EFFECTS OF A FEW PLANT SPECIES ON SOIL PHYSICAL PROPERTIES

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PARTHIBAN, K.T. & VINAYA RAI, R. S. 1994. Effects of a few plant species on soil physical properties. Seven plant species, *Bambusa bambos, Cassia siamea, Casuarina equisetifolia, Ceiba pentandra, Eucalyptus tereticornis, Leucaena leucocephala and Tectona grandis*, each raised as woodlots in a farmer's holding at Coimbatore, India (11°20' N; 77°10' E; 310*m* a.s.l) were investigated for their effects on soil physical properties relative to a site without vegetation and a cultivated soil in the proximity. The age of the plants ranged between 6 and 8 years except for *Ceiba pentandra* which was 15 years. Compared to the vegetationless site, a distinct improvement in soil properties like bulk density, porosity, waterholding capacity and volume expansion was evident under *Casuarina equisetifolia, E. tereticornis. Ceiba pentandra* and *L. leucocephala*, whereas soils under other plant species exhibited no change. Compared to the cultivated field, a debilitation in soil physical properties was associated with several plant species. Thus bulk density increased under *B.bambos, Cassia siamea, Ceiba pentandra* and *T. grandis*. Waterholding capacity and porosity registered a decline notably with *Cassia siamea*. No soil under any plant species proved superior to the cultivated field. The beneficial effects of plants on soil fertility need further investigation.

Key words: Plants - soil properties - wood lots - vegetationless site - cultivated site

PARTHIBAN, K.T. & VINAYA RAI, R. S. 1994. Kesan beberapa spesies tumbuhan pada ciri-ciri fizikal tanih. Tujuh spesies tumbuhan, *Bambusa bambos, Cassia siamea, Casuarina equisetifolia, Ceiba pentandra, Eucalyptus tereticornis, Leucaena leucocephala* dan *Tectona grandis* ditanam sebagai lot hutan didalam kebun seorang petani di Coimbatore, India (11° 20'N, 77° 10'E, 310 *m* a.p.l.). Kesan tujuh spesies tumbuhan ini pada ciri-ciri fizikal tanih dikaji berbanding dengan kawasan yang tiada tumbuhan dan kawasan yang tanihnya diusahakan. Julat umur spesies tumbuhan itu ialah 6 hingga 8 tahun kecuali *Ceiba pentandra* yang berumur 15 tahun. Berbanding dengan tanih tanpa tumbuhan, ciri-ciri tanih seperti ketumpatan pukal, keliangan, kapasiti menampung air dan pengembangan isipadu telah jelas bertambah baik bagi *Casuarina equisetifolia, E.tereticornis, Ceiba pentandra* dan *L. leucocephala*. Tanih yang ditanam spesies lainnya tidak menunjukkan sebarang perubahan. Berbanding dengan kawasan yang tanihnya diusahakan, kelemahan pada ciri-ciri fizikal tanih berkait dengan beberapa spesies tumbuhan. Oleh itu, ketumpatan pukal tanih yang ditanami *B.bambos, Cassia siamea, Ceiba pentandra* dan *T.grandis* bertambah. Kapasiti untuk menampung air dan keliangan pada tanih yang ditanami *Cassia siamea* merosot. Tiada tanih yang ditanami mana-mana pun spesies terbukti lebih baik daripada tanih dikawasan yang diusahakan. Kesan-kesan tumbuhan yang mendatangkan faedah pada kesuburan tanih perlu dikaji dengan lebih lanjut.

Introduction

Many benefits like nutrient pumping from deeper soil profiles, fixation of atmospheric nitrogen, reduction of soil evaporation, mitigation of soil erosion,

augmentation of soil nutrient status and amelioration of soil structure (Douglas 1972, Kirby 1976, MacDaniels & Lieberman 1979, Vietmeyer 1979, Myers 1980) have been attributed to the agroforestry land system. However, these are assumptions based on indirect evidences and only a few of these benefits have been established scientifically. In an undisturbed forest, macropores dominate the pore space and facilitate rapid movement of water through the soil profile (Humbel 1975, Wilkinson & Ania 1976). Afforestation of degraded soils improves soil physical properties and enhances infiltration rate (Patnaick 1978). But these only show the effects of trees on soil physical properties and few quantitative data on the effect of trees on soil physical properties are available (Lal 1989). Thus, the objective of this study was to investigate the effects of some tree or plant species, both indigenous and exotic, that are commonly planted in peninsular India, *i.e.*, *Bambusa bambos, Cassia siamea, Casuarina equisetifolia, Ceiba pentandra, Eucalyptus tereticornis, Leucaena leucocephala* and *Tectona grandis* on soil physical properties.

Table 1. Details of tree species in the study

Tree species	Age at sampling (y)	Spacing (*m*)	Planted area (*ha*)
Bambusa bambos Baker ex K. Heyne	6	2 × 2	0.08
Cassia siamea Lamk	8	2 × 2	0.08
Casuarina equisetifolia Forst and Forst	6	1 × 1	0.04
Ceiba pentandra (L) Gaertn	15	6 × 6	0.36
Eucalyptus tereticornis Sm	6	2 × 2	0.16
Leucaena leucocephala (Lamk) De Wit	6	2 × 2	0.16
Tectona grandis L.f	8	2 × 2	0.40

Table 2. Soil profile characteristics of study area

Horizon	Depth (*cm*)	Description
Ap	0.20	Dark reddish brown (2.5 YR 3/4), sandy loam, moderate, medium, crumb structure with rodent burrows: moderately hard when dry, friable to somewhat firm when moist, slightly sticky and non-plastic when wet, pH 7.8 clear smooth boundary; few roots.
B	20 - 150	Dark reddish brown (2.5 YR 2/4) clay loam, fine moderate angular blocky, slightly hard when dry, firm when moist, sticky and plastic when wet pH 8.5, diffused boundary.
B2	150+	Red (2.5 YR 4/6) gravelly clay loam mixed with plenty of iron gravel and a few lime concretions, medium crumb structure slightly sticky and slightly plastic when wet, pH 9.1.

Materials and methods

Seven plant species (Table 1) each raised as woodlots in a farmer's holding at Coimbatore (11°20' N; 77°10'E; 310 *m* a.s.l: 557 *mm*), were chosen for the study. A site without vegetation and a cultivated field in the proximity were included as checks. The soil of the study area is Alfisol (Rhodustalf) and the soil profile characteristics are furnished in Table 2. The cultivated soil is being grown with a mixed crop of banana-cum-tobacco for more than ten successive years. Banana is raised at a spacing of 2×2 *m* and tobacco grown in between the banana. These field crops receive fertilizers at recommended doses. The vegetationless site also contiguous to the woodlots has remained uncultivated for the past 10 years and barring weed growth has no other vegetation. Soil samples were collected under each tree species at four depths of 15, 30, 45 and 60 *cm* at about 1 *m* away from the tree base. For each species such sampling was done at four random locations within the woodlot sufficiently removed from one another which served as replications. Soil samples were also collected from the vegetationless site and the cultivated field at four depths and four locations. Bulk density, absolute specific gravity, maximum water holding capacity, pore space and volume expansion were estimated gravimetrically using the Keen-Reczkow-Skibox (Piper 1966). Data were subjected to an analysis of variance and treatment differences tested (t-test) for significance ($p < 0.05$) after Panse and Sukhatme (1967).

Results and discussion

Compared to the barren site, a decrease in soil bulk density was evident under *Casuarina equisetifolia, Eucalyptus tereticornis* and *Leucaena leuecocephala* (Table 3). But absolute specific gravity did not show any variation under the different plant species nor under the cultivated land relative to the vegetationless site. In all cases the specific gravity was around 2.50. Water holding capacity and porosity (Table 4) were higher in soils under *C. equisetifolia, Ceiba pentandra* and *E. tereticornis* than in the uncultivated soil. Among these three species, *C. equisetifolia* proved superior to the other two species. Such disparate effect has also been reported by Aggarwal *et al.* (1976) who found moisture content in surface soil to be greater under *Prosopis cineraria* than under *Tecomella undulata.* Soil volume expansion (Table 5) was comparatively more under two species, *viz.*, *C. equisetifolia* and *Ceiba pentandra* than in the vegetationless site. These observations are consistent with the reported augmentative effects of trees in a landscape on soil physical characteristics and related hydrological characteristics (Pereira 1979). The present study clearly establishes the beneficial effect of trees on soil physical properties compared to a vegetationless soil. However, as no such ameliorative effects were evident in the cultivated soil, the assumption of trees as better conservators of soil than field crops becomes suspect. Compared to the cultivated land, the bulk density registered an increase for several species, like *B. bambos, Cassia siamea, Ceiba pentandra* and *T.grandis*; decreased bulk density was evident only for two species, *viz. C. equisetifolia* and *E. tereticornis.*

Table 3. Soil bulk density and absolute specific gravity under the selected multipurpose plant species

Tree species	Bulk density ($g\ cm^{-3}$) Soil depth (*cm*)					Absolute specific gravity Soil depth (*cm*)				
	15	30	45	60	Mean	15	30	45	60	Mean
Bambusa bambos	1.30	1.28	1.36	1.40	1.34	2.47	2.47	2.42	2.75	2.52
Cassia siamea	1.21	1.46	1.46	1.48	1.40	2.29	2.67	2.79	2.60	2.58
Casuarina equisetifolia	1.19	1.20	1.22	1.30	1.23	2.48	2.46	2.41	2.53	2.47
Ceiba pentandra	1.23	1.53	1.29	1.36	1.35	2.49	2.44	2.47	2.57	2.49
Eucalyptus tereticornis	1.22	1.23	1.27	1.29	1.25	2.63	2.43	2.49	2.48	2.50
Leucaena leucocephala	1.14	1.21	1.33	1.36	1.27	2.33	2.32	2.42	2.46	2.38
Tectona grandis	1.44	1.34	1.34	1.58	1.42	2.52	2.57	2.72	2.59	2.60
Cultivated land	1.18	1.19	1.21	1.23	1.20	2.39	2.28	2.36	2.57	2.40
Vegetationless site	1.44	1.41	1.34	1.34	1.38	2.74	2.80	2.51	2.18	2.55
Mean	1.26	1.31	1.31	1.37	1.31	2.48	2.49	2.51	2.52	2.49
		SE_d	CD ($p \leq 0.05$)				SEd	CD ($p \leq 0.05$)		
Species (S)		0.03	0.07				ns	ns		
Depth (D)		0.02	0.05				ns	ns		
S × D		ns	ns				ns	ns		

Table 4. Water holding capacity and porosity under the selected multipurpose plant species

Tree species	Water holding capacity (%) Soil depth (*cm*)					Porosity (%) Soil depth (*cm*)				
	15	30	45	60	Mean	15	30	45	60	Mean
Bambusa bambos	38.9	39.6	36.6	37.0	38.0	50.5	50.2	48.6	51.3	50.2
Cassia siamea	42.6	35.5	38.2	31.6	36.9	49.9	47.2	45.9	44.1	46.6
Casuarina equisetifolia	48.5	46.0	45.0	42.1	45.4	57.4	56.3	55.5	54.4	56.0
Ceiba pentandra	40.7	44.2	42.9	40.0	44.2	56.2	55.0	54.5	51.4	54.3
Eucalyptus tereticornis	46.4	41.3	40.3	41.1	42.3	58.8	53.8	54.9	51.0	54.6
Leucaena leucocephala	43.7	38.9	33.5	32.8	37.2	52.4	50.4	48.7	46.8	49.4
Tectona grandis	33.3	39.7	38.0	29.3	35.1	53.9	55.4	49.1	51.1	52.4
Cultivated land	46.8	43.6	43.7	47.5	45.4	53.4	50.8	52.1	55.3	52.9
Vegetationless site	36.4	35.4	36.5	35.2	35.9	51.5	52.6	49.9	43.8	49.4
Mean	42.9	40.5	35.2	37.4	40.0	53.8	52.5	50.9	49.9	51.8
		SE_d	CD ($p \leq 0.05$)				SE_d	CD ($p \leq 0.05$)		
Species (S)		1.96	3.89				1.92	3.81		
Depth (D)		1.30	2.59				2.28	2.54		
S × D		ns	ns				ns	ns		

Table 5. Soil volume expansion under the selected multipurpose tree species (%)

Tree species	Soil depth (*cm*)				
	15	30	45	60	Mean
Bambusa bambos	5.39	5.21	5.80	4.06	5.12
Cassia siamea	5.65	4.30	4.10	3.19	4.31
Casuarina equisetifolia	11.60	8.66	10.14	10.44	10.21
Ceiba pentandra	13.39	8.14	9.43	9.10	10.01
Eucalyptus tereticornis	8.35	6.79	5.35	4.51	6.25
Leucaena leucocephala	5.90	2.92	2.24	1.87	3.23
Tectona grandis	6.26	3.55	3.51	4.50	4.45
Cultivated land	6.01	6.54	5.99	7.10	6.41
Vegetationless site	7.27	4.96	6.53	8.30	6.77
Mean	7.75	5.67	5.90	5.90	6.31

	SE_d	CD ($p \leq 0.05$)
Species (S)	0.83	1.66
Depth (D)	0.55	1.10
S × D	ns	ns

Waterholding capacity was also less than that of the cultivated soil for several species like *B. bambos, Cassia siamea, L.leucocephala* and *T. grandis*; even the waterholding capacity for the other species was only comparable with or inferior to that of the cultivated land. Porosity was distinctly lower for *Cassia siamea*, but for other species it showed parity with the agricultural land. The volume expansion for only two species, *viz. Casuarina equisetifolia* and *Ceiba pentandra* excelled that of the cultivated soil. These observations are in sharp contradistinction to several reports on the augmentative effect of tree crops especially in agroforestry systems. Soil bulk density has been reported to be lower in a *Leucaena* and *Gliricidia* based agroforestry system than in a non-agroforestry system (Lal 1989). Porosity and water retention capacity were reported to be higher in soils under dadaps (*Erythrina lithosperma*) underplanted with tea (Ananthakumarasamy *et al*.1988). But in the present study no tree species proved superior in its effect on soil porosity compared to the crops on the cultivated soil, and in fact, one species *Cassia siamea* gave poorer response. The lack of any beneficial effects observed in the present study may possibly be due to the young age of the plant species in the study, which varied from 6 years for *B.bambos* and *Casuarina equisetifolia* and 8 years for *T.grandis* to 15 for *Ceiba pentandra*. The report of bulk density to be lesser and porosity to be greater under a 34-y-old *Pinus patula* than under a 25-y-old stand of the same species in eastern Himalayas (Singh & Raman 1979) lends support to this assumption. Therefore, perhaps with the passage of time and comcomitant addition of organic matter, the soils under the test species might show improvement in their physical properties. However, in an extensive review, Lundgren (1978) concluded that the establishment of some fast-growing perennials can also cause pronounced degradation of soil productivity. Lal (1989) stated, however, that little quantitative data are available on the effects of forestry and agroforestry based systems on soil physical

properties and that the effects of trees and perennial shrubs in a landscape on soil hydrological characteristics have not been extensively studied. In the light of these observations and the conflicting results obtained in the present study there is need for further elucidation of the effects of plants on soil physical properties.

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