration period confirming the hydrological homogenity of the watersheds. The regression equations were developed based on data collected during this period (1968-72) for estimating the total runoff, surface runoff and base flow for watershed 'B' from the observed values for watershed 'A' such that any future change in hydrological behaviour brought about due to change in land use could be quantified in relation to the equations developed during the calibration period (1968-72). Linear regression equations were developed for three runoff components viz., total runoff, surface runoff and sub-surface runoff in watersheds 'A' Vs. three runoff components in watershed 'B'. The runoff calibration equations are given below

$$Y_1 = (-)4.4377 + 1.1736\, X_1 \quad \ldots (1)\ r = 0.987$$

$$Y_2 = 0.0525 + 0.9491\, X_2 \quad \ldots (2)\ r = 0.984$$

$$Y_3 = (-)6.3403 + 1.3032\, X_3 \quad \ldots (3)\ r = 0.980$$

Where Y_1, Y_2, and Y_3 = Total runoff, surface runoff and baseflow respectively in Catchment 'B' mm.

X_1, X_2, and X_3 = Total runoff, surface runoff and baseflow respectively in Catchment 'A' mm.

The high values of correlation coefficients indicate that the two watersheds are identical in their hydrological behaviour.

POST CALIBRATION PERIOD

(a) Before coppicing

Double mass curves for total runoff and base flow were drawn to study the behaviour of water yield in both the watersheds. It is observed that during the period 1972 to 1974 after the plantation of bluegum in watershed 'B'., the difference in total and base flow between the two watersheds continued to be negligible. However, from 1975 onwards, watershed 'A'. To assess the impact of bluegum plantation on water yield, the calibration equation developed during the calibration period were used to compute the total runoff, surface runoff and base flow in watershed 'B' as compared to watershed 'A' if the same earlier land use would have continued. These computed values when compared with the observed values of total surface and base flows in watershed 'B' during the treatment period will give the net reduction due to bluegum plantation (Table No.2). To assess as to whether the differences in total runoff, surface runoff and base flow in the two watersheds is statistically significant or not, the student's 't' test was applied for the treatment period. The 't' test has revealed that the total flow and base flow in watershed 'B' significantly reduced after the treatment of bluegum plantation was imposed during 1972 to 1981. The average annual reduction in total flow and base flow were found to be 87 mm (16%) and 59 mm (15%) respectively which is significant at 1% level.

The study has further indicated that there was no soil loss after conversion of grasslands into bluegum plantations.

<u>Table No.2</u> : Observed and computed values of total runoff and base flow for Catchment 'B'

Year	Total runoff (mm)		Base flow (mm)		Surface flow(mm)	
	Computed	Observed	Computed	Observed	Computed	Observed
1972	609	600	437	431	167	168
1973	541	523	362	346	162	177
1974	431	432	360	349	72	83
1975	787	585	683	438	126	147
1976	259	203	213	167	42	36
1977	556	479	397	302	149	177
1978	713	619	491	392	209	227
1979	697	516	322	311	311	205
1980	436	301	272	212	140	89
1981	463	368	247	258	183	110

b) After coppicing

Both the watershed 'A' and 'B' - one with coppiced E. globulus and the other with natural vegetation were studied from 1983 to find out the effect of coppiced E. globulus on water yield. The monthly observed runoff (total flow and base flow) for the calendar year 1985 from watershed A and B and the computed runoff from watershed 'B' during the calibration period indicated that the coppiced Eucalyptus caused reduction in the total annual flow from 257 mm to 207 mm as deduced from the observed values of A and B and from 258 mm to 207 mm as deduced from the computed values of 'B' and observed values of 'B', the percentage reduction being 19.5% and 19.7% respectively, for total flow (annual).

Table No.3: Percentage reduction in water yield from *E. globulus* coppiced watershed

	Observed 'A' and Observed 'B'	Observed 'B' and Computed 'B'
Annual flow (January-December 1985)		
i) Total flow	19.5%	19.7%
ii) Base flow	28.3%	27.5%
Seasonal flow (February-June 1985)		
i) Base flow	53.4%	48.4%

and 28.3% and 27.5% for base flow (annual). This reduction is less by 11.6% and 12.5% respectively for total flow (annual) and base flow (annual) when compared to a reduction of 31.4% and 40.7% for total flow and base flow during 1984.

A closer look into the seasonal flows (February-June) reveal that the percentage of reduction is to the tune of 53.4% between observed base flows of A and B and 48.4% between observed flow of B and computed base flow B.

The observed runoff data (total flow and base flow) from watersheds A and B and the computed runoff data B has been subjected to student 't' test for finding out the statistical significance of the reduction. It was observed that in all the cases, the reduction was observed to be statistically significant at both 5 and 1% levels.

The data on rainfall-runoff from A and B clearly showed that the water used by the coppiced *E. globulus* was higher than that consumed by the natural grassland. From January to March, the coppiced Eucalyptus watershed consumed 12% more water than grassland watershed (Table No.4)

Table No.4 : Rainfall-runoff as seasonal consumptive use indicator for coppiced *E. globulus*-Glenmorgan

Season	Rainfall (mm)	Consumptive use from grassland	Consumptive useas % of rain fall	Consumptive use from coppiced *E.globulus* (mm)	Consumptive use as % of rainfall
January to March 1985	15.60	(-)11.64	-	2.01	12.90
April to June 1985	451.10	393.70	87.28	407.29	90.29
July to Sept. 1985	496.40	377.72	76.09	399.95	80.57
October to December,1985	244.70	175.72	71.81	179.52	73.36

Annual consumptive use Y (in mm) in Catchment B for the 10 years period 1973-1982 after planting Eucalyptus has been worked out as a function of age of plantation in years X_1 and annual rainfall in mm X_2. The relationship $Y=144.85+4.4820\ X_1 +0.6045\ X_2$ is highly significant with the multiple correlation coefficient of 0.9715.

The reduction in total water yield from the moderately grazed grassland on account of conversion into *E. globulus* is given in Table No. 5. The entire period of the experimentation from 1968-1986 has been divided into four periods. viz., calibration period (1968-72), middle of first rotation(1973-77) end of first rotation and first half of second rotation. The runoff ratios for the treated watershed 'B' to untreated watershed 'A' for four quarters of the year (January-March, April-June, July September and October-December) have been worked out. It was seen that the B/A ratios had progressively reduced in all quarters over years indicating the reduction on account of bluegum plantation. The reduction is more pronounced in the first quarter (January-March). Similar trends have been observed for half yearly periods also (January-June and July-December). On an annual basis also, reduction has been observed in B/A ratios and it is to the tune of 23%.

ECONOMICS

These plantations spread over an area of 18.76 ha possessed 24,911 marketable trees (survival-53.12%) which gave an average yield of 10 t/ha/year. The income in the first rotation of ten years (1972-1982) was Rs.3,250/ha/year. In addition to this, the bluegum leaves of 1.2 t/ha/year and a green fodder of 8 q/ha/year were also obtained (Samraj) et al. 1983).

Table No.5: The reduction in total water yield from the grassland on account of conversion into Eucalyptus globulus is indicated in the table below

Runoff in mm depth and runoff ratios

	1968-1972 (Calibration period)			1973-1977 (Middle of rotation)			1978-1982 (End of Ist rotation)			1983-1986 (2nd rotation first half)		
	A	B	B/A	A	B	B/A	A	B	B/A	A	B	B/A
January-March	36.84	30.88	0.838	38.41	30.52	0.795	44.30	26.67	0.602	28.71	16.40	0.571
April-June	76.73	62.35	0.813	67.83	55.92	0.824	66.45	42.59	0.641	43.85	29.40	0.670
July-September	169.57	185.11	1.092	241.97	240.97	0.996	222.62	189.11	0.849	134.66	116.92	0.868
October-December	128.50	143.59	1.117	139.85	133.13	0.952	168.98	154.61	0.915	106.28	84.25	0.793
	411.64	421.93	1.025	488.06	460.54	0.944	502.35	412.98	0.822	313.50	246.97	0.788
Half year periods												
January-June	113.57	93.23	0.821	106.24	84.44	0.814	110.75	69.26	0.625	72.56	45.80	0.631
July-Dec.	298.07	328.70	1.103	381.82	374.10	0.980	391.60	343.72	0.878	240.94	201.17	0.835

Assuming a full stocking of 2500 trees/ha (a hectare would normally be expected to bear this number of bluegum trees), the effective area is worked out to be 9.96 ha which is estimated to give Rs. 61,174/- for a rotation of ten years or Rs. 6,117/ha/year. The benefit cost ratio of raising bluegum plantation in the hilly regions of the Nilgiris on a ten years rotation is worked out to be 4:1 (Economics of utilization of degraded lands - Narayana and Ram Babu,1984).

The plantation was ready for the first felling during 1982-1983, the approximate quality class was II/III (Average height of dominant trees 25m and 18m and yield 383 cu.m and 246 cu.m/ha respectively on the 10th year).

If the reservoir capacities are not affected adversely due to plantations of bluegum in their catchments and the reduction of 16% in the expected water yield can be afforded, the plantation of bluegum can be economically practised as the loss in water yield will certainly outweight by the good returns from bluegum after a period of ten years. The reduction in total water yield can be minimised by adoption of suitable silvicultural management practices such as wider plant spacing and by reducing rotation period from 10 years to a lesser period of eight years. If the bluegum plantations are to be raised over the entire catchment area, the area should be covered with different maturity periods of plantation to minimise their undesirable effect such as drastic reduction in water yields due to simultaneous peak water consumption, lack of enough canopy in the initial stages, etc.

The scarcity of water in various reservoirs of this region is generally experienced during January to April and bluegum (<u>Eucalyptus globulus</u>) further brings reduction in water yield during this period. Therefore, water yields in the catchments of hydel reservoirs need to be critically examined during this period before taking up any large scale bluegum plantations in the catchments of the Nilgiri hills. The Eucalyptus plantations support many wood based industries such as paper making, rayon pulp, distillation of oil for medicinal purposes, etc. Presently, M/s South India Viscose Limited, depend largely on these produce for first grade rayon pulp. The hydro-electric power is equally important to support various power based industries. The policy decisions with regard to planting Eucalyptus should be such that a proper balance is struck between the hydro power based industries on one hand and the wood based industries on the other, keeping in view the overall impact on the environment of the region.

CONCLUSIONS

From the study conducted during the first rotation (1972-82) of bluegum (<u>Eucalyptus globulus</u>), it is concluded that raising of bluegum in the Nilgiris brings significant reduction in the total runoff during the first rotation of 10 years. The total reduction amounts to 867.74 mm for the entire rotation of 10 years or an average of 87.00 mm per year. This indicates a reduction of about 16% in the expected water yield from the open grasslands (control) if the bluegum plantations are raised in these watersheds. The water use by coppiced E. globulus has been considerably higher than that consumed by the natural grasslands during the beginning of the second rotation. The results of this study indicate that caution may have to be exercised while planting large scale conversion of grasslands in the catchments of the Nilgiris into Eucalyptus plantations. Policy decisions by the Government are needed to strike a balance between hydro power based industries on one hand and the wood based industries on the other, besides its environmental impact in the region.

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REFERENCES

1. Effect of Bluegum plantation on water yield in Nilgiri Hills - Bulletin No. T-18/O-3 - Central Soil and Water Conservation Research and Training Institute, Research Centre, Udhagamandalam-1987.

2. Soil Conservation Annual Report, 1985 - PP 70-72, Central Soil and Water Conservation Research and Training Institute, Dehradun.

3. Soil Conservation Annual Report, 1986 - PP 107-110 Central Soil and Water Conservation Research and Training Institute, Dehradun.