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Soil Moisture Conservation and Depletion Pattern under Even-Aged Plantation of Different Tree Species in Degraded Soil

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Abstract

Studies on soil moisture conservation and depletion pattern under even-aged plantation of 12 tree species planted on gravelly loam soil was conducted during January to December 1996. Soil moisture conservation and exhaustion trend due to different tree species after 66 months of planting shows appreciable increase in soil moisture under all tested tree species. However, influence of vegetative cover was found to be more pronounced on surface than sub-soil depth. The depletion trend in moisture level was also noted around active rooting zone under all species, particularly in summer seasons. The maximum moisture conservation on surface soil was observed under *Tectona grandis* followed by *Dalbergia sissoo*, while minimum by *Acacia benthamii*. As a whole after 66 months of planting all 12 species were found to conserve the soil moisture among which maximum by *Tectona grandis*, *Dalbergia sissoo, Cassia siamea, Albizia procera* while as minimum by *Acacia benthamii, Emblica officinalis* and *Dalbergia latifolia.* A significant positive correlation was noted between net moisture increment and mean annual moisture increment.

Key words : Soil moisture, Conservation and exhaustion, Tree species, Degraded soil.

Soil moisture plays a significant role in several natural processes that influence energy balance on the surface of earth. Evaporation, infiltration and drainage of water, diffusion of gases, conduction of heat and movement of salts and nutrients all depend upon the amount of water present in the soil. Bioclimate (microclimate and soil climate) is most important environmental factor controlling the regeneration, survival of seedlings, establishment and growth of plant. The soil climate and climate close to the forest floor are affected to the great extent iter-alia by the nature and composition of surface layer, which in turn is affected by the litter produced by the plant communities it selves or its vegetative cover. However, evapotraspiration has a significant role in reducing soil moisture content and the evapotraspiration is greatly influenced by reduction in solar radiation due to cloud cover and canopy density of plantation, consequently status of surface and sub-surface soil moisture may change in similar soil depending upon the nature of tree stand (1—3). Soil moisture regulates soil physical, chemical and biological behavior contributing a variety of conditions for soil to act as a growth medium and to protect trees. The nature and quantity of litter produced by forests largely depend upon the species, age and tree density (4, 5). Different types and thickness of tree cover affect downward movement of water in the soil in different ways (6, 7). The present study will be helpful in assessing the moisture conservation pattern at different soil depths under different monoculture plantations. The study may also be helpful to ascertain the soil moisture regeneration or losses at different soil depths during different seasons due to different tree species particularly in degraded soil. This will certainly help in developing a quantitative understanding of post afforestation changes in the soil moisture regime.

Methods

Soil samples for moisture determination were collected in the third week of every month during January 1996 to December 1996. Soil samples for moisture determination were collected from different plantations and adjoining open sites at the depths of 0—20, 20—40, 40—60 and 60—80 cm. These samples were dired at 105 C for 48 h to obtain constant oven

Table 1. Plantation site characteristics, growth and surviving details of plants. Year of planting : July 1991. Observation December 1996.

Tree species	Spacing	Surviving trees/ha	DBH (cm)	Average height (m)	Active rooting zone depth (cm)	Site characteristics
Acacia benthamii	2 × 2	0850	3.61	2.8	20—40	Topographically site convex upland, slightly eroded, well drained to excessively drained, gravelly clay loam texture, gentle slope and moderately deep.
Acacia nilotica	2 × 2	1750	7.14	4.5	20—40	Do
Albizia lebbek	2 × 2	1250	7.57	6.41	20—40	Do
Albizia procera	2 × 2	2000	10.62	8.23	20—45	Do
Azadirachta indica	2 × 2	2050	87.07	5.96	20—40	Do
Cassia siamea	2 × 2	1525	7.2	7.51	20—45	Do
Dalbergia sissoo	2 × 2	2150	9.7	7.52	20—45	Do
Dalbergia latifolia	3 × 3	0988	8.3	7.94	20—45	Do
Dendrocalamus strictus	4 × 4	450×10= 4500	4.87	7.0	15—30	Do
Emblica officinalis	2 × 2	2000	6.9	6.15	20—40	Do
Pongamia pinnata	2 × 2	1700	6.66	4.82	20—40	Do
Tectona grandis	2 × 2	1725	6.56	6.09	20—45	Do

dry weight. Moisture percent was calculated on the basis of loss in weight on oven drying.

The study was conducted in the 66 months old monoculture plantations of 12 different tree species planted in July 1991 in the premises of Tropical Forest Research Institute, Jabalpur. Geographically the plantation sites lies between 23 5′57′′ to 23 6′10′′ N latitude to 79 58′49′′ to 79 59′42′′ E longitude and is situated at 400 m from MSL. The general land scape of plantation site is nearly plain to gently sloping with moderate relief. Meteorological details i.e. rainfall, temperature and humidity of TFRI campus have been shown in Figure 1 for 1996.

Results and Discussion

Plantation site characteristics, details of growth and number of surviving trees per hectare of 12 different tree species have been presented in Table 1. Seasonal meteorological information of study site, soil moisture percent at different soil depth under different tree cover, soil moisture in different seasons, net moisture status and mean annual moisture increment and with correlation values are presented in Tables 2, 3, 4 and 5 respectively. Plantation site for all twelve species topographically fall under convex upland, moderately eroded, well drained to excessively well

Table 2. Meteorological information (seasonal) for 1996.

Seasons	Total	Rainfall (mm) Max	Rainfall (mm) Min	Temperature C Max	Temperature C Min	Humidity Max	Humidity Min
1. Jul to Sep	723.40	379.00 Aug.	71.80 Sep.	32.00 Jul.	23.20 Sep.	96.3 Aug.	59.70 Jul.
2. Oct to Jan	195.80	105.60 Oct.	00.00 Nov.	30.80 Oct.	06.80 Dec.	94.40 Oct.	24.00 Dec.
3. Feb to Jun	073.60	44.20 Feb.	00.00 May.	40.90 May.	11.90 Feb.	86.10 Feb.	12.2 May.

Table 3. Soil moisture status (percent) under different tree cover (after 66 months of planting).

	At depth (cm)								
	0—20		20—40		40—60		60—80		
Species	P	O	P	O	P	O	P	O	Balance
A. benthamii	8.38	8.17	10.27	10.35	9.14	9.21	8.88	8.88	0.06
A. nilotica	8.90	8.58	9.55	9.75	9.59	9.56	7.99	8.03	0.08
A. lebbek	9.54	8.14	10.53	10.82	9.43	9.35	8.60	8.56	0.23
A. procera	10.69	9.79	12.28	12.88	10.63	10.65	8.93	8.87	0.34
A. indica	9.05	8.72	10.69	10.80	9.22	9.25	7.63	7.67	0.15
C. siamea	10.36	9.31	11.45	11.91	9.60	9.80	8.20	8.22	0.37
D. latifolia	8.27	7.98	9.79	10.08	9.51	9.39	7.38	7.36	0.14
D. sissoo	10.08	9.11	10.08	10.57	9.31	9.37	8.08	8.18	0.32
D. strictus	8.3	7.9	9.22	9.26	8.25	8.40	7.36	7.38	0.19
E. officinalis	9.10	8.7	9.87	10.05	9.31	9.33	7.56	7.57	0.13
P. pinnata	9.52	9.07	10.52	10.86	10.08	9.89	7.14	7.49	0.17
T. grandis	10.87	9.30	10.63	11.50	9.75	9.89	7.38	7.49	0.45
Mean	9.42	8.82	10.41	10.74	9.49	9.51	7.96	7.98	0.22
SD ±	0.877	0.557	1.029	0.949	0.543	0.513	0.568	0.542	0.118

drained with gently sloping class. In terms of textural constituents entire plantation area fall under general category of gravelly clay loam with the soil depth of moderately deep. Table 1 shows the growth performance including per hectare stading trees of different species and thus better performance was observed by *Albizia procera* (2,000 trees/ha, 10.62 cm dbh and 8.23 m ht), followed by *Cassia siamea* (1,525 trees/ha, 7.2 cm dbh and 7.51 m ht), *Dalbergia sissoo* (2,150 trees/ha, 9.7 cm dbh and 7.52 m ht) while poor performance by *Acacia benthamii* (850 trees/ha, 3.61 and 2.8 m ht) was recorded. Active rooting zone of all tree species was found to be concentrated in between 15 to 45 cm depth.

Seasonal soil moisture distribution for 1996 shows that the moisture distribution under all twelve species follows almost similar trend (Table 4). The average moisture content recorded under vegetative cover was estimated to be 9.3% while at corresponding open site it was observed 8.7% on the surface layer and thus there is a net increase of 0.6 units due to impact of vegetative cover. Moisture availability trend in subsoil was found to be some what in different manner. Below the depth of 20 cm the depletion trend in mois-

Table 4. Soil moisture status at different depth in different seasons after 66 months of planting.

	Jul to Sep at depth (cm)								Oct to Jan at depth (cm)							
	0—20		20—40		40—60		60—80		0—20		20—40		40—60		60—80	
Species	P	O	P	O	P	O	P	O	P	O	P	O	P	O	P	O
A. benthamii	18.6	17.5	19.0	20.1	22.0	23.1	17.7	17.9	10.0	10.1	11.5	11.7	13.3	13.3	8.7	7.8
A. nilotica	17.2	17.7	24.3	24.5	20.4	20.5	15.6	15.1	11.4	11.1	13.2	13.9	13.5	13.5	10.0	9.6
A. lebbek	16.3	15.2	23.4	25.1	20.1	19.7	14.8	15.1	12.9	11.8	15.4	16.1	12.8	12.6	10.2	10.0
A. procera	18.6	17.8	23.4	24,2	20.4	21.2	18.7	18.7	12.7	11.9	15.2	16.3	12.3	12.0	8.6	8.4
A. indica	17.5	16.6	22.6	23.5	18.3	18.7	16.6	17.3	12.2	11.4	14.4	15.2	13.5	13.6	10.8	10.7
Bamboo	18.6	17.4	20.4	20.0	13.1	13.8	19.6	20.2	9.9	9.7	8.5	6.4	8.3	8.3	9.1	9.3
C. siamea	18.7	18.1	22.0	24.4	21.6	22.7	17.2	17.5	13.5	12.6	14.6	16.1	13.8	13.8	10.0	10.0
D. latifoli	17.7	16.9	19.3	20.9	15.8	16.7	17.4	17.9	11.1	10.9	11.5	13.0	11.8	12.2	9.5	9.8
D. sissoo	20.0	18.6	21.5	23.6	17.6	18.2	15.4	15.7	13.1	11.8	15.3	16.2	12.6	13.1	10.4	10.2
E. officinali	17.7	17.6	21.7	22.1	17.0	16.5	12.5	13.1	11.7	11.2	12.9	14.1	11.1	11.5	9.7	9.8
P. pinnata	19.0	18.8	22.3	23.0	15.7	16.7	13.6	14.8	12.8	11.7	14.8	16.4	11.7	12.0	9.3	10.1
T. grandis	20.7	17.4	21.7	22.1	14.0	15.9	13.5	12.2	14.6	12.2	15.0	17.3	13.1	13.2	9.3	9.8
Mean	18.4	17.5	21.8	22.8	18.0	18.6	16.1	16.3	12.2	11.4	13.5	14.6	12.3	12.4	9.6	9.6
SD ±	1.16	0.19	1.54	1.49	2.83	2.74	2.10	2.26	1.34	0.80	2.02	2.23	1.45	1.42	0.65	0.76

Table 4. Continued.

Species	Feb to Jun at dapth (cm) 0—20 P	0—20 O	20—40 P	20—40 O	40—60 P	40—60 O	60—80 P	60—80 O
A. benthamii	6.2	6.3	8.0	8.3	6.7	6.0	4.5	4.9
A. nilotica	7.4	6.7	7.0	7.8	7.9	7.9	7.1	7.5
A. lebbek	10.7	9.9	7.6	7.9	8.2	8.6	8.2	8.1
A. procera	9.3	8.0	7.7	9.0	7.1	6.9	6.1	6.0
A. indica	6.2	6.2	6.5	6.4	6.8	6.2	6.1	5.6
Bamboo	5.4	5.1	5.2	5.3	5.5	5.0	6.4	6.2
C. siamea	8.8	7.5	7.2	7.0	6.5	6.0	5.1	4.3
D. latifoli	5.6	5.6	6.3	5.5	6.7	5.8	5.5	5.8
D. sissoo	7.8	7.1	6.8	7.4	7.1	6.2	5.7	5.4
E. officinali	7.4	6.6	6.6	6.8	7.9	7.8	7.3	6.4
P. pinnata	8.3	6.9	7.3	7.7	5.8	5.2	6.5	5.1
T. grandis	8.7	7.3	7.2	8.3	8.7	8.0	7.0	6.5
Mean	7.7	6.9	7.0	7.3	7.1	6.6	6.3	6.0
SD ±	1.54	1.18	0.72	1.08	0.92	1.13	0.9	1.0

ture availability was noticed and this depletion trend in sub soil horizon was observed to be common feature except one species (*A. benthamii*) whose density per hectare and growth performance was very poor. Soil moisture content at the soil depth of 20—40 cm was estimated to be 10.39% under vegetative cover while at corresponding open site it was 10.75% and thus there was a net depletion of 0.39%. Depletion in the moisture level below the depth of 20 cm may be because of intensity and abundance of active roots. However, below the depth of 40 cm as the intensity and abundance of roots decreases depletion in moisture level simultaneously reduces such as in the depth of 40—60 cm, it was 0.16% and in the depth 60—80 cm it was 0.01%. Soil moisture conservation and depletion pattern varies species to species. During 66 months maximum conservation on surface layer (0—20 cm) was recorded under *Tectona grandis* (1.57%) followed by *Cassia siamea* (1.05%), other species were also found to be conserve appreciable amount of moisture i.e. *Dalbergia sissoo* (0.97%), *A. procera* (0.90%), *Pongamia pinnata* (0.43%), *Albizia lebbek* and *Dendrocalamus strictus* (0.4%) each. Maximum soil moisture conservation by *C. siamea* (7.83%), *T. grandis* (7.4%) and *A. procera* (7.42%) has also been reported by Prasad and Mohammad (3) on upper layer in the plantation raised on loamy soil. Jha and Rathor (2) have also reported that moisture content in surface and bottom layers was higher as compared to middle layer because of the higher root activity in this zone (30—90 cm depth). In sub-soil (20—40) maximum depletion in moisture content was noted under *T. grandis* (0.87%) followed by *D. sissoo* (0.49%) and *A. procera* (0.6%) and minimum under *A. banthamii* (0.08). Moisture level under other species was also found to be depleted like *P. pinnata* (0.34%), *A. lebbek* (0.29%), *D. latifolia* (0.29%), *A. nilotica* (0.2%) and minimum under *A. benthamii* (0.08%) followed by *E. officinalis* (0.04%). Below 40 cm depth difference in moisture conservation and depletion was negligible. The monthly soil moisture distribution pattern indicated retention of maximum moisture during August followed by September and minimum moistutre was retained in May. These values are correlated with the meteorological parameters of the study area (Fig. 1). Soil moisture increased down the depth as the mansoon progressed in August and September and decreased as summer progressed in April and May. During rainy season (July to September) total rainfall received was 723.4 mm and decreased to

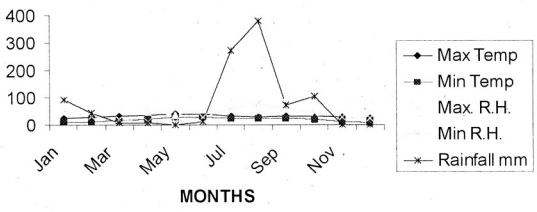

Figure 1. Meteorological data for Year 1996.

Table 5. Net moisture status and mean annual increment and their coefficient values after 66 months of planting. **Significant at 1%, S = Species, NMI= Net moisture increment, MAMI = Mean annual moisture increment.

Species	MAMI (%)	N M I (%)	Correlation coefficient value			
A. benthamii	0.008	+0.05		S	N M I %	M A M I %
A. nilotica	0.015	+0.10	S	1.0000	–	–
A. lebbek	0.025	+0.16	N M I %	0.3818	1.0000	–
A. procera	0.046	+0.30	MAMI%	0.3819	0.9890**	1.0000
A. indica	0.015	+0.10				
C. siamea	0.054	+0.35				
D. latifolia	0.031	+0.20				
D. sissoo	0.061	+0.40				
D. strictus	0.031	+0.20				
E. officinalis	0.023	+0.15				
P. pinnata	0.034	+0.22				
T. grandis	**0.085**	**+0.55**				
Total	0.428	+2.78				
Mean value	0.036	+0.232				

195.8 during winter season, however, it was only 73.6 mm during summer season (February to June). The rate of loss of moisture from soil increases as temperature is increases.

Soil moisture values during rainy, winter and summer seasons were also summarized in Table 3. Data reveal that maximum soil moisture conservation was observed during rainy season. During rainy season of 1996 (July to September) moisture in 0—20 cm soil depth was 14.50% under vegetative cover and under corresponding open site it was 13.60% as such net increase in moisture content during rainy season was 0.9%. At other soil depths (20—40, 40—60 and 60—80 cm) the moisture values under different tree covers were quite close to mean values (Table 3). During winter season of 1996 (October to February) moisture in 0.20 cm depth was 9.2% under vegetative cover and under corresponding open site it was 8.9% as such net increase in moisture content during winter season was 0.4%. Difference in moisture values during summer and winter seasons were quite close to each other i.e. 0.3% in summer and 0.4% in winter.

Rainfall, temperature and humidity are important factors which affect the losses of soil moisture but these factors are common to all species. The depletion in soil moisture depends upon the extent, abundance and density of root distribution in the soil. In the present case, more moisture losses (0.46 to 0.87%) have been observed in the sub-soil depth (20—40 cm) under the species like *A. procera, C. siamea, D. sissoo* and *T. grandis* and correspondingly these species were observed to have better growth and their active rooting zones were concentrated between 20—40 cm depth. Jha and Rathor (2) have also reported maximum soil moisture loss in the zone of higher root activity (30—90 cm depth). They observed that eucalyptus root strike deeper and therefore expected this species to dry out profile faster than pine which has shorter root system. Minimum soil moisture loss (0.08%) in the sub-soil was observed under *A. benthamii* whose growth performance was poor (Table 1). The net moisture balance and mean annual moisture increment after 66 months of planting shows maximum (0.55%) soil moisture at the rate of 0.08% per annum by *T. grandis* and minimum by *A. benthamii* (0.05%) at the rate of 0.008% per annum (Table 5). There is a highly significant positive correlation (cv 0.9890* at 0.01%) between mean annual moisture increment (MAMI) v/s net moisture increment (NMI).

These findings show that there are possibilities for computing optimum quantity of water required for maintaining specific soil depths. The soil water balance which can be achieved for different plantations may be helpful in better forest management.

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