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Assessment of Soil Properties and Nutrients Status in three Horticultural Land use System of Coastal Odisha, India

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Abstract

A study was conducted to examine the different horticultural land use system on soil properties and nutrients status in Odisha coastal plain. Soil samples were collected from major three land uses (viz. cashew, mango and arecanut) in different depths (0–25, 25–50, 50–75, and 75–100 cm) and analyzed for soil physical and chemical properties. The different landuse are significantly varied with soil properties viz. pH, EC, CEC, AWC and rich in OC on surface (0–25 cm) soils. The available N content in surface and subsurface soils ranged from 85 to 259 and 40 to 221 kg ha^{-1}. The greatest P content was 10.7 to 57.1 kg ha^{-1} in the surface layer of arecanut and the least was 3.7 kg ha^{-1} in cashew. K content in surface and subsurface soils ranged from 57 to 438 and 14 to 553 kg ha^{-1}. Nutrients index values N was low (1.0), P was low to medium (1.0–1.6) and K was categorized medium in all the land use. The content of Fe and Mn were sufficient (>4.5 and >2 mg kg^{-1}) in all landuse. The Cu was rich in surface soils (1.76–3.57 mg kg^{-1}) of arecanut. Zinc content varied from 0.68 to 1.68 mg kg^{-1} in the surface to subsurface layers of soils respectively. Pearson's correlation matrix revealed significant positive correlations of soil properties with fertility indices.

Keywords: Coastal, cashew, mango, arecanut, soil properties, soil fertility

1. Introduction

The coastal agro-ecosystem occupies 19.6 mha (6.2%) of total geographical area in India where about 14.2% of the population lives. With the increasing human and animal population, the competition between various land uses has become intensive in coastal ecosystem (Srinivasan et al., 2015). Odisha coast line, a narrow strip of land along the sea coast has extended from east to southern, about 445 km (Bandyopadhyay et al., 2011). This narrow strip of coastal belt forms a habitat of the major horticultural crops. Their total coverage is comparatively less as compared to other areas and they are mostly confined to small land holders.

Horticulture as a sub-sector of agriculture, contributes 18% of the gross produce of agriculture sector and 52% of export earnings. India ranks second in horticulture production in the world. Its varied agro climatic conditions help to produce variety of horticulture crops throughout the year (www.nabcons.com). The major horticultural crops viz. cashew, mango and arecanut are occurring in sizable area. These land-use systems play a tremendous role in influencing nutrient availability and cycling and may also influence secondary succession and biomass production (Lu et al., 2002). Cashew grows up well in plains as well as hill slopes upto 600–700 feet elevation. Mango mostly prefers red loamy soil with good drainage and ideal pH range from 6.5 to 8.0. Arecanut is well adapted to a variety of soils and thrives best in well drained soils. Adequate protection from exposure to south-western sun is essential to avoid sun-scorch. Quick growing shade trees have to be planted on the southern and western sides well in advance of planting of arecanut seedlings. It is sensitive to moisture deficit and should be grown where adequate water facilities are available.

Therefore, climate, soil types and management could determine the better productivity of the horticultural crops. In coastal, degraded soil and water quality together with climatic adversities like cyclone, heavy rains, floods and droughts etc. contributed to the poor livelihood security and low productivity of the area (Swagatika et al., 2015). Therefore, farmers need more awareness and knowledge on soils characteristics for better management to increase the crops yield and farmer's income (Barghouti et al., 2005). An understanding on types of soils and their physico-chemical properties and nutrients status, can able to solve the major soil constraints and increase the crops productivity. Keeping these in view a case study was attempted to assessing major soils properties and fertility status in three Horticultural crops in Ganjam block of Ganjam district, in coastal region of Odisha.

2. Materials and Methods

2.1. Study area

The study was conducted during 2014–15 in Ganjam block of Ganjam district, Odisha which is located in eastern part of the state, covering 216.12 km^2 (Figure 1). Detailed soil survey at 10,000 scale was done based on the Major zone of the horticultural crops and are extending and productivity (Table 1). The mean annual rainfall is 1449 mm and more than 60–70% is received during south-west monsoon (June-September). The mean maximum summer temperature is 39 °C and means minimum winter temperature is 11.5 °C. The soil temperature class is "*hyperthermic*" and moisture regime is "*ustic*" which is hot humid plain with LGP of 180–210 days. The soils are formed mainly in the deltaic alluvium of rivers.

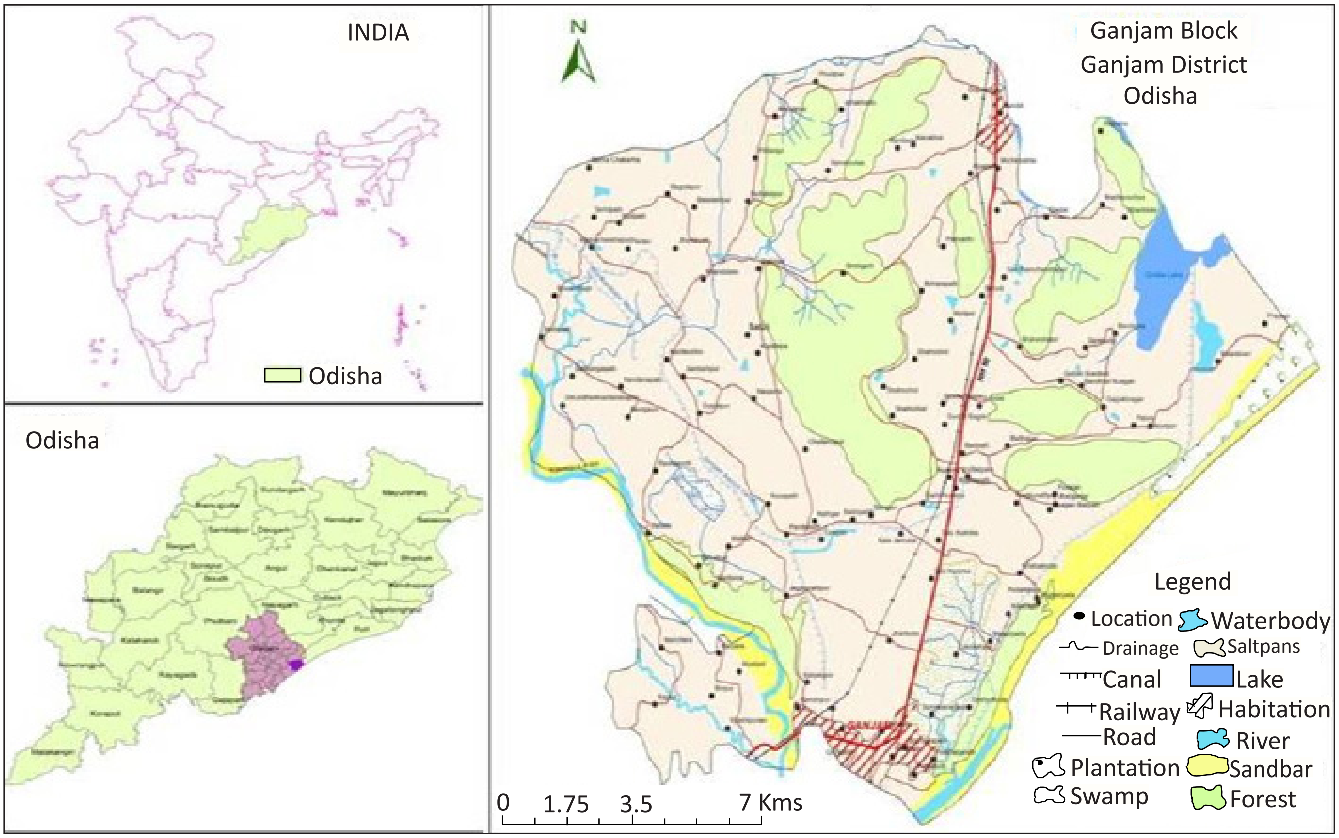


Figure 1: Location of the study area

Table 1: Major crops, area and productivity of the study area

Crops	Area focused on (ha)	Production (average) (kg ha^{-1})
Cashew (*Anacardium occidentale* L.)	4349 (18.14%)	450–690
Mango (*Mangifera indica* L.)	433 (1.81%)	5000–6500
Arecanut (*Areca catechu* L.)	237 (0.9%)	735–1050

Soils of lacustrine sediment of Chilika Lake are affected by salts due to flooding of brackish water during monsoon seasons and build up of sub-soil salinity due to high ground water table in low lying areas in dry season.

2.2. Field studies

Three sites were selected in each plantation system, profiles were dug, and soils were described morphologically (Soil Survey Staff, 2003). Composite soil samples were collected from the entire soil horizon in different depths (0–25, 25–50, 50–75 and 75–100 cm) in duplicate from three different plantation systems (three repetitions) for laboratory analysis. Soil samples were air dried, crushed, and passed through a 2-mm sieve, and physical and chemical characteristics were determined.

2.3. Laboratory study

Particle-size distribution was determined by using the international pipette method (Day, 1965). Soil pH and Electrical Conductivity (EC) were determined using the procedures described by Page et al. (1982). Soil organic carbon (OC) was determined by the wet oxidation method of Walkey and Black (1934). Cation exchange capacity (CEC) was determined *1 N* ammonium acetate at pH 7.0 (Page et al., 1982). Exchangeable calcium (Ca) and magnesium (Mg) was determined by using EDTA titration (Jackson, 1973). Soil moisture-retention characteristics were determined by soaking disturbed soil samples for 48 hrs to allow complete saturation. The saturated soil samples were put in the pressure plate extractor and pressure applied at 0.03, 0.05, 0.1, and 1.5 MPa suction until water ceased to drain out. The soil samples were weighed and oven dried at 105 °C for 24 hrs. Available water capacity (AWC) was calculated as the water retained between suction 0.03 and 1.5 Mpa (Klute, 1986). The available nitrogen (N) was estimated through alkaline pemanganate method as suggested by Subbiah and Asija (1956). Available phosphorus (P) in soils was determined calorimetrically following ascorbic acid method as outlined by Bray and Kurtz (1945) and available potassium (K) was estimated by flame photometer after extraction with Neutral normal ammonium acetate solution (pH 7.0). The available micronutrients (Fe, Mn, Cu and Zn) were determined by using DTPA (Lindsay and Norvell, 1978).

2.4. Nutrient index values

Nutrient index values (NIV) calculated by using methodology given Parker et al. (1957). From the proportion of soils under low, medium and high available nutrient categories, as represented by the following expression:

$$\frac{Nl+2Nm+3Nh}{Nl+Nm+Nh}$$

Where, NIV is nutrient index value, N_l, N_m and N_h are the number of soil samples falling in the category of low, medium and high nutrient status and are given weight age of 1, 2 and 3, respectively. Accordingly, areas with nutrient index value>2.50 could be considered high, those with NIV between 1.50 and 2.50 could be considered medium, and those with values <1.5 could be grouped as low in native supply of that nutrient.

2.5. Statistical analysis

An analysis of variance (ANOVA) was tested to compare the impact of land use on soil properties and available nutrient status by the method of least significant difference at a significant level of $p<0.05$. The relationship between soil properties and soil fertility indices were determined by Pearson's correlation matrix using SPSS Windows version 14.0 (SPSS Inc., Chicago, Ill.).

3. Results and Discussion

3.1. Physical properties

The variation in soil properties of different horticultural land use systems are presented in Table 2 and Table 3. Sand fraction was invariably higher compared to clay and silt in all land use systems. There were significant differences in sand, silt and clay with different depths and with different land use systems. Clay distribution in cashew and mango surface soils (Table 2) were lower (2.5–20.7 and 5.1–18.9%) than subsurface soils (6.8–46.2 and 11.1–45.2%). The results of increased clay particles in subsurface horizons are due to vertical movement from surface to subsurface by illuvation process. Movement and accumulation of soil leading variation in soil properties (Moges and Holden, 2008), which may lead to variation in soil fertility parameters. Furthermore, the not much significant difference in texture sequence is in arecanut plantation, due to fluvial deposits of river with different period. The water-release pattern of soils in three different landuse systems were not much significant (10.8 to 14.7%) but between the soil layers, surface soils are have low water holding capacity than subsurface soil, which is directly related with quantity clay content of the soils (Lingade et al., 2008; Pankaj et al., 2012).

3.2. Physico-chemical properties

Data presented in Table 3 showed that, soil pH was had significant with three different lanuse but not with respect

Table 2: Range of varing soil properties under different three landuse systems

Land uses	Samples	Physical				Physico-chemical				Exchange-able cations
		Sand	Silt	Clay	AWC	pH	EC	OC	CEC	Ca^{2+}
Cashew	Surface	70.1-95.4 (80.3)	2.1-9.2 (6.7)	2.5-20.7 (12.9)	4-16 (11)	6-7.7 (6.6)	0.05-0.46 (0.23)	0.22-0.94 (0.6)	1-11.8 (5.07)	0.4-6.4 (2.57)
	Subsur-face	44.7-90.5 (66.4)	1.3-18.6 (6.5)	6.8-46.2 (27)	4-16 (10.8)	5.5-7.9 (6.6)	0.03-0.46 (0.18)	0.01-0.68 (0.2)	1-18.6 (11.1)	0.5-10.5 (5.8)
Mango	Surface	68.5-92.2 (80.7)	2.7-12.6 (8.6)	5.1-18.9 (10.7)	8-15 (11)	5.9-7.6 (6.6)	0.04-0.18 (0.11)	0.17-0.89 (0.5)	1.9-6.6 (3.9)	0.8-2.6 (1.5)
	Subsur-face	44.9-80.2 (59.5)	4.6-24.6 (12.5)	11.1-45.2 (28)	11-17 (14.7)	5.6-9.2 (7.2)	0.03-0.86 (0.23)	0.14-0.35 (0.2)	2.5-23.9 (12.4)	1.1-13.1 (5.9)
Areca nut	Surface	51.9-67.8 (58.5)	11.8-23.6 (18.3)	20.4-28.5 (23.1)	10-12 (10.7)	6.2-7.8 (6.9)	0.08-0.59 (0.27)	0.27-0.34 (0.3)	6.6-9.6 (7.9)	2.7-3.7 (3.3)
	Subsur-face	22.5-77.2 (58.1)	3.5-45.6 (17.1)	11.4-36.6 (24.8)	8-19 (13)	6.3-7.9 (7.1)	0.05-0.55 (0.24)	0.11-0.62 (0.2)	5-14.6 (9.5)	2.6-7.5 (4.2)

Continue...

Land uses	Samples	Exchangeable cations				Available nutrients						
		Mg^{2+}	Na^{+}	K^{+}	sum	N	P	K	Fe	Mn	Cu	Zn
Cashew	Surface	0.3-1.8 (0.83)	0.1-0.4 (0.2)	0.1-0.4 (0.2)	0.9-9 (3.8)	141-226 (186)	2.7-15.3 (8.03)	57-398 (238)	4.8-19.8 (11.1)	10.1-101 (51)	0.18-2.29 (1.04)	0.35-1.06 (0.68)
	Subsurface	0.2-3.9 (1.6)	0.1-0.9 (0.3)	0.1-0.5 (0.3)	0.9-15.6 (8.1)	62-217 (152)	1.9-9.5 (4.2)	31-553 (263)	2.62-36 (13.5)	1.2-96 (46)	0.12-2.3 (1.26)	0.15-0.75 (0.38)
Mango	Surface	0.4-0.9 (0.6)	0.1-0.4 (0.3)	0.1-0.3 (0.2)	1.4-4.2 (2.6)	85-220 (162)	10.3-25.2 (16.7)	126-280 (224)	15.7-35.5 (22.8)	27.7-85.8 (47)	0.86-3.4 (2.1)	0.32-3.82 (1.6
	Subsurface	0.6-3.2 (1.72)	0.1-0.8 (0.4)	0.1-0.4 (0.3)	1.9-16.5 (8.31)	40-221 (171)	1.9-22.1 (8.04)	163-334 (232)	6.6-35.3 (18.2)	11-59 (32)	0.83-1.85 (1.31)	0.13-83 (9.6)
Arecanut	Surface	1.6-2.6 (1.9)	0.3-0.5 (0.4)	0.3-0.5 (0.4)	5.9-6.3 (6.1)	186-259 (224)	10.7-57.1 (26.3)	178-438 (280)	39-55.3 (47.2)	27.1-66 (52)	1.76-3.57 (2.3)	0.19-2.21 (1.3)
	Subsurface	1.1-4.4 (2.1)	0.2-1.2 (0.5)	0.1-0.7 (0.4)	4.3-12.9 (7.2)	102-213 (168)	2.9-45 (16.4)	14-236 (96)	12.6-35.2 (24.4)	14.9-36.8 (26)	0.45-1.6 (1.1)	0.2-1.2 (0.4)

Values are means (SEm±)

Table 3: significance of depth wise varing soil properties under different three land use system

Land uses	depths	Physical				Physico-chemical				Exchangeable cations				
		sand	silt	clay	AWC	pH (1:2.5)	EC (dSm^{-1})	OC (%)	CEC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	sum
		(%)								(cmol (p+) kg^{-1})				
Cashew	0–25	80.30	6.77	12.93	11.00	6.60	0.23	0.60	5.07	2.57	0.83	0.20	0.20	3.80
	25–50	68.83	3.70	27.47	10.00	6.40	0.19	0.33	9.47	4.97	1.23	0.23	0.27	6.70
	50–75	64.30	9.80	25.90	10.67	6.60	0.18	0.17	11.97	6.27	1.57	0.30	0.33	8.67
	75–100	66.27	6.03	27.70	11.67	6.70	0.17	0.17	12.00	6.27	2.10	0.37	0.30	9.03
	SEm±	69.9[a]	6.6[b]	23.5[a]	10.8[b]	6.6[b]	0.2[a]	0.3[a]	9.6[a]	5.0[a]	1.4[a]	0.3[b]	0.3[ab]	7.1[a]
Mango	0–25	80.7	8.6	10.7	11.0	6.6	0.11	0.51	4.0	1.6	0.6	0.27	0.17	2.6
	25–50	68.0	13.1	18.9	13.0	7.2	0.10	0.24	8.1	4.0	1.0	0.40	0.17	5.6
	50–75	61.4	9.3	29.3	15.3	7.2	0.36	0.22	15.5	8.1	2.0	0.40	0.30	10.8
	75–100	49.1	15.1	35.7	15.7	7.1	0.23	0.19	13.6	5.8	2.1	0.37	0.30	8.6
	SEm±	64.8[a]	11.5[ab]	23.7[a]	13.8[a]	7.0[a]	0.2[a]	0.3[a]	10.3[a]	4.9[a]	1.4[a]	0.4[ab]	0.2[b]	6.9[a]
Areca nut	0–25	58.5	18.3	23.1	10.7	6.9	0.27	0.32	7.9	3.3	1.9	0.43	0.43	6.1
	25–50	59.1	17.2	23.7	12.3	7.0	0.25	0.33	9.2	4.3	2.2	0.33	0.33	7.1
	50–75	50.5	21.2	28.3	15.0	7.0	0.24	0.23	10.5	4.7	2.6	0.50	0.33	8.1
	75–100	65.0	13.0	22.3	12.0	7.2	0.23	0.17	8.9	3.6	1.7	0.67	0.40	6.4
	SEm±	58.3[a]	17.4[a]	24.4[a]	12.5[ab]	7.0[a]	0.2[a]	0.3[a]	9.1[a]	4.0[a]	2.1[a]	0.5[a]	0.4[a]	6.9[a]
LSD (LU)		14.0	6.0	10.4	2.36	0.31	0.17	0.14	3.93	2.14	0.77	0.14	0.10	2.77

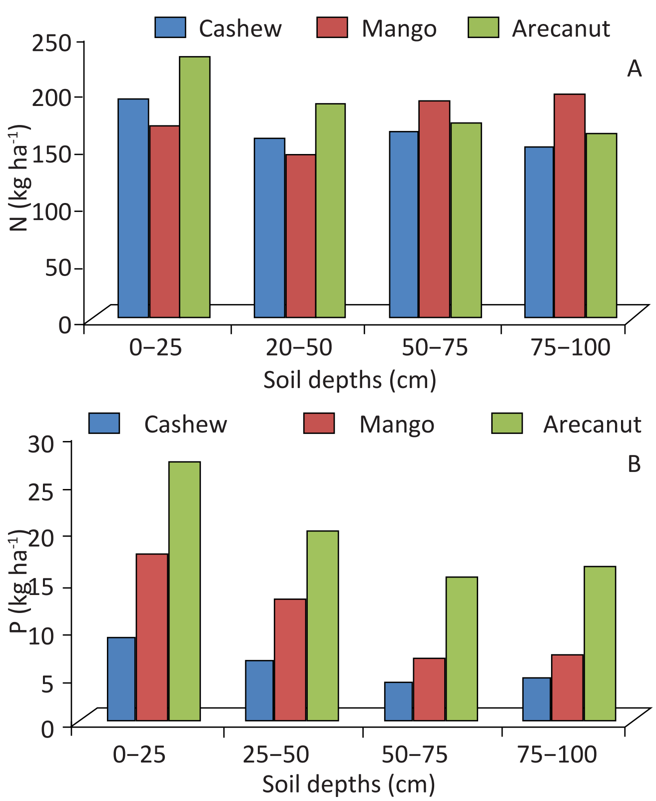
[a]Standard deviation in parentheses, mean of nine observations. Values with different letters (a–b) in the column indicate a significant difference at $p<0.05$.

of soil depth. Soil pH varied from 6.6 to 7.2 in three landuses. Among them, cashew soils shown low pH than others, which could be attributed to the release and leaching of base and their deposition in lower horizon over a long period. The EC did not vary significantly under different land uses at varying soil depths, although the greater values of EC under arecanut landuse system in surface (0.08–0.59 dSm^{-1}) and subsurface (0.05–0.55 dSm^{-1}) as compared to other land use systems. The least value for OC (0.17%) was in found in subsurface soil layers for all the land uses. As a general trend, the OC decreased with increase in the depth of soil layer. The enrichment of OC content in surface (0–25 cm) soils of cashew and mango systems, could be due to litter fall and root biomass accumulation (Panda et al., 2010). CEC values were significantly different with depths. Relatively fine textured subsoils from cashew and mango showed higher CEC (1.0–18.6 and 2.5–23.9 cmol kg^{-1}), which suggests that clay was the main contributor of CEC in these soils. The strong dependence of CEC on clay content was also observed by Reza et al. (2011). Exchangeable cations (Ca, Mg, Na and K) were significantly influenced by different land use systems (Table 2) and soil depths (Table 3). Among the cation calcium (Ca) was found high in all the landuse system followed by Mg, Na and K. Total sum cations were maximum from subsurface soils than surface soil. Among the landuse, arecanut plantation has higher 6.1 in surface and 7.2 cmol kg^{-1} in subsoils. The consistent trend was observed in exchangeable cations were increased with depth in three land use systems. Similar kinds of result also reported by Sharma et al. (2009); Panwar et al. (2011).

3.3. Fertility status

3.3.1. Macronutrients

Available macronutrients contents were significantly influenced by land use and soil depths (Table 2 and Figure 2). The available N content in surface and subsurface soils ranged from 85 to 259 and 40 to 221 kg ha^{-1}. Nitrogen content tended to decrease with increasing soil depth was observed in cashew and arecanut landuse. The attributed to more accumulation of biomass through leaf litter fall and root biomass (Srinivasan and Caulfield, 1989) over long period. The P content was high (26.3 kg ha^{-1}) in the surface layer of arecanut and the least as 4.2 kg ha^{-1} in subsurface soils of cashew landuse. Available P is in lower range in cashew and mango soils. The soils are characterized by high fixation capacities resulting mainly on account of low soil pH nature (Vijaya Kumar et al., 2013). In



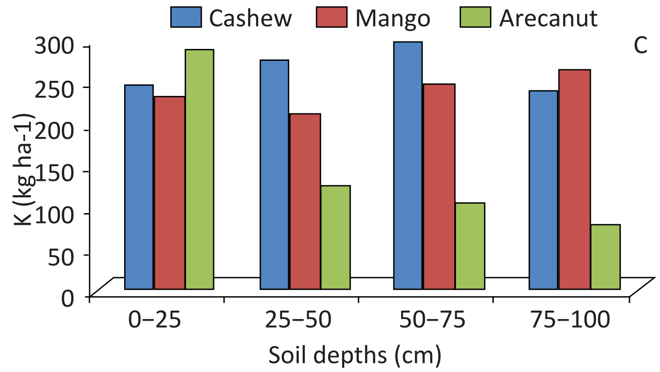


Figure 2: Effect of different land use systems on soil macro nutrients

tree-based land-use system, the greater P content could be due to recycling of P through mining by the tree species and subsequently recycling by way of surface litter fall. Kumar and Chaudhuri (1997) had also reported greater P availability in tree-based land-use systems. The available K content in surface and subsurface soils ranged from 57 to 438 and 14 to 553 kg ha^{-1}. Among the landuse, arecanut subsurface layers had much less K content (14–236 kg ha^{-1}) than others. Adequate available K in these soils may be attributed to the prevalence of potassium-rich minerals like illite and feldspars presenting in the soils and transported and deposited by coastal system (Sharma et al., 2008).

3.3.2. Soil nutrient index

Nutrients index was represented in Table 4. The major nutrients (N, P and K) were categorized for better way of nutrient management on sustainable basis. Nitrogen (N) was low critical value (1.0) in all the land use. Phosphorus (P) was medium (1.6) in arecanut plantation, whereas cashew and mango was rated as low. Potassium (K) was categorized medium in all the land use, maximum (2.0) from cashew and mango soils.

Table 4: Nutrients index of different land use soils

Land uses	Nutrients	Range (kg ha^{-1})	Nutrients index	Category
Cashew	N	280-560	1.0*	Low
	P	10-24.6	1.0*	Low
	K	108-280	2.0*	Medium
Mango	N	280-560	1.0*	Low
	P	10-24.6	1.3*	Low
	K	108-280	2.0*	Medium
Arecanut	N	280-560	1.0*	Low
	P	10-24.6	1.6*	Medium
	K	108-280	1.6*	Medium

*mean values, nutrient critical values <1.50-low, 1.50-2.50-medium, >2.50-high

3.3.3. *Micronutrients*

The effects of land use on micronutrients such as iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) were studied in three different plantation soils (Figure 3). There was a significant difference was observed in different land uses and soil depths. The content of Fe and Mn were sufficient (>4.5 and >2 mg kg^{-1}) in three landuses in all depths. Fe varied in surface 11.1 to 47.2 mg kg^{-1} and subsurface 13.5 to 24.4 mg kg^{-1} and maximum Fe was present in arecanut plantation with decreased trend with increasing depths. The Cu status was rated as sufficient and found as high in surface soils of all land uses, arecanut plantations (1.76–3.57 mg kg^{-1}) had maximum. Zinc content in surface soils varied from 0.68 to 1.6 mg kg^{-1} and subsurface layers were found deficient (<0.30 to mg kg^{-1}) in cashew land use system. The inconsistent trend in micronutrients, particularly Cu and Zn, with respect to different depth and land uses was observed from our study. Similar kind of results also reported by Sharma et al. (2009) and Singh and Bordoloi (2014).

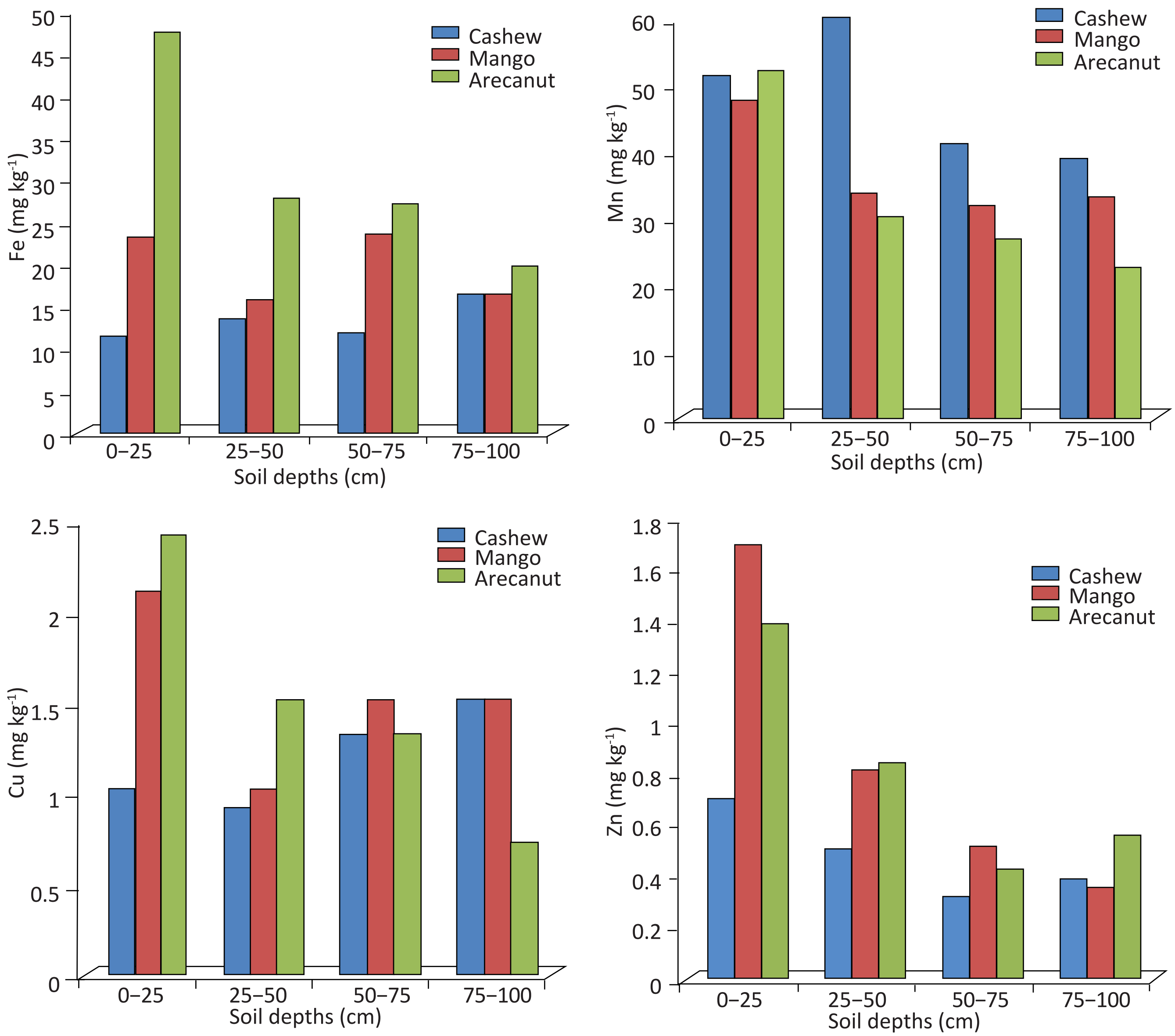


Figure 3: Effect of different land use systems on soil Micro nutrients

3.4. *Correlation between soil properties and soil fertility indices*

Pearson's correlation matrix (Table 5) revealed strong significant positive correlations of soil properties with fertility indices. Physical properties (texture and AWC) are directly influencing OC, N, Mn and Cu. Water retention values has been related to physical properties of soil such as organic matter, particle-size distribution, and land uses (Dharmarajan et al., 2013). The chemical properties (pH, EC, CEC and OC)

Table 5: Correlation between soil properties and plant available nutrients

	pH	EC	Sand	Silt	Clay	OC	AWC	CEC	Ca	Mg	Na	K	Sum	N
pH	1													
EC	.668**	1												
Sand	.471**	.352*	1											
Silt	NS	NS	-.764**	1										
Clay	-.570**	-.386*	-.865**	.337*	1									
OC	-.505**	-.409*	NS	NS	NS	1								
AWC	-.445**	-.431*	-.783**	.517**	.744**	.450**	1							
CEC	-.578**	-.386*	-.798**	NS	.919**	NS	.734**	1						
Ca	-.534**	NS	-.724**	NS	.805**	NS	.668**	.926**	1					
Mg	-.491**	NS	-.852**	.568**	.800**	NS	.715**	.761**	.733**	1				
Na	NS	-.397*	-.442**	NS	.439**	NS	NS	.441**	.496**	.482**	1			
K	-.509**	-.356*	-.673**	.403*	.672**	NS	.557**	.605**	.424**	.673**	.380*	1	.	
Sum	-.556**	-.349*	-.802**	.407*	.852**	NS	.715**	.932**	.980**	.847**	.568**	.544**	1	
N	-.456**	-.492**	-.598**	.368*	.585**	.565**	.660**	.559**	.467**	.501**	.450**	.612**	.523**	1
P	NS	NS	-.398*	.624**	NS	.388*	NS	NS	NS	NS	NS	.333*	NS	.369*
K	-.401*	NS	NS	NS	.365*	.424**	.376*	.356*	NS	NS	NS	NS	NS	.430**
Fe	NS	NS	-.440**	.439**	NS	NS	NS	NS	.330*	.496**	.363*	.339*	.401*	.425**
Mn	-.683**	-.463**	-.410*	NS	.497**	.662**	.408*	.424**	.461**	NS	NS	NS	.434**	.563**
Cu	-.392*	-.404*	-.427**	NS	.407*	.521**	.472**	.349*	NS	NS	NS	.362*	.332*	.734**
Zn	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Contonue...

	P	K	Fe	Mn	Cu	Zn
P	1					
K	NS	1				
Fe	.421*		1			
Mn	NS	.584**		1		
Cu	.417*	.444**	.495**	.661**	1	
Zn	NS	NS	NS	NS	NS	1

* and ** significant at (p=0.05) and (p=0.01), respectively

showed significant correlation with AWC, exchangeable bases and N, Mn and Cu. Exchangeable bases (Ca, Mg, Na and K) were positively correlated with pH, EC, texture, CEC, N and Fe.

4. Conclusion

The results of this study indicated that different horticultural land use led to significant changes in soil properties such as textures, AWC, organic carbon, pH, CEC and exchangeable cations and they had influenced on soil fertility. Result indicate that the values significantly varied with soil depths but between land uses was non significant. Therefore, the horticultural land use system in coastal Odisha required better treatment or management for maintaining sustainable productivity.

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