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Nutrient Dynamics and Accumulation of Organic Carbon Under Even Aged Monoagroforestry Models

R. Shankar, B. Joseph, K.B. Sunitha Devi and K. Sandya Rani
Department of Agronomy, College of Agriculture,
Acharya N.G Ranga Agricultural University, Rajendranagar, Hyderabad- 500 030 (A.P)

Organic carbon, nitrogen, phosphorus and potassium availability in the soil under multipurpose tree cropping system in Andhra Pradesh were estimated. The results revealed that the soil organic carbon and nitrogen content were higher in *Pongamia pinnata* tree based systems due to accumulation of plant residue, its decomposition, high N fixation rate and increased availability of nutrients in the soil due to quick mineralization. Among the multipurpose tree systems, the phosphorus availability under *Dalbergia sissoo* showed significantly higher quantities. Due to high plant residue and efficient nutrient recycling capacity, the available potassium content under *Acacia nilotica* cropping systems was high at three depths when compared to the other systems. The organic carbon and major nutrient contents decreased significantly with increased depth due to huge build-up of different nutrients on surface layers than in lower layers.

Key words: Available C,N, P and K, Agroforestry model

Increasing industrial growth and changes in land use patterns increase atmospheric pressure and deforestation. Rise in fossil fuel emission has increased carbon dioxide concentration in the atmosphere, which has increased global warming. Trees offer significant opportunities to sequester substantial quantity of atmospheric carbon framing an important option for carbon mitigation. An agroforestry system is an important sink of carbon on earth in comparison to other land use. Density of soil organic carbon in different ecosystems vary from 3.7 kg m^{-3} in arid to 24.0 kg m^{-3} in boreal regions (Lal, 2001). The tree residues (leaf, twigs and dead plant parts) affect the organic matter and nutrient dynamics of soils due to their decomposition in soils. The quality and quantity of tree residues produced depend on tree species, its genetic nature (deciduous or evergreen), age and existing climatic conditions. The magnitude of total leaf and litter fall in different types of forest in India range 'a' between 1585-and 17,578 kg ha^{-1} (Shanmughavel and Francis, 1998). The mean annual litter fall (kg^{-1} ha^{-1}) for tropical dry deciduous, tropical, dry evergreen and temperate moist deciduous forest are reported as 4.33, 7.52, 6.44 and 8.39 amounts, respectively (Dadhwal *et al.,* 1993). Temperate moist deciduous forest registered high while tropical dry deciduas forest accounts the lowest litter fall. Generally, higher soil organic carbon and nutrient content under the trees have been observed than in adjacent sites without trees (Sharma and Pande, 1989). Major multipurpose agroforestry practiced in India include *Acacia nilotica, Azadirachta indica, Dalbergia sisso, Eucalyptus tetranicus, Albizia lebbeck, Pongamia pinnata* and *Tectona grandis.* Information on the effect of residues of these species on soil properties is lacking. Therefore, the present study was conducted to estimate organic carbon and macronutrients accumulated in the soil profiles under varions tree canopy.

*Corresponding author email : acharlashankar.angrau@gmail.com

Materials and Methods

The present investigation was carried out at Acharya N G Ranga Agricultural University, Hyderabad (Andhra Pradesh), which is located altitude of 542.6 m above MSL and $17^{o}19^{1}$ N latitude. The climate is mainly characterized by a very hot summer, a short rainy season and a very cold winter; it is arid, with high variation between summer and winter. The mean monthly maximum temperature of the study area varies from 31.5^{0}C to 33.3^{0}C in January to June. Rain fall is received primarily from south west monsoon and the mean rain fall (>75%) of the total 788.2 mm per annum will be normally received during July to September. The soils of the region are light in colour and classified under alfisols or vertisols, have salinity associated with brackish ground water. An experiment in 10-30 years old *Acacia nilotica*, *Azadirachta indica, Dalbergia sisso, Eucalyptus tetranicus, Albizia lebbeck, Pongamia pinnata* and *Tectona grandis* speed at 4x4 m was conducted. The depth wise (0-30, 30-60 and 60-90 cm) soil samples collected from one m^3 pit from each replication under each tree species along with the samples from adjacent open area without trees (control) during December 2012 were subjected to nutrient analyses. The soil samples were air dried, grounded in a wooden pestle with mortar, passed through a 2 mm stainless steel sieve and stored for organic carbon (OC) and available macronutrients. The organic carbon by Walkley and Black's method (Jackson, 1967), available N, and by alkaline permanganate method (Subbiah and Asjia, 1956), available P_2O_5 by Olsen's method using colorimeter (Olsen *et al.,* 1954) and available K_2O by neutral ammonium acetate method using flame photometer (Jackson, 1967) were estimated. The accumulation of organic carbon (mg ha^{-1}) and available nutrients (kg ha^{-1}) in different soil layers was calculated by multiplying their concentration with the weight of soil collected in different depth in one ha. The data were subjected to statistical analysis using ANOVA in a randomized block design in six replications at different locations and treatments following the statistical methods suggested by Panse and Shuhatme, (1985).

Results and Discussion

Soil organic carbon content decreased with increased in soil depth under tree species as well in control. The interaction effect varied significantly among tree species and soil depth. The effect of plant residue addition were higher in the surface layer (0-30 cm) than in the lower soil depths. The organic carbon content was 0.57% under *Pongamia pinnata* followed by 0.47% in *Albergia lebbeck,* whereas under *Tectona grandis* and depth of *Acacia nilotica it was* 0.30 and 0.26% respectively. The soil organic carbon accumulation in 60-90 cm soil profile under tree species varied from 0.29 % (*Pongamia pinnata)* to 0.25% (*Albergia lebbeck)* and this was found to be significantly higher when compared to control (0.08%) (Table 1). Out of this, >42% of organic carbon was present in the surface (0-30cm) and >21% in 30-60cm soil depth under different tree species. The regular plant residue accumulation on soil surface layer, its decomposition and incorporation into the soil might have led to higher buildup of organic carbon on surface layers than in lower layers. Increase in organic carbon status under tree species with addition of organic matter through litter fall has been reported by Patel and Singh (2000). Lower build up of organic carbon status under *Azadiracta indica* may due to lesser biomass and poor litter quality than others. In addition to that, *Azadiracta indica* has thick and leathery bark with none of alkaloid, nimbin which might have prevented its decomposition by fungi and other fauna.

Table 1. Organic carbon content (%) under multipurpose tree systems at different depths

Depth	0-30cm						30-60cm						60-90cm					
Locations	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean
Multipurpose tree system																		
Fallow land	0.03	0.07	0.16	0.03	0.14	0.09	0.02	0.06	0.12	0.13	0.11	0.09	0.01	0.02	0.11	0.17	0.1	0.08
Acacia nilotica	0.28	0.21	0.25	0.26	0.28	0.26	0.19	0.17	0.18	0.21	0.23	0.20	0.14	0.15	0.13	0.19	0.17	0.16
Azadiracta indica	0.03	0.07	0.16	0.03	0.14	0.09	0.17	0.19	0.19	0.11	0.15	0.16	0.15	0.18	0.16	0.10	0.13	0.14
Dalbergia sisso	0.22	0.25	0.19	0.18	0.18	0.20	0.24	0.26	0.23	0.21	0.28	0.24	0.18	0.16	0.17	0.19	0.16	0.17
Eucalyptus tetranicus	0.24	0.23	0.25	0.24	0.28	0.25	0.19	0.18	0.16	0.15	0.19	0.17	0.11	0.16	0.15	0.13	0.16	0.14
Albergia lebbeck	0.42	0.46	0.58	0.48	0.43	0.47	0.31	0.35	0.33	0.38	0.34	0.34	0.24	0.27	0.26	0.22	0.27	0.25
Pongamia pinnata	0.57	0.54	0.52	0.57	0.67	0.57	0.43	0.41	0.31	0.34	0.41	0.38	0.36	0.26	0.24	0.22	0.37	0.29
Tectona grandis	0.38	0.31	0.29	0.27	0.24	0.30	0.21	0.25	0.24	0.19	0.16	0.21	0.14	0.19	0.23	0.16	0.11	0.17
Mean	0.30	0.31	0.32	0.29	0.33	0.31	0.22	0.23	0.21	0.21	0.23	0.22	0.16	0.17	0.18	0.17	0.18	0.18
SEM ±			0.06						0.06						0.06			
CD(0.05)			15.89%						15.46%						25.23%			
CV%			0.03						0.07						0.16			

Table 2. Available nitrogen content (kg ha^{-1}) under multipurpose tree systems at different depths

Depth	0-30cm						30-60cm						60-90cm					
Locations	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean
Multipurpose tree system																		
Fallow land	107.00	113.30	105.11	97.00	103.62	105.50	98.52	85.11	89.24	64.51	95.22	86.35	64.80	69.30	71.40	62.10	74.10	68.20
Acacia nilotica	178.91	175.63	181.93	180.60	181.41	179.61	153.61	155.84	175.25	174.10	170.50	165.80	140.20	148.9	160.40	156.70	169.80	155.20
Azadiracta indica	156.82	174.32	179.62	182.40	183.76	175.34	147.40	151.40	173.90	169.20	175.00	163.30	129.80	141.6	157.70	152.50	167.20	149.70
Dalbergia sisso	313.60	316.41	212.31	131.60	162.94	227.43	250.60	289.30	111.40	101.60	149.30	180.40	209.40	239.5	158.30	197.30	131.40	167.10
Eucalyptus tetranicus	187.51	189.10	201.93	189.50	187.22	191.10	176.20	177.50	197.80	163.00	176.20	178.10	157.20	163.7	186.00	142.50	163.20	162.05
Albergia lebbeck	161.43	171.01	186.40	178.40	180.35	175.57	159.40	159.40	176.20	169.50	173.10	167.50	129.00	143.4	163.10	153.30	170.30	151.80
Pongamia pinnata	376.52	317.52	221.62	152.10	189.06	251.30	239.00	301.70	114.00	139.4	150.80	189.00	201.70	227.9	196.10	101.20	129.10	171.20
Tectona grandis	173.10	179.11	184.10	177.60	176.37	178.00	165.40	164.90	169.10	168.20	168.10	167.10	161.50	166.30	158.0	159.80	156.00	160.30
Mean	211.60	204.50	184.14	161.13	170.50	185.42	173.73	185.61	150.86	143.62	157.24	162.24	149.20	162.50	156.32	140.40	145.10	131.71
SEM ±			19.21						18.3						11.9			
CD(0.05)			55.67						52.93						34.4			
CV%			23.17%						25.2%						17.6%			

The available nitrogen content under *Pongamia pinnata* (251.30 kg ha^{-1}) land use system showed significantly higher over others and on par with *Dalbergia sissoo* (227.43 kg ha^{-1}). High N fixation rate, increased availability of nutrients in the soil due to quick mineralization of leaf with improved soil properties could have resulted in high nitrogen content under *Pongamia pinnata*. Among the different species the content of nitrogen in *Acacia nilotica, Eucalyptus teticornis, Albergia lebbeck, Tectona grandis* and *Azadiracta indica* varied from (175.34 to 191.10 kg ha^{-1}) and all these reserves were found to be significantly higher over fallow land (105.50 kg ha^{-1}). The nitrogen content of soil under different tree component land use systems increased from medium to high N status mainly due to N fixation, nature of plant species, plant residue, root activity, microbial mineralization as supported by the findings of Basvavraj *et al*. (2010). The results showing variation in the nitrogen content at lower depths with minimum addition might be due to poor organic carbon and microbial activity at deeper soil layers. Fallow land showed poor nitrogen content at all three depths may be due to poor vegetation and higher nitrogen losses as indicated by Heim and Frey (2004).

Table 3. Available phosphorus content (kg ha^{-1}) under multipurpose tree systems at different depths

Depth	0-30cm						30-60cm						60-90cm					
Locations	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean
Multipurpose tree system																		
Fallow land	15.4	11.3	14.1	15.3	21.4	15.5	11.9	9.5	12.8	13.1	18.5	13.1	10.8	8.1	11.1	11.5	11.7	10.6
Acacia nilotica	13.1	13.5	17.4	13.4	19.1	15.3	10.2	14.7	16.5	10.0	16.7	13.6	7.4	12.3	13.2	9.6	11.0	10.7
Azadiracta indica	18.9	17.5	12.6	15.3	14.1	15.6	17.5	15.8	10.9	12.5	12.8	13.9	10.7	11.4	9.6	10.1	10.2	10.4
Dalbergia sisso	20.5	18.9	22.5	21.0	25.5	21.6	15.6	15.1	17.1	17.1	17.6	16.5	11.4	14.3	10.5	12.5	15.2	12.7
Eucalyptus tetranicus	13.4	14.6	11.6	18.1	15.1	14.5	10.2	13.7	9.7	11.3	13.5	11.6	9.8	10.1	7.8	8.4	12.7	9.7
Albergia lebbeck	15.4	13.5	14.1	15.1	17.8	15.1	12.5	11.5	10.9	14.1	16.7	13.1	12.0	10.1	9.8	12.1	11.3	11.0
Pongamia pinnata	20.0	15.6	18.5	12.1	14.3	16.1	17.3	14.3	16.3	11.4	12.6	14.3	14.6	10.6	11.7	9.8	10.9	11.5
Tectona grandis	15.2	15.2	13.4	14.2	13.2	14.2	12.7	12.5	11.2	11.6	11.8	11.9	9.87	8.3	9.6	11.9	10.0	9.9
Mean	16.49	15.01	15.53	15.56	17.56		13.49	13.39	13.18	12.64	15.03		10.82	10.65	10.42	10.74	11.63	
SEM ±			3.29						3.06						2.04			
CD(0.05)			15.86%						17.46%						15.48%			
CV%			15.4						11.3						14.1			

The available phosphorus content decreased with increasing soil depth in all land use systems. Among the plant species *Dalbergia sissoo showed* higher phosphorus content at three differents soil depth (Table 3). The P_2O_5 content under *Acacia nilotica*, *Azadiracta indica, Albergia lebbeck* and *Pongamia pinnata* ranged from 15.1 to 16.1 kg ha^{-1} which was found to be on par with fallow land (15.5 kg ha^{-1}). Minimum level of P_2O_5 was recorded under *Tectona grandis* (14.2 kg ha^{-1}), *Eucalyptus tetranicus* (14.5 kg ha^{-1}) which may be attributed to phosphorus fixation by organic matter content, pH variation, mineralization of phosphotic nutrients under these tree crop land use systems as reported earlier by Basvavraj *et al*. (2010).

Table 4. Available potassium content (kg ha^{-1}) under multipurpose tree systems at different depths

Depth	0-30cm						30-60cm						60-90cm					
Locations	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean
Multipurpose tree system																		
Fallow land	112.70	176.31	164.10	186.31	114.16	150.54	112.6	176.0	152.0	165.0	185.0	158.12	103.20	189.11	104.21	156.31	153.02	141.04
Acacia nilotica	698.2	414.72	402.88	646.2	936.32	619.66	568.09	358.43	382.4	595.2	508.32	482.49	484.72	434.85	514.12	492.68	446.12	474.50
Azadiracta indica	546.94	555.36	539.2	528.4	580.21	550.02	499.84	408.48	475.52	453.76	471.1	461.74	318.08	400.48	420.71	440.96	467.29	409.50
Dalbergia sisso	470.24	494.43	412.32	452.95	435.91	453.17	340.0	480.0	394.16	431.93	218.03	372.82	365.76	312.48	348.96	389.3	386.52	360.60
Eucalyptus tetranicus	402.08	400.32	415.2	455.68	443.91	423.44	390.24	480.36	394.24	431.09	328.98	404.98	270.24	282.43	202.88	306.43	289.98	270.39
Albergia lebbeck	596.64	501.28	492.71	504.96	509.64	521.05	521.6	437.44	402.01	462.13	496.71	463.98	450.88	402.04	398.3	359.52	437.02	409.55
Pongamia pinnata	564.48	571.63	458.24	539.04	489.34	524.55	459.2	532.01	408.64	417.31	446.89	452.81	318.56	391.05	365.44	380	326.24	356.26
Tectona grandis	333.76	338.08	358.24	314.08	372.96	343.42	317.28	334.24	246.4	251.64	314.31	292.77	239.84	290.24	228.72	276	218.42	250.64
Mean	465.63	431.47	405.34	453.41	485.28	448.23	401.10	400.87	356.92	401.00	371.16	386.21	318.91	337.82	322.89	350.11	340.57	334.06
SEM ±			37.5						29.4						17.1			
CD(0.05)			108.7						84.1						49.53			
CV%			18.7%						16.8%						11.5%			

The available potassium (619.66 kg ha^{-1}) content under *Acacia nilotica* land use system was found to be high at three depths. This might be due to high K content in a*cacia* residue (1.1–1.6%), efficient nutrient recycling capacity and tapping of nutrients in deeper layers. Similar results were observed by Deans *et al*. (1999) and Raddad *et al*. (2006). Available potassium content under *Azadiracta indica, Pongamia pinnata and Albergia lebbeck* land use systems showed variation from 521 to 550 kg ha^{-1} which was found to be on par with *Acacia nilotica* soils. Among the land use systems lower reserves of K was observed in *Eucalyptus tetranicus*, *Dalbergia sissoo* and the lowest under *Tectona grandis* (Table 4). It was further observed from the results that potassium content under all land use systems showed higher values over fallow. These results were in conformity with the findings of

Nsabimana *et al.* (2008). Potassium content decreased with increased soil depth.

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