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Studies on effect of eucalyptus plantations on soil ecology

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Abstract
The effect of trees on soil physical properties, there was a slight reduction in bulk density between soil depth and ages of plantations. The infiltration rate was significantly varied between the ages and the data depicted that there was a gradual increase in infiltration rate over the ages of trees (from 0.35 cm hr^{-1} to 0.50 cm hr^{-1}). With regard to soil pH slight decline in soil pH was noticed due to ages in contrary to electrical conductivity where it found slight enhancement in the value. However, both soil pH and electrical conductivity were found to be non significant over the distance and depth. The results showed that there was an increasing trend in soil available N due to the increase of age. Of the two distances, the maximum soil available N was observed in closer distance and minimum in wider distance. Among the soil depths, maximum soil available N was recorded in surface layer and minimum in subsurface layer. Similar trend was observed in phosphorus and potassium. Alike soil physiochemical properties, the soil biological properties *viz*., bacteria, fungi and actinomycetes population was found to be increased over the ages of plantation. Of the two distances, closer distance (0.5m) registered significantly maximum microbial population and among the soil depths, surface (0-15 cm) recorded maximum microbial population for all the ages of the plantation whereas sub surface (15-30 cm) recorded minimum microbial population. From the present study, it is found that the Eucalyptus plantations have positive effect on soil ecology.

Keywords: Infiltration rate, physicochemical properties, microbial population and soil ecology

Introduction
Eucalyptus is an evergreen tree species and it is indigenous to Australia, New Guinea, Indonesia, Philippines and is grown to mainly for pulp and paper, fuel wood, plywood, gum and oil used in medicines. Eucalyptus has 700 species sub species and more than 100 species are economically important (Amenu, 2017) [2]. Growing eucalyptus in low precipitation or dry areas may cause adverse environmental problems because of increasing the competition between other species *viz.*, water, nutrient, sunlight and space and may occurrence of allelopathy. The allelochemicals effects of eucalyptus reducing the crop yields due to nutrient depletion and exudation of toxic chemicals. And also, the eucalyptus trees need more amount of water and compete with associate species for the available water in the soil (Anib *et al.*, 2001) [3]. The eucalyptus species released volatile and non-volatile components *viz.*, benzoic, terpene, Cinnamic acids and phenolic acids which inhabited or reducing the growth of neighboring plants, weed growth and germination of other crops (Shiming, 2005 [22]; Sasikumar *et al.*, 2006) [21]. Different studies around global level reported that eucalyptus plantation has negatively impacts on the soil physico-chemical properties, reducing the soil organic matter, nutrient cycling capacity and soil faunas' population and devasting impacts soil hydrology (Goya *et al.*, 2008 [9]; Lane *et al.*, 2004 [14]; Kindu *et al.*, 2006; Ravi and Divya, 2009; Terrai *et al.*, 2014; Rajalingam *et al.* (2015) [26]. Therefore, this study is planned with the aim of assessing the impact of Eucalyptus plantation on soil physico-chemical and biological properties.

Materials and Methods
The soil samples were collected from 1, 2, 3, 4 and 5 years old Eucalyptus plantations in the identified area at two different depths *viz*., 0-15 cm and 15-30 cm at 0.5 m and 1m distance away from all the directions of the tree base. The collected samples were pooled, air dried, ground, sieved in 2 mm sieve and stored in polythene bag for analysis. The bulk density was determined by core sample method and infiltration rate was calculated by double ring infiltrometer method (Gupta and Dakshinamoorthy, 1981) [10].

The pH and electrical conductivity were estimated by soil water suspension 1:2 ratio method (Jackson, 2005) [11]. The organic carbon by wet chromic aid digestion (Walkley and Black, 1934) [28], Available nitrogen by alkaline permanganate method (Subbaiah, 1956) [25], Available phosphorous by Olsen's method and Available potassium by Neutral Normal NH_4OAc flame photometry method (Standford and English, 1949) [24] were estimated. For microbial population analysis, the soil samples were collected at two different depths *viz*., 0-15 cm and 15-30 cm at 0.5 m and 1m distance away from the tree base from the experimental site and analysed for microbial population and enumeration was done using the serial dilution techniques of Parkinson *et al.* (1971) [16]. Soil microbial analysis was done for enumeration of bacteria, fungi and actinomycetes population using serial dilution 10^7, $10^5$and 10^2 respectively and in appropriate medium (Nutrient Agar, Rose Bengal Agar and Ken Knights Agar) in sterile plates. The composition of each medium is given below. Enumeration was done after 24 hours. The results were subjected to an analysis of variance and tested for significant difference according to Panse and Sukhatme (1967) [15].

Results and Discussion

The present study indicated there was a slight decrease in the bulk density of soil when age of the plantation increased from 1.28 Mg m^{-} in one year old to 1.24 Mg m^{-3} in five year old plantation (Table 1). The possible reason for this includes organic matter enrichment through plant biomass and as a result of better aggregation and other structural indices brought about by organic addition. The result of the current study was supported by Aweto (1981) [4] that with the increase of age of trees soil bulk density decreased while porosity and water holding capacity increased.

Table 1: Bulk density of Eucalyptus plantations at different ages (Mg m^{-3})

Age of plantations (yrs)	Lateral distance from the tree base (m)	Bulk density (Mg m^{-3})		
		Soil depth (cm)		Mean
		0-15 (P1)	15-30 (P2)	
1	0.5	1.21	1.35	1.28
	1.0	1.21	1.35	1.28
	Mean	1.21	1.35	1.28
2	0.5	1.20	1.35	1.28
	1.0	1.20	1.35	1.28
	Mean	1.20	1.35	1.28
3	0.5	1.19	1.34	1.27
	1.0	1.19	1.34	1.27
	Mean	1.19	1.34	1.27
4	0.5	1.17	1.32	1.25
	1.0	1.17	1.32	1.25
	Mean	1.17	1.32	1.25
5	0.5	1.15	1.32	1.24
	1.0	1.15	1.32	1.24
	Mean	1.15	1.32	1.24
Control (Open Field)		1.22	1.37	1.29

	SED	CD (0.05)		SED	CD (0.05)
T	0.066	NS	TD	0.011	NS
D	0.037	NS	DP	0.007	NS
P	0.037	NS	TP	0.011	NS
TDP	0.015	NS			

A significant difference in the infiltration rate was observed between the ages and it was increased when age of the trees increases from 0.35 cm hr^{-1}in one year old to 0.52 cm hr^{-1} in five year old plantations (Table 2). It is well known that organic matter addition to the soil hold more moisture and at the same time facilitated better water movement which resulted soil – water – plant relationship. The usefulness of organic matter addition for the increasing water holding power and enhanced hydraulic conductivity was reported by Aggelides *et al*., (2000) [1].

Table 2: Infiltration rate of Eucalyptus plantations at different ages (cm hr^{-1})

Age of plantations (yrs)	Infiltration rate (cm hr^{-1})
1	0.35
2	0.38
3	0.41
4	0.45
5	0.50
Control (Open field)	0.32

SED	CD (0.05)
0.007	0.015

There was no significant difference between distance and soil depth, the pH decreased over the period of time from 8.37 in one year old to 7.62 in five years old plantation (Table 3). The influence of Eucalyptus plantation on pH is a prime consideration as pH is known to directly and indirectly remain responsible for exposition of various properties. The present study revealed that there was no significant difference in pH between the distance and soil depth. However, the decrease of pH between the ages might be due to the incorporation of biomass into the soil. Pessaraki and Szabolcs (2019) [18] reported that the organic matter addition reduces the soil pH.

The results on salinity development as a consequence of Eucalyptus plantation is perhaps a greater significance because, Eucalyptus carried considerable alkaloids (Table 4). The result of present study revealed that there was accumulation of salt in soil both in distance and depth. However, a slight accumulation of salt could be observed over the ages. Nevertheless, close agreement with the findings of Paydar *et al*. (2005) [17].

Table 3: pH in Eucalyptus plantations at different ages

Age of plantations (yrs)	Lateral distance from the tree base (m)	pH		
		Soil depth (cm)		Mean
		0-15 (P1)	15-30 (P2)	
1	0.5	8.29	8.32	8.31
	1.0	8.43	8.43	8.43
	Mean	8.36	8.38	8.37
2	0.5	7.48	7.45	7.47
	1.0	7.52	7.50	7.51
	Mean	7.50	7.48	7.49
3	0.5	8.02	7.97	7.99
	1.0	8.15	8.09	8.12
	Mean	8.09	8.03	8.06
4	0.5	8.42	8.34	8.38
	1.0	8.35	8.39	8.37
	Mean	8.39	8.37	8.38
5	0.5	7.53	7.67	7.60
	1.0	7.61	7.64	7.63
	Mean	7.57	7.66	7.62
Control (Open Field)		8.10	7.95	8.02

	SED	CD (0.05)		SED	CD (0.05)
T	0.069	0.138	TD	0.098	NS
D	0.044	NS	DP	0.062	NS
P	0.044	NS	TP	0.098	NS
TDP	0.139	NS			

The impact of Eucalyptus plantation on the fertility value of soil was an added asset. It could be seen in the organic matter which is well known to be the key to the soil fertility and productivity got substantially increased with the concomitant direct and indirect benefits. The present investigation confirmed that there was a built up of nitrogen, phosphorous and potassium status in the soil. The increased soil fertility under Eucalyptus plantation was supported by Bhatia *et al.* (2010) [7] who reported improvement in soil fertility due to organic matter addition and also leaf litter accumulation by the plantations. Pleiothora of evidences are available that organic matter increases the availability of nitrogen (Table 4). The similar results were observed in the present study. The increased nitrogen content might be due to the transformation of organic nitrogen from the inorganic nitrogen. In the current study, the soil available nitrogen decreased with the increase in soil depth in all the age groups (270 Kg ha^{-1}in 0.5 m depth and 249 Kg ha^{-1}in 1.0 m depth of one year old plantation. This was in accordance with the Raj *et al.*, (2016) [19] who reported that a negative relationship was observed between soil depth and available nitrogen content under the *Eucalyptus tereticornis.*

Table 4: Soil available nitrogen in Eucalyptus plantations at different ages (Kg ha^{-1})

Age of plantations (yrs)	Lateral distance from the tree base (m)	Soil available nitrogen (Kg ha^{-1}) Soil depth (cm) 0-15 (P1)	15-30 (P2)	Mean
1	0.5	274	265	270
	1.0	253	244	249
	Mean	263	255	259
2	0.5	274	272	273
	1.0	260	249	255
	Mean	267	260	264
3	0.5	294	286	290
	1.0	281	280	280
	Mean	283	287	285
4	0.5	303	284	294
	1.0	286	284	285
	Mean	294	284	289
5	0.5	316	308	312
	1.0	295	285	290
	Mean	306	297	301
Control (Open Field)		270	269	270

	SED	CD (0.05)		SED	CD (0.05)
T	0.163	0.325	TD	0.231	0.460
D	0.103	0.206	DP	0.146	0.291
P	0.103	0.206	TP	0.231	0.460
TDP	0.327	0.651			

The increased phosphorus content over the ages and plantations was observed it might be due to the increased organic matter and it had concomitant effect on microbial population (Table 5). Kaul (1966) [12] reported that the available P played a major role in the growth and productivity of *Eucalyptus tereticornis.* In the current study phosphorus content was higher in surface layer (0-15 cm). The result was concomitant with the studies of Chotchutima *et al.* (2016) [8] who reported that the available P in surface and sub-surface soils under dry temperate zone of *Leucaena leucochephala.*
Similar results were reported by Kalavathi *et al.* (2000) and inferred that the combined inoculation of VA-mycorrhizal fungus and phosphobacteria markedly increase the nitrogen uptake in neem seedlings.

Table 5: Soil available phosphorous in Eucalyptus plantations at different ages (Kg ha^{-1})

Age of plantations (yrs)	Lateral distance from the tree base (m)	Soil available phosphorous (Kg ha^{-1}) Soil depth (cm) 0-15 (P1)	15-30 (P2)	Mean
1	0.5	12.46	11.93	12.20
	1.0	11.34	9.81	10.58
	Mean	11.90	10.87	11.39
2	0.5	13.17	12.04	12.61
	1.0	13.53	11.76	12.65
	Mean	13.35	11.90	12.63
3	0.5	14.61	13.26	13.94
	1.0	14.94	12.66	13.80
	Mean	14.78	12.96	13.87
4	0.5	16.78	14.16	15.47
	1.0	15.79	13.24	14.52
	Mean	16.29	13.70	14.99
5	0.5	17.26	16.75	17.01
	1.0	15.81	11.32	13.57
	Mean	16.54	13.70	15.29
Control (Open Field)		11.70	10.52	11.11

	SED	CD (0.05)		SED	CD (0.05)
T	0.175	0.349	TD	0.248	0.493
D	0.111	0.221	DP	0.157	0.312
P	0.111	0.221	TP	0.248	0.493
TD	P 0.35	0 0.697			

The increased available potassium between ages, distance and depth was observed after 5 yrs of plantation (Table 6). It is well known that addition of tree litter contains increased amount of Potassium. Hence addiction of Eucalyptus litter enhanced the potassium pool in the soil. The result was in accordance of Singh *et al*. (1997) [23] who reported that an appreciable increase in K status of soil with addition of litter from Eucalyptus. In the current study the available potassium status showed an increasing trend in the soils under the cover of Eucalyptus plantation which was supported by Bhardwaj *et al*. (2017) [6].

Table 6: Soil available potassium in Eucalyptus plantations at different ages (Kg ha^{-1})

Age of plantations (yrs)	Lateral distance from the tree base (m)	Soil available potassium (Kg ha^{-1}) Soil depth (cm) 0-15 (P1)	15-30 (P2)	Mean
1	0.5	190	186	188
	1.0	189	183	186
	Mean	190	185	187
2	0.5	212	208	210
	1.0	209	203	206
	Mean	210	206	208
3	0.5	225	215	220
	1.0	221	210	216
	Mean	223	213	218
4	0.5	239	233	236
	1.0	234	227	230
	Mean	237	230	233
5	0.5	247.4	240.2	243.8
	1.0	243.8	231.4	237.6
	Mean	245.6	235.8	240.7
Control (Open Field)		187.5	183.4	185.5

	SED	CD (0.05)		SED	CD (0.05)
T	0.030	0.060	TD	0.042	0.085
D	0.019	0.038	DP	0.027	0.053
P	0.019	0.038	TP	0.042	0.085
TDP	0.060	0.120			

Microbial analysis of soil sample revealed that the microbial load (bacteria, fungi and actinomycetes) increased with the age of the plantations. In order to assess the effect of tree species on microbial population, the soil samples were assessed at two distances *viz.*, 0.5 and 1.0 m away from the tree base. The result of the present study stated that the microbial population reduced with the distance but comparatively greater over open area (barren land). Among bacteria, fungi and actinomycetes bacterial population dominated in all ages of plantations. Maximum bacterial population was observed in the sample collected at 0.5m away from the tree base at a depth of 0-15 cm in a5 yr old plantation. It is quite obvious, as the organic matter availability for soil heterotrophic microbes enhanced with the age of plantation. It is also evident from the nutrient analysis that the 5 yr old plantation site had maximum available N, P, K and organic matter content. Similar results were quoted by Behera and Sahani (2003) [5] who reported high organic content under Eucalyptus plantation due to high accumulation of litter and slow decomposition rates. The pH of the soil is also quite suited to the growth of microbes compared to other soil samples. In case of fungi, the variation in the population due to ages and soil depth was not significant among the samples. Since this organisms is obligatory aerobic and acidophilic in nature, the alkaline nature of the samples might not have supported the growth of fungi in these study area, even though the samples are rich in nutrients. Due to aerobic nature the population decreased with the depth as reported by Ranjan *et al.*, (2016) [20] and Vennila and Muthusamy (2011) [27]. Hence it is indirectly evident that there is an increase in organic matter content of the soil with the increase in age and there is accumulation of storage of carbon in soil and micro flora, etc. It is evident from the microbial analysis that there is increase in aerobic, facultative and heterotrophic micro flora with the increase in the age of the plantation. Hence some quantum of carbon fixed by the tree species is released into the soil environment as litter and further separated by the microbes and converted into soil biomass.

Conclusion
From this study the results showed that there was an increasing trend in soil available N due to the increase of age. Of the two distances, the maximum soil available N was observed in closer distance and minimum in wider distance. Among the soil depths, maximum soil available N was recorded in surface layer and minimum in subsurface layer. Similar trend was observed in phosphorus and potassium. Alike soil physiochemical properties, the soil biological properties *viz*., bacteria, fungi and actinomycetes population was found to be increased over the ages of plantation. Finally, we concluded from this study, it is found that the Eucalyptus plantations have positive effect on soil ecology.

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