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Seasonal Variation of Physico-chemical Properties and Fertility of Soils under Different Land Uses in Nagaland

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ABSTRACT

The present study was conducted in the Department of Agricultural Chemistry and Soil Science, SASRD, Nagaland University during 2018 to evaluate the seasonal variation of soil physico-chemical properties under forest (natural), pineapple and paddy (low land) land use systems (LUS) of Medziphema block, Dimapur, Nagaland. 432 geo-referenced composite soil samples were collected during pre-monsoon, monsoon and post-monsoon seasons from surface and sub-surface soil. pH of soils under paddy LUS was found highest (4.95) followed by forest (4.84) and pineapple (4.65) LUS. Significantly minimum values of BD was recorded in forest LUS (1.17 and 1.20 Mg m^{-3}) followed by higher BD (1.21 and 1.25 Mg m^{-3}) in pineapple and maximum in paddy LUS (1.34 and 1.37 Mg m^{-3}) during post-monsoon season at surface and sub-surface soil respectively. Forest LUS recorded maximum average content of organic carbon (16.72 g kg^{-1}). Available nitrogen, available phosphorus, exchangeable calcium and magnesium content was also found maximum in soils of forest LUS. Significant positive correlation among soil fertility parameters were obtained in different seasons. Results of the investigation revealed that the pineapple LUS in the study area can be considered as a sustainable LUS owing to its comparable soil physico-chemical properties with the forest LUS. However, there is need for large scale adoption of location specific soil management practices for sustainable production and management of soil health in order to counteract deterioration of soil fertility under traditionally practiced low land paddy LUS.

KEYWORDS: Depth, LUS, Nagaland, physico-chemical properties, seasons

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1. INTRODUCTION

Qualitative and quantitative changes of soil properties are common under different land use systems. Soils under particular land use system may affect physico-chemical properties which may modify fertility status and nutrient availability to plants (Tsanglao et al., 2014). Different land use systems viz. agriculture, horticulture, forestry leads to the change in physico-chemical properties and also change in nutrient content (Kavianpoor et al., 2012; Singh et al., 2014; Ally-Said et al., 2015, Hedge et al., 2021). Land uses have significant effect on soil nutrients and thus its fertility. The status of soil nutrients in 2–5 years old *Jhum* fallows exhibited soil properties ranging between soil properties of paddy fields and natural forest (Chase and Singh, 2014). Hence, land uses should be chosen with care to preserve the quality of the soil. Extensive studies have recommended optimum soil management practices for sustainable yields (Vasundhara et al., 2020).

Soil organic carbon (SOC) compoundly affects chemical, physical and biological aspects of soil (Sainepo et al., 2018). Conversion of native forests and pristine soils to cultivation is usually accompanied by decline in SOC content and deterioration of soil structure. Clearing of forests and their subsequent conversion into croplands greatly influence soils in terms of its water holding capacity, structural stability and compactness, nutrient supply and storage as well as its biological life (Reza et al., 2014; Shimrah et al., 2015; Manpoong and Tripathi, 2019; Konyak et al., 2020). Reduction in SOM increases BD, decrease porosity, infiltration and water storage capacity (Jiao et al., 2020). Significant modifications in soil properties are influenced by land use systems in tropical areas, in which agriculture have a major contribution. Intensive tillage reduces SOC and degrades soil (Srinivasarao et al., 2013; Hadole et al., 2020). Higher total nitrogen content in forest soil may be because of high organic carbon (Moges et al., 2013; Dutta et al., 2018). Higher content of exchangeable and non-exchangeable potassium content was reported in forest soils compared to rice-mustard (Das et al., 2019).

Seasons and plant species have significant impact on abundance of soil microbial community and hence nutrient availability (Kumar et al., 2021). Seasonal variation in soil quality parameters is brought about by land cover change, seasonal temperature and moisture availability as well as microbial activity. Change in soil chemical properties in the form of P mineralization-immobilization of organic P are strongly influenced by seasonal variations in temperature, moisture, plant growth and root activity, and by organic matter accumulation from litter fall (McGrath et al., 2000). Mean available potassium content found high in pre-monsoon season and least in monsoon season (Bini et al., 2015; Das et al., 2018). Variation in organic matter content at different soil layers, leaching of nutrients etc. can be the major causes of differential soil fertility in surface as well as sub-surface soils. Differential distribution of available nutrients in different depth was reported from various studies conducted world-wide (Padhan et al., 2016; Amgain et al., 2020; Negasa, 2020).

Nagaland, in North-East India is known for its hilly terrain. Although limited information on the effects of land use systems on the selected indicators of soil fertility is available for Nagaland soils, the information on dynamics of soil fertility parameters are scarce. Hence, the present study was undertaken to assess the seasonal and depth wise variation in soil physico-chemical parameters under selected land use systems in Medziphema block of Dimapur district, Nagaland.

2. MATERIALS AND METHODS

2.1. Experimental site and collection of samples

The study was undertaken during 2018 at 'Medziphema block' of Dimapur district, Nagaland, India that lies between 25.69347° N to 25.76559° N latitude and 93.82366° E to 93.88039° E longitudes. Dimapur district falls under humid sub-tropical agro climate zone (ACZ). In summer it is hot and humid and moderately cold in winter. The average rainfall varies from 1500–2500 mm. Three prevalent land use systems viz. forest LUS (natural), pineapple LUS and paddy LUS (low land) were selected for the study. From the discussion with farmers and key informants, it was revealed that the selected LUS existed there in place for past 18–20 years. A total of 432 geo referenced composite soil samples have been collected using GPS device (Model: GARMIN etrex 30x) over three seasons viz. pre-monsoon (in the month of May), monsoon (in the month of August) and post-monsoon (in the month of November) from surface (0.25 m) and sub-surface (0.50 m) soils. The soil samples were air-dried, ground and passed through 2 mm sieve for analysis of physico-chemical and fertility parameters.

2.2. Analysis of soil samples

Soil physico-chemical properties were evaluated following standard procedures. Soil pH was determined in 1: 2.5 soil: water suspension using glass electrode pH meter as described by Jackson (1973). Air dried and processed samples collected at the start of the experiment (pre-monsoon) were analyzed for particle-size distribution (sand, silt and clay) following International Pipette method (Baruah and Barthakur, 1999). After obtaining the percentage sand, silt and clay; textural classes were obtained using textural triangle. Bulk density and particle density of the soil was determined by procedures outlined by Chopra and Kanwar (1991). Water holding capacity was determined using Keen Rackzowaski boxes as described by Baruah and Borthakur, 1999. Total porosity of the soil was calculated from the bulk density and particle density values using the formula:

Porosity (%)=(1-bulk density)/(particle density)×100 ......(1)

Organic carbon (OC) and available nitrogen were determined by wet digestion and alkaline potassium permanganate method respectively using procedure described by Jackson (1973). Available phosphorus (P_2O_5) was determined by Bray's I method and available potassium was determined by neutral normal ammonium acetate method (Jackson, 1973). Available sulphur was determined by turbidimetric method as illustrated by Baruah and Borthakur, 1999. Exchangeable Ca and Mg were determined by versenate method (Jackson, 1973).

2.3. Statistical analysis

Pearson's correlation analysis was carried out using SPSS software (version 23.0). Soil physico-chemical properties measured in the study were subjected to correlation analysis. One way ANOVA and Duncan's multiple range test (DMRT) for comparison of means with LUS as factor was carried out to assess the significance of difference in physico-chemical attributes among LUS under study in different seasons. Post hoc test was carried out at 0.05 level of significance throughout.

3. RESULTS AND DISCUSSION

3.1. Soil texture

While soils of forest lands were 'sandy clay loam' and 'sandy loam'; soils of pineapple land use were found mostly as 'sandy clay loam' and 'clay loam' in their textural class. However, dominant textural class of soils of paddy land use was 'clay loam'. Sand content was found comparatively high in soils of forest, whereas silt and clay particles were found more under paddy land use. Increased amount of clay content at sub-surface soil was recorded for different land uses compared to surface soil; maximum amount of clay (33.70%) being recorded in sub-surface soils under paddy LUS followed by pineapple LUS (31.97%). However, difference in clay content of pineapple and paddy LUS was found non-significant at both the depths (Table 1). The higher clay fraction in soil under paddy cultivation may be due to the high intensity weathering associated with shearing and pulverization of soils compared to forest and pineapple land use. Possible translocation of clay to the sub-surface soil may be the reason for high clay content in the sub-surface soil. Similar results were reported by Moges et al. (2013). The result of this study was also in conformity with Jiao et al. (2020).

Table 1: Variation in particle size distribution under different land use systems in pre-monsoon season

Land use	Textural class	Sand (%)		Silt (%)		Clay (%)	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
Forest	scl, sl	50.36^{a}	50.49^{a}	23.60^{a}	23.30^{a}	26.05^{a}	26.20^{a}
Pineapple	cl, scl	44.15^{b}	45.63^{b}	25.46^{a}	22.42^{a}	30.40^{ab}	31.97^{b}
Paddy	cl, scl	40.93^{bc}	39.87^{c}	26.14^{a}	26.44^{a}	32.95^{bc}	33.70^{bc}

scl: Sandy clay loam; sl: Sandy loam; cl: Clay loam; (p<0.05) using Duncan's multiple range test

3.2. Soil pH

The pH of soils under paddy land use was found highest (4.95) followed by forest (4.84) and pineapple (4.65) land use irrespective of seasons and depth of sampling. SoilpH increased with depth in all the land uses. During monsoon season, slight reduction in pH values was recorded compared to pre-monsoon and post-monsoon season for all the three different land uses in both the depths (Table 2). The high pH value in paddy land use may be because of reduction of Fe and Mn oxides to Fe^{2+} and Mn^{2+} under submerged condition of low land paddy which consume H^{+} ions. The increased in pH at 0.50 m depth can be attributed to leaching of bases with percolating water to the sub-surface soil. High microbial activities in the monsoon season might have facilitated the decomposition of organic matter and release of some organic acids, thus resulted in temporary drop in pH of soils. Salim et al. (2015) also reported significant variation in soil pH values of the natural forest, plantation and grass lands with less pH under natural forest.

3.3. Bulk density

Bulk density (BD) of forest LUS was recorded minimum (1.21 Mg m^{-3}) and maximum in paddy LUS (1.41 Mg m^{-3}) irrespective of seasons and depths. Similar trend of seasonal variation of bulk density was recorded for different LUS, indicating minimum values in post-monsoon season, followed by increased values in pre-monsoon season which was further increased in monsoon season. Significantly minimum values of BD was recorded in forest LUS (1.17 and 1.20 Mg m^{-3}) followed by higher BD (1.21 and 1.25 Mg m^{-3}) in pineapple and maximum in paddy LUS (1.34 and 1.37 Mg m^{-3}) during post-monsoon season at surface and sub-surface soil respectively (Table 2). Higher values of BD were obtained in the sub-surface soils compared to surface soil for all LUS under study. The highest bulk density values

Table 2: Variation in physico-chemical properties under different land use systems in different seasons

Parameters	Land use	Pre-monsoon		Monsoon		Post-monsoon		Average
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	
pH	Forest	4.87[a]	5.17[a]	4.57[a]	4.78[a]	4.70[a]	4.94[a]	4.84
	Pineapple	4.75[b]	4.94[b]	4.38[b]	4.58[b]	4.53[b]	4.73[b]	4.65
	Paddy	4.90[ac]	5.06[c]	4.83[c]	4.95[c]	4.90[c]	5.03[ac]	4.95
BD (Mg m^{-3})	Forest	1.19[a]	1.21[a]	1.21[a]	1.26[a]	1.17[a]	1.20[a]	1.21
	Pineapple	1.25[b]	1.29[b]	1.29[b]	1.34[b]	1.21[b]	1.25[b]	1.27
	Paddy	1.38[c]	1.41[c]	1.45[c]	1.51[c]	1.34[c]	1.37[c]	1.41
PD (Mg m^{-3})	Forest	2.48[a]	2.39[a]	2.40[a]	2.42[a]	2.49[a]	2.41[a]	2.43
	Pineapple	2.37[b]	2.46[b]	2.41[ab]	2.55[b]	2.34[b]	2.42[ab]	2.42
	Paddy	2.61[c]	2.65[c]	2.67[c]	2.68[c]	2.58[c]	2.63[c]	2.64
Porosity (%)	Forest	52.12[a]	49.21[a]	49.44[a]	47.80[a]	52.96[a]	50.16[a]	50.28
	Pineapple	47.42[b]	47.34[b]	47.34[b]	46.19[b]	48.59[b]	47.91[b]	47.46
	Paddy	47.09[bc]	46.26[c]	45.22[c]	43.91[c]	48.16[bc]	47.74[bc]	46.40
WHC (%)	Forest	47.33[a]	45.71[a]	43.95[a]	42.60[a]	47.27[a]	45.24[a]	45.35
	Pineapple	41.71[b]	40.64[b]	40.50[b]	40.12[b]	42.86[b]	41.84[b]	41.28
	Paddy	41.04[bc]	39.98[bc]	38.62[c]	37.12[c]	41.98[bc]	41.28[bc]	40.00

Values followed by different letters for a particular parameter under different land uses are significantly different (p<0.05) by the Duncan's multiple range test

in paddy LUS may be due to compaction induced by the puddling action. On the other hand, increased porosity and reduced soil compaction due to high organic matter content in forest floor might have resulted low BD. Increase in BD at sub-surface soil may also be accounted for lower organic carbon content at 0.25–0.50 m depth. The results of the present research is in conformity with Fageria et al. (2011) who opined that in compacted soil, bulk density, microvoids, thermal conductivity and diffusivity increases. Moges et al. (2013) have reported similar findings; where they have revealed high BD in lower soil layers due to the effects of weight of the overlying soil and the decrease in soil organic matter content.

3.4. Particle density

Particle density (PD) of soils followed almost similar trend with that of BD as maximum particle density was recorded under paddy LUS>forest LUS>pineapple LUS with the average values of 2.64, 2.43 and 2.42 Mg m^{-3} under paddy, forest and pineapple LUS respectively. Higher values of PD were recorded at sub-surface soil for paddy and pineapple LUS. Minimum PD values for different LUS were observed during post-monsoon season. During post-monsoon season, the values of PD was 2.49 and 2.41 Mg m^{-3} for forest, 2.34 and 2.42 Mg m^{-3} for pineapple and 2.58 and 2.63 Mg m^{-3} for paddy at 0–0.25 m and 0.25–0.50 m depth respectively (Table 2). The variation in PD under different LUS was significant during pre-monsoon season. However, in monsoon and post-monsoon season, significant difference in PD between pineapple and paddy LUS was not recorded. There exists a direct relationship between soil BD and PD (Jiao et al., 2020). That may be the reason of increase or decrease in PD with the corresponding increase or decrease in BD under different LUS. However, decrease of SOM might cause the increase of BD and hence PD.

3.5. Porosity and water holding capacity

Mean porosity of soils was found maximum under forest LUS (50.28%) followed by pineapple LUS (47.46%) and paddy LUS (46.40%) irrespective of depth and season of sampling. Significantly higher porosity was recorded in forest (52.96% and 50.16%) followed by pineapple (48.59% and 47.91%) and paddy (48.16% and 47.74%) LUS at surface and sub-surface soil respectively during post-monsoon season (Table 2). However, the variation in porosity of pineapple and paddy LUS was found non-significant during that particular season. Percent pore space decreased with depth.

Water holding capacity (WHC) also followed the similar trend where highest average value of WHC was recorded in forest (45.35%) followed by pineapple (41.28%) and least was recorded in paddy (40.0%) LUS. Significantly higher values of WHC were recorded in case of forest (47.27% and 45.24%) followed by pineapple (42.86% and 41.84%)

and paddy (41.98% and 41.28%) in surface and sub-surface soil during post monsoon season (Table 2). The variation in WHC between pineapple and paddy LUS was however non-significant during post-monsoon season in both the depths. Increase in porosity and corresponding increase in WHC in forest soils can be related to decrease in BD of soil. Variation in seasonal accumulation of organic matter may be the reason of difference in porosity and WHC in different sampling seasons.The findings of Jiao et al. (2020) supported the present findings. The process of puddling in low land paddy cultivation employ shearing and compactive forces that destroys natural structure of soil and result in a condition of reduced pore space (Anonymous, 2008).

3.6. *Organic carbon*

Across the different seasons and depths, forest LUS recorded maximum average content of organic carbon (16.72 g kg^{-1}) followed by pineapple (14.23 g kg^{-1}) and paddy LUS (10.70 g kg^{-1}). Gradual decline in OC content along the depth was recorded in all the LUS. Significant seasonal variation in OC content among LUS was recorded during three different seasons; maximum variation in OC was recorded during post-monsoon season (18.69, 15.61 and 12.09 g kg^{-1} in forest, pineapple and paddy LUS respectively) followed by pre-monsoon season (17.72, 15.02 and 11.20 g kg^{-1} in forest, pineapple and paddy LUS respectively). Least but significant variation was recorded in monsoon season (17.11, 14.59 and 10.68 g kg^{-1} in forest, pineapple and paddy LUS respectively) (Table 3). The higher OC under forest LUS may be due to abundant and varied above ground and below ground plant biomass availability. The less OC content in pineapple plantation and paddy LUS may be attributed to site disturbance that leads to exposure of litter material for decomposition. The deposition of high amount of organic residues in the surface soil may be attributed to high OC content in surface soil compared to sub-surface soil. In winter or in case of post-monsoon season, because of low temperature and less moisture availability, there is reduced rate of residue decomposition owing to reduced microbial activity, which adds to higher carbon values. Chase and Singh (2014) reported similar findings of higher SOC content in natural forest and least in soils of paddy fields under Nagaland condition. Dluzewski et al. (2019) reported higher SOC content in the surface horizon in autumn and winter months, while lower SOC content in spring and summer.

3.7. *Available nitrogen*

Nitrogen availability in soils of forest LUS was found higher (304.47 kg ha^{-1}) followed by pineapple (270.08 kg ha^{-1}) and paddy LUS (245.37 kg ha^{-1}) respectively across the sampling seasons and depths. Nitrogen content decreased with depth under all the LUS. Significantly higher available nitrogen content was recorded under forest LUS (325.33 kg ha^{-1}) during post-monsoon season in surface soil followed by pineapple (284.57 kg ha^{-1}) and paddy (262.27 kg ha^{-1}) LUS (Table 3). Least amount of available nitrogen was recorded during monsoon season. Higher available nitrogen content under forest LUS may due to relatively high amount of organic carbon content. Most soil nitrogen is bound in organic carbon and it was expected to record high available nitrogen content in organic carbon rich soils. Moreover, undisturbed nature of forest floor allows deposition of more biomass and thus more availability of nitrogen. On the other hand, lesser amount of available nitrogen content under pineapple and paddy LUS can be attributed to less accumulation of organic biomass due to cultivation practices like tillage operation and removal of residues after crop harvest coupled with inefficient replenishment through manures and fertilizers. In the post-monsoon season, there was high accumulation of organic matter and corresponding high organic carbon content due to lesser degree of decomposition owing to less microbial activity might have resulted higher available nitrogen content compared to pre-monsoon and monsoon season. The present findings were in conformity with Chase and Singh (2014) who have reported high available nitrogen content under natural forest LUS compared to *Jhum* fallow and low land paddy LUS. Salim et al. (2015) revealed the increased amount of total nitrogen in the soils under natural forest in autumn season followed by winter, spring and the least was observed in summer season under different land uses. Similar findings of decreasing trend of available nitrogen with depths were reported by Amgain et al. (2020)

3.8. *Available phosphorus*

Phosphorus availability was recorded as low to medium range under different LUS. Forest LUS recorded higher available P_2O_5 (32.11 kg ha^{-1}) followed by paddy LUS (23.51 kg ha^{-1}) and pineapple LUS (22.82 kg ha^{-1}) respectively. There prevailed a decreasing trend of available phosphorus content with the increasing depth. Significant seasonal variation in available phosphorus content was recorded between forest LUS and pineapple LUS as well as between forest and paddy LUS; maximum being recorded in pre-monsoon season. Phosphorus content of pineapple and paddy LUS was at par in all the three sampling seasons. Available phosphorus content was found maximum in forest LUS (35.06 kg ha^{-1}), followed by paddy (26.14 kg ha^{-1}) and pineapple (25.83 kg ha^{-1}) during pre-monsoon season (Table 3). The high available phosphorus content in the forest LUS may be attributed to favorable soils reaction and high organic matter leading to the formation of organophosphate complexes and coating of iron and aluminum particles by humus. Moreover, the organic anions released during decomposition of organic matter form chelates with Fe and Al and make the P available. The high available phosphorus content in the surface soil may be due to high organic matter content leading to formation of more organophosphate complex and subsequent availability of phosphorus. Increased level pH of soil during pre and post-monsoon season compared to monsoon season can also be held responsible for corresponding increase in phosphorus availability in those seasons. The findings of Salim et al. (2015) supported the present findings where they have reported maximum available phosphorus under natural forest followed by plantation and least under grassland. In accordance with the present findings, Bini et al. (2015) have reported high available phosphorus in pre-monsoon than post-monsoon and monsoon season under agricultural lands.

3.9. Available potassium

Pineapple LUS recorded mean maximum available potassium as K_2O (210.49 kg ha^{-1}) followed by forest (148.32 kg ha^{-1}) and paddy LUS (131.71 kg ha^{-1}) across the seasons. Sub-surface soil exhibited lesser amount of potassium availability than the surface soil in all the three LUS. Seasonal variation in available potassium was found significant among various LUS; the pattern of seasonal variation in available potassium was: pre-monsoon > post-monsoon > monsoon for all three LUS. Maximum available potassium was recorded in pineapple (230.24 kg ha^{-1}) followed by forest (166.1 kg ha^{-1}) and paddy (145.13 kg ha^{-1}) LUS during pre-monsoon season (Table 3). The high available potassium content under pineapple LUS compared to the other LUS might be due to application of K through fertilizers. The comparatively higher available potassium under pineapple and forest LUS may be attributed to release of labile K from organic residues owing to favorable micro-climate under these LUS. The accumulation of K in the forest LUS is likely due to the undisturbed ecosystem where natural balance is maintained. No addition of any inputs for nutrient supplementation in paddy fields may have resulted in low K content. Higher amount of available K was observed in the surface horizons might be due to favourable condition that facilitates more intense weathering of K-bearing minerals, release of liable K from organic residues, and upward translocation of K from lower depths along with capillary rise of ground water. Chase and Singh (2014) have also reported similar findings where they have reported maximum exchangeable K under *Jhum* fallow followed by natural forest and least was reported in paddy field. Findings of Sharma et al. (2015) is also in line with the present findings who have reported higher available K in natural forest than orchards and cereals.

3.10. Available sulphur

Maximum content of available sulphur was recorded in pineapple LUS (32.26 kg ha^{-1}) followed by forest (27.09 kg ha^{-1}) and paddy LUS (22.01 kg ha^{-1}). More amounts of available sulphur content in surface soil of all the LUS was recorded which exhibited similar decreasing trend down the soil profile. Significant seasonal variation in available sulphur content was evident among the different LUS. Significantly high amount of available sulphur was recorded in pineapple LUS (42.20 kg ha^{-1}) followed by forest (36.21 kg ha^{-1}) and paddy LUS (30.02 kg ha^{-1}) during post-monsoon season (Table 3). Higher amount of available S in pineapple LUS may be due to higher mineralization of organic S triggered by the better microbial activity. Furthermore, progressive farmers of Medziphema area are applying S bearing fertilizers like SSP in pineapple cultivation, which may be another reason for high available S in soils of pineapple LUS. The low available S content in paddy LUS might be because of continuous mono-cropping of rice that removed greater amount of S. The possible reason for decline in available S content along the depth may be due to lower mineralization rate in the lower depth owing to slower microbial activity. Seasonal variation in available S content can be linked to organic carbon content in soil. Hence, high organic carbon content in post-monsoon and pre-monsoon season can be the reason for corresponding high available S content in these seasons. Majumdar and Patil (2016) reported less available S in paddy land use compared to forest and orchard (mango) land use.

3.11. Exchangeable calcium and magnesium

Higher value of Exch. Ca was recorded in forest LUS {2.33 cmol (P^+) kg^{-1}} and minimum {1.32 cmol (P^+) kg^{-1}} was recorded in paddy LUS across the seasons and depths. The same was 1.56 cmol (P^+) kg^{-1} in pineapple LUS. Lesser content of Exch. Ca was recorded in sub-surface soil compared to surface soils. In the pre-monsoon season, significantly higher content of Exch. Ca was recorded in forest LUS {2.78 cmol (P^+) kg^{-1}} followed by pineapple {1.64 cmol (P^+) kg^{-1}} and paddy LUS {1.41 cmol (P^+) kg^{-1}}. During post-monsoon season the same was 2.60, 1.59 and 1.37 cmol (P^+) kg^{-1} in forest, pineapple and paddy LUS respectively. However, least content of Exch. Ca was recorded in monsoon season as 1.97, 1.55 and 1.35 cmol (P^+) kg^{-1} in forest, pineapple and paddy LUS respectively (Table 3).

Exchangeable magnesium (Exch. Mg) content under different LUS was found as: forest > pineapple > paddy. Maximum content of Exch. Mg {1.16 cmol (P^+) kg^{-1}} was recorded in forest LUS and minimum {0.52 cmol (P^+) kg^{-1}} in paddy LUS, along with {0.74 cmol (P^+) kg^{-1}} in pineapple LUS. The Exch. Mg was 1.41, 0.83 and 0.63 cmol (P^+) kg^{-1} in forest, pineapple and paddy LUS respectively during pre-monsoon season. During post-monsoon season it was

Table 3: Variation in soil fertility parameters under different land use systems in different seasons

Parameters	Land use	Pre-monsoon		Monsoon		Post-monsoon		Average
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	
OC (g kg^{-1})	Forest	17.72^a	15.26^a	17.11^a	14.72^a	18.69^a	16.79^a	16.72
	Pineapple	15.02^b	13.30^b	14.59^b	12.95^b	15.61^b	13.93^b	14.23
	Paddy	11.20^c	9.75^c	10.68^c	9.82^c	12.09^c	10.67^c	10.70
AvN (kg ha^{-1})	Forest	315.51^a	293.45^a	301.58^a	286.40^a	325.33^a	304.52^a	304.47
	Pineapple	278.33^b	261.53^b	270.69^b	257.09^b	284.57^b	268.31^b	270.08
	Paddy	252.68^c	236.91^c	245.67^c	232.81^c	262.27^c	241.87^c	245.37
AvP_2O_5 (kg ha^{-1})	Forest	35.06^a	32.42^a	32.17^a	28.24^a	33.86^a	30.92^a	32.11
	Pineapple	25.83^b	22.75^b	22.84^b	20.39^b	23.89^b	21.22^b	22.82
	Paddy	26.14^{bc}	23.23^{bc}	23.28^{bc}	20.29^{bc}	25.63^{bc}	22.52^{bc}	23.51
AvK_2O (kg ha^{-1})	Forest	166.10^a	147.98^a	146.82^a	130.87^a	157.63^a	140.53^a	148.32
	Pineapple	230.24^b	209.85^b	213.25^b	190.74^b	220.90^b	197.97^b	210.49
	Paddy	145.13^c	133.39^c	131.00^c	119.91^c	134.92^c	125.91^c	131.71
AvS (kg ha^{-1})	Forest	32.54^a	22.53^a	25.10^a	18.25^a	36.21^a	27.91^a	27.09
	Pineapple	38.32^b	25.80^{ab}	33.05^b	22.14^b	42.20^b	32.06^b	32.26
	Paddy	25.07^c	17.73^c	20.65^c	14.87^c	30.02^c	23.71^c	22.01
Exch.Ca [cmol (P+) kg^{-1}]	Forest	2.78^a	2.47^a	1.97^a	1.78^a	2.60^a	2.40^a	2.33
	Pineapple	1.64^b	1.55^b	1.55^b	1.48^b	1.59^b	1.52^b	1.56
	Paddy	1.41^c	1.30^c	1.35^c	1.24^c	1.37^c	1.28^c	1.32
Exch. Mg [cmol (P+) kg^{-1}]	Forest	1.41^a	1.24^a	1.00^a	0.76^a	1.31^a	1.22^a	1.16
	Pineapple	0.83^b	0.75^b	0.72^b	0.67^{ab}	0.78^b	0.73^b	0.74
	Paddy	0.63^c	0.51^c	0.53^c	0.42^c	0.59^c	0.47^c	0.52

Values followed by different letters for a particular parameter under different land uses are significantly different (p<0.05) by the Duncan's multiple range test

decreased to 1.31, 0.78 and 0.59 cmol (P^+) kg^{-1} in forest, pineapple and paddy LUS. The same was further decreased to 1.0, 0.72 and 0.53 cmol (P^+) kg^{-1} for surface soil (0 - 0.25 m) in forest, pineapple and paddy LUS respectively during monsoon season (Table 3). The difference in Exch. Mg content among three LUS was found significant in each of the seasons. Thick litter layer in the forest floor may be the reason of higher content of Exch. Ca and Mg in the forest LUS. High organic matter content might have increased CEC and thus exchangeable bases i.e. Exch. Ca and Mg content. The decreasing content of Exch. Ca and Mg down the depths might be due to lesser organic matter in the sub-surface soil. During the pre and post-monsoon season, the little or no rainfall might be responsible for accumulation of these cations at the upper depth. Less Exch. Ca and Mg during monsoon season may be attributed to these elements being utilized by the regenerating plants, there by indicating temporary disappearance of these elements in the soil. In conformity with the present findings, Bini et al. (2015) have reported higher magnesium and calcium in grass land habitat than agricultural habitat, maximum in pre-monsoon season, followed by post-monsoon and least in the monsoon season. Wani et al. (2017) reported higher calcium and magnesium content in surface and sub-surface soils in pear orchards.

3.12. Correlation analysis

Significant negative correlation between OC-BD and OC-PD was observed; while a strong positive correlation between OC-porosity and OC-WHC was evident irrespective of LUS. The positive correlation between OC and WHC indicated that OM increased aggregation of soil particles and water retention capacity of soil. WHC increased with parallel increase in organic matter. A positive correlation was observed between soil pH and organic matter for all the different LUS across the seasons and depths (Table 4). This might be due to amphotaric nature of organic matter that tries to buffer the soil pH. Moreover, increase in organic matter content increased the CEC of soils and checks the rise in H^+ ions concentration in soil solution. Positive

Table 4: Correlation among surface soil (0–0.25 m) parameters of various land use systems in different seasons

parameters	Forest LUS			Pineapple LUS			Paddy LUS		
	Pre-monsoon	Monsoon	Post-monsoon	Pre - monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
OC-pH	0.746*	0.775*	0.793*	0.743*	0.855**	0.854**	0.759**	0.758*	0.780*
OC-BD	-0.854**	-0.835**	-0.888**	-0.819*	-0.880**	-0.812*	-0.796*	-0.875**	-0.812*
OC-PD	-0.849**	-0.894**	-0.862**	-0.811*	-0.891**	-0.880**	-0.766*	-0.804*	-0.753*
OC-porosity	0.865**	0.821*	0.878**	0.881**	0.955**	0.869**	0.893**	0.810*	0.651
OC-WHC	0.788*	0.816*	0.876**	0.833*	0.821*	0.849**	0.896**	0.839**	0.752*
OC-AvN	0. 870**	0.921**	0.964*	0.910**	0.887**	0.983**	0.847**	0.899**	0.804*
OC-AvP_2O_5	0.794*	0.882**	0.852**	0.749*	0.822*	0.805*	0.742*	0.762*	0.714*
OC - AvK_2O	0.740*	0.757*	0.779*	0.768*	0.708*	0.769*	0.749*	0.724*	0.742*
OC-AvS	0.859**	0.932**	0.889**	0.949**	0.847**	0.967**	0.814*	0.861**	0.802*
OC-Exch.Ca	0.829*	0.871**	0.743*	0.721*	0.722*	0.723*	0.721*	0.770*	0.769*
OC- Exch. Mg	0.731*	0.861**	0.752*	0.776*	0.707*	0.888**	0.700*	0.760*	0.713*

correlation between soil pH-OC was also reported by Singh et al. (2014) and Reza et al. (2014). Positive correlation was observed between organic carbon and available N, P, K, S, Exch. Ca and Mg indicating that organic matter was the major source of these nutrients under different LUS. Singh et al. (2014) also reported significant positive correlation between above parameters.

4. CONCLUSION

The pineapple LUS extensively followed in the Medziphema block can be considered as a sustainable land use system owing to its comparable soil physico-chemical properties with the forest land use system. Traditionally practiced low land paddy LUS was found as a sick system with deteriorated soil quality. Therefore, special emphasis to be given in motivating farmers to adopt best management strategy for enhancing soil fertility status of low land paddy to increase production as well as livelihood.

5. REFERENCES

Ally-Said, M., Canisius, K.K., Douglas, N.A., Paul, O.A., Frank, B.G., Gabriel, O.D., Philip, O.O., Ayub, V.O.O., 2015. Effects of land use change on land degradation reflected by soil properties along Mara River, Kenya and Tanzania. Journal of Soil Science 5, 20–38.

Amgain, R., Khadka, D., Joshi, S., Malla, R., 2020. Depth-wise variations of soil physico-chemical properties in the apple growing area of Mustang district, Nepal. Journal of Agriculture and Natural Resources 3(2), 92–103.

Anonymous, 2008. Glossary of Soil Science Terms. Soil Science Society of America, Madison. Wisconsin, 1–17.

Baruah, T.C., Barthakur, H.P., 1999. A Text Book of Soil Analysis.Vikas Publishing House Pvt Ltd, New Delhi, 4–179.

Bini, B., Sanal Kumar, M.G., Vinod, P., 2015. Comparative study on the seasonal variations in the soil edaphic and chemical factors of agricultural and grass land habitats of Central Travancore Kerala. International Journal of Science and Research 4(2), 387–391.

Chase, P., Singh, O.P., 2014. Soil nutrients and fertility in three traditional land use systems of Khonoma, Nagaland, India.Resources and Environment 4(4), 181–189.

Chopra, S.L., Kanwar, J.S., 1991. Analytical Agricultural Chemistry. Kalyani Publishers, New Delhi-Ludhiana, 157–159 .

Das, A., Biswas, D.R., Das, D., Sharma, V.K., Das, R., Ray, P., Ghosh, A., Mridha, N., Biswas, S.S., 2019. Assessment of potassium status in soils under different land use systems of Assam. Indian Journal of Agricultural Sciences 89(7), 1077–1081.

Das, D., Nayak, A.K., Thilagam, V.K., Chatterjee, D., Shahid, M., Tripathi, R., Mohanty, S., Kumar, A., Lal, B., Gautam, P., Panda, B.B., Biswas, S.S., 2018. Measuring potassium fractions is not sufficient to assess the long-term impact of fertilization and manuring on soil's potassium supplying capacity. Journal of Soils and Sediments 18, 1806–1820.

Dluzewski, P., Wiatrowska, K., Kozlowski, M., 2019. Seasonal changes in organic carbon content in post-arable forest soil. Soil Science Annual 70(1), 3–12.

Dutta, M., Kichu, R., Mezhii, R., Ram, S., 2018.

Fertility status of soils under different land uses in Chiephobozou sub-division of Kohima, Nagaland. Journal of Soil and Water Conservation 17(3), 299–302.

Fageria, N.K., Carvelho, G.D., Santos, A.B., Ferreira, E.P.B., Knupp, A.M., 2011. Chemistry of low land rice soils and nutrient availability. Communications in Soil Science and Plant Analysis 42(16), 1913–1933.

Hadole, S.S., Sarap, P.A., Parmar, J.N., Lakhe, S.R., Rakhonde, O.S., Dhule, D.T., Sathyanarayan, E., Nandurkar, S.D., 2020. Study of soil chemical properties, available sulphur and micronutrients status of soils in Solapur district of Maharashtra. Indian Journal of Pure and Applied Biosciences 8(6), 67–72.

Hegde, R., Kumar, M., Niranjana, M.B.K.V., Seema, K.V., Dhanorkar, B.A., 2021. Study on the soil fertility and mapping in Ramasamudram-1 microwatershed of Yadgirtaluk and district of Karnataka, India. International Journal of Bio-resource and Stress Management 12(4), 348–360.

Jackson, M.L., 1973. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 41– 316.

Jiao, S., Li, J., Li, Y., Xu, Z., Kong, B., Li, Y., Shen, Y., 2020. Variation of soil organic carbon and physical properties in relation to land uses in the Yellow River Delta, China. Scientific Reports 10(1), 1–13. DOI doi.org/10.1038/s41598-020-77303-8.

Kavianpoor, H., Esmali Ouri, A., Jeloudar, J., Kavian, A., 2012. Spatial variability of some chemical and physical soil properties in nesho mountainous rangelands. American Journal of Environmental Engineering 2, 34–44.

Konyak, L., Sharma, Y. K., Sharma, S.K., Bordoloi, J., 2020. Fertility status, potassium fractions and acidity nature of thesoils of Mon district, Nagaland in relation to land uses. Journal of the Indian Society of Soil Science 68(2), 201–209.

Kumar, D., Dalal, R.P.S., Kumar, R., Parshad, J., Jaipal, J., 2021. Seasonal variation in microbial communities in rhizosphere and non- rhizosphere soil of different fruit tree species in semiarid irrigated conditions of Haryana. International Journal of Bio-resource and Stress Management 12(5), 468–476.

Majumdar, S., Patil, P.L., 2016. Sulphur dynamics under different land use systems of a micro-watershed in Northern transition zone of Karnataka. Ecology, Environment and Conservation 22(1), 207–213.

Manpoong, C., Tripathi, S.K., 2019. Soil properties under different land use system of Mizoram, North East India. Journal of Applied and Natural Science 11(1), 121–125.

McGrath, D.A., Comerford, N.B., Duryea, M.L., 2000. Litter dynamics and monthly fluctuations in soil phosphorus availability in an Amazonian agroforest. Forest Ecology and Management 131, 167–181.

Moges, A., Dagnachew, M., Yimer, F., 2013. Land use effects on soil quality indicators: a case study of Abo- Wonsho Southern Ethiopia. Applied and Environmental Soil Science 2013, 1–9. DOI doi.org/10.1155/2013/784989.

Negasa, D.J., 2020. Effects of land use types on selected soil properties in central highlands of Ethiopia. Applied and Environmental Soil Science 2020, 1–9. DOI doi.org/10.1155/2020/7026929.

Padhan, D., Pradhan, A.K., Chakraborty, M., Sen, A., 2016. Assessment of the effects of land use pattern on distribution of sulphur fractions in soil. Journal of Applied and Natural Science 8(3), 1685–1691.

Reza, S.K., Baruah, U., Nath, D.J., Sarkar, D., Gogoi, D., 2014. Microbial biomass and enzyme activity in relation to shifting cultivation and horticultural practices in humid subtropical North-Eastern India. Range Management and Agroforestry 35(1), 78–84.

Sainepo, B.M., Gachene, C.K., Karuma, A., 2018. Assessment of soil organic carbon fractions and carbon management index under different land use types in Olesharo Catchment, Narok County, Kenya. Carbon Balance Management 13(4), 1–9. DOI doi org/ 10.1186/ s 13021-018-0091-7.

Salim, M., Kumar, P., Gupta, M.K., Kumar, S., 2015. Seasonal variation in some chemical characteristics of the soils under different land uses of JhilmilJheel Wetland, Haridwar- Uttrakhand, India. International Journal of Scientific and Research Publication 5(10), 1–9.

Sharma, Y.K., Sharma, S.K., Sharma, A., 2015. Status of available nutrients and potassium fraction in soils of Dimapur, Nagaland in relation to land use systems. Annals of Plant and Soil Research 17(1), 50–54.

Shimrah, T., Rao, K.S., Saxena, K.G., 2015. Soil property variations under different land use/ cover types in traditional agricultural landscape in Northeast India. Journal of Chemistry, Environmental Sciences and its Applications 2(1), 73–79.

Singh, A.K., Bordoloi, L.J., Kumar, M., Hazarika, S., Parmer, B., 2014. Land use impact on soil quality in eastern Himalayan region of India. Environmental Monitoring and Assessment 186(4), 2013–2024.

Srinivasarao, C., Venkateswarlu, B., Lal, R., Singh, A.K., Kundu, S., 2013. Sustainable management of soils of dryland ecosystems of India for enhancing agronomic productivity and sequestering carbon. Advances in Agronomy 121, 253–329.

Tsanglao, C., Sharma, Y.K., Sharma, S.K., 2014. Fertility status and soil acidity under different land use systems in Wokha district of Nagaland. Journal of the Indian Society of Soil Science 62, 414–418.
Vasundhara, R., Hedge, R., Dharumarajan, S., Niranjana K.V., 2020. Spatial assessment of soil fertility status in Shiratti sub watershed of semi-arid tropics in Southern India. International Journal of Bio-resource and Stress Management 11(2), 163–170.
Wani, S.A., Najar, G.R., Padder, B.A., Akhter, F., Chand, S., 2017. Altitudinal and depth-wise variation of soil physico-chemical properties and available nutrients of pear orchards in Jammu & Kashmir, India. Chemical Science Review and Letters 6(23), 1638–1645.

