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Soil Nutrients and Fertility in Three Traditional Land Use Systems of Khonoma, Nagaland, India

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Abstract Status of soil nutrients and fertility was studied in three traditional land use systems *viz* Natural Forest (NF); Alder based Jhum Fallow (JF) and Wet Terrace Paddy cultivation (PF) in Khonoma, Nagaland located in North- East India. Soil samples were collected from the three sites and soil fertility indicators such as pH, mineralizable Nitrogen (N), available Phosphorus (P), available Potassium (K), Soil Organic Carbon (SOC) and Soil Organic Matter (SOM) were analyzed using standard procedures. The soil of Natural Forest was found to be most fertile based on the calculated Nutrient Index followed by Alder based Jhum Fallow and Paddy Fields. The analysis of variance (ANOVA) showed significant ($P< 0.05$) differences among the three land use types with regard to the soil nutrients studied. These results showed that land use types have significant effect on soil nutrients and thus its fertility. Continuous agricultural activities deplete soil fertility, but by maintaining a period of fallow this decrease in soil fertility is reclaimed. The rate of reclamation from a nutrient deficient condition to nutrient rich condition is found to be enhanced in the study site by growing and maintaining *Alnus nepalensis* D Don, more popularly known as the Alder tree. This is evident from the present study of soil nutrients from 2-5 years old jhum fallows showing soil properties ranging between soils of paddy fields and Natural Forest. The study thus establishes that land use should be chosen with care to preserve the quality of the soil.

Keywords Jhum fallow, Paddy field, Soil nutrients and fertility, Khonoma

1. Introduction

Forest ecosystems are important both ecologically and economically, and forest soil is the most fundamental terrestrial asset and natural resource [1]. However, non-forest activities are expanding rapidly worldwide at the expense of natural forests and at a pace which is much faster in environmentally fragile mountainous areas. Globally, agricultural expansion and infrastructural development contributes 37% of forest degradation, responsible for one third of tropical deforestation [7]. Land use in tropical areas cause significant modifications in soil properties in which agriculture have a major contribution [14] and especially cultivation of deforested land, may rapidly diminish soil quality [2]. These changes in land use is often localized and site specific, however their impacts collectively lead to changes in the larger global scale resulting in desertification, biodiversity loss, global warming, etc. Apart from land use, soil degradation also depends on soil types, topography and climatic factors. Tropical soils around the world are widely known to be declining in fertility. Soil is a non renewable resource and the need to protect, maintain or improve its ability to perform a myriad array of functions has been widely acknowledged. Thus, if used inappropriately it may deteriorate over a short period of time, with very little prospect for regeneration [24].

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To circumvent the difficulties of the hilly terrain, in North-East India, the local communities have developed unique indigenous farming systems based on local resources, which facilitate conservation as well as effective and efficient use of natural resources [27]. Three traditionally practiced agricultural systems forms the major land use in the tropical forest of Khonoma in Nagaland viz., Natural Forest, Alder based Jhum (shifting cultivation intercropped with *Alnus nepalensis* D. Don) and Wet Terrace Paddy cultivation. *Alnus nepalensis* D. Don is more commonly known as Alder trees. Hereafter, Alder based Jhum Fallow and Wet Terrace Paddy Fields will be referred to as Jhum Fallow (JF) and Paddy Field (PF) for convenience. The repeated use of cultivable land with short jhum cycle is feared to convert the Jhum Fields into wastelands. The region is bestowed with rich natural resources of soil, water, and climate [27] but high rainfall and mismanagement of rainwater has resulted in extreme soil erosion through runoff in the hills [26]. Studies on impact of jhum on soil are thus warranted to determine how availability of soil nutrients and soil fertility can be maintained and the land use systems improved. The Paddy Fields of Khonoma are intensively cultivated throughout the year, with a single crop of rice and a variety of vegetable crops are grown in succession after the harvesting of rice.

North-East India is becoming increasingly deforested and its crop productivity is declining primarily due to shortening of jhum cycle [21]. Natural as well as anthropogenic activities have rendered natural resources *viz* soil, water, and forests, vulnerable to such an extent that river flow during the monsoon causes landslides and erosion, and during dry season, the problem of water shortage ensues [27].

The effects of cropping systems and management practices on soil properties provide essential information for assessing environmental impact [10]. Analyzing the soil nutrient status to overcome the problems of ecological imbalance for sustainable crop production is one such method.In Khonoma, with increasing population, demand for food and fuel increased and land availability for agriculture has reduced. As a result, both these forms of traditional cultivation are getting modified and are being overused. In this study, the effects of land use systems are evaluated on the selected indicators of soil fertility to evaluate the changes in response to two different traditional agricultural land uses, taking forest as the control.

2. Study Area

The study was conducted at Khonoma (Longitude E94˚2'0" Latitude N25˚39'0) located about 20 km west of Kohima, the capital town of Nagaland, India. With its location at the foothill of the Barial range, Khonoma is a part of the Eastern Himalaya and Indo-Burma Biodiversity Hotspot [5]. The study area covers an area of about 123Km^2 with elevation ranging from 1200 m to 2868 masl. The population of the village is 2,500 comprising of 500 households. The study area receives an annual rainfall of 2000 to 2500 mm from May to September, with a warm climate followed by dry and cold winter season from October to March. Atmospheric temperatures vary from 15℃ to 30℃ in summer and less than 5℃ to 25℃ in winter. Major soil types found in Khonoma are inceptisols which are soils in the beginning stages of formation and ullisols, base poor mineral soils developed under high rainfall and forest vegetation [15].

Prior to any form of cultivation operating in Khonoma, a rich forest resource abounds in the area. A large part of these rich forests is still being preserved (Figure 2A). Agriculture is the main occupation of the Khonoma people and, Natural Forests, Alder based Jhum cultivation and Wet Terrace Paddy cultivation together represents the predominant traditional land use systems [5]. These systems of cultivation are best suited for the region under the prevailing climatic condition and topography. Alder based jhum among the Angamis is well developed in Khonoma village [11]. All kinds of essential crops like rice, maize, millet, soyabeans, potato, etc., are planted in mixture. The lands are abandoned after 2 years of cultivation for natural build up of soil fertility and regeneration of vegetation for 3-5 years (Figure 2B). With the capability of fixing Nitrogen and being fast-growing, the native tree *Alnus nepalensis* D. Don., intercropped in jhum fields in Khonoma requires less rejuvenation period. Wet Terraced Paddy cultivation is practiced throughout the hilly terrain, both at low and high elevations (Figure 2C). This form of cultivation system is a sedentary land use system based on the cultivation of paddy or rice (*Oryza sativa*) on soil flooded naturally or artificially induced. Some people continued the old tradition of planting only rice while others planted upto a dozen crops in addition to rice [4]. Paddy fields continue to produce good crops by use of Farm Yard Manure (FYM) and nutrient wash-out from the hill slopes and people do not make use of fertilizers. This land use system is cultivated year after year, unlike the jhum system that undergoes cropping once or twice in a few years of fallow interval depending upon the jhum cycle.

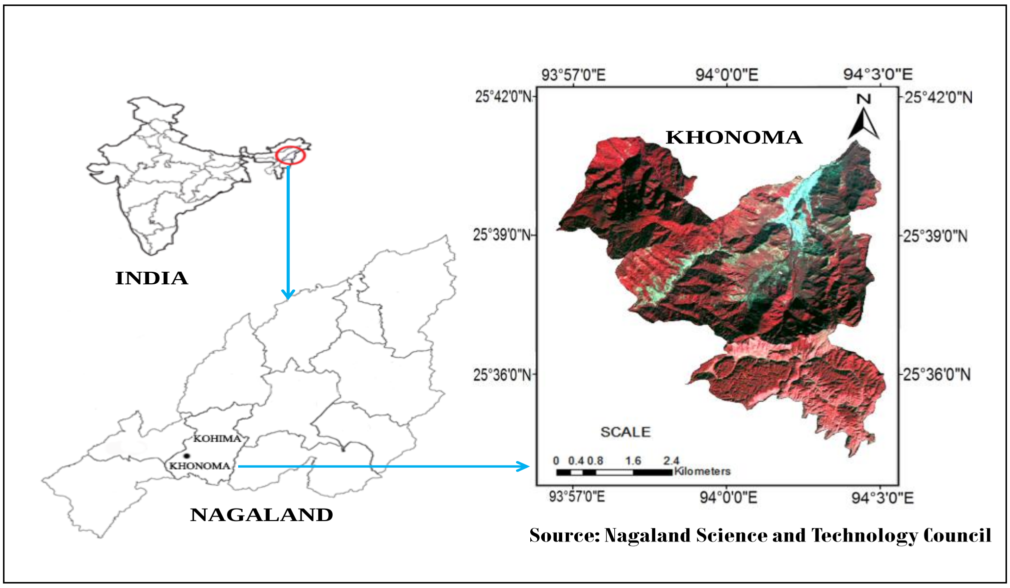

Figure 1. Location map of Khonoma Village, Nagaland

A) Natural forest

B) Alder based Jhum fallow (circled)

C) Wet terrace paddy fields

Figure 2. Photographs showing a view of major land use system in Khonoma, Nagaland. A) Natural Forest; B) Alder based Jhum Fallow [encircled in yellow] and C) Wet terrace Paddy Fields

3. Methodology

Soil samples from three different land uses – Natural Forest, Jhum Fallow and Paddy Field were collected from the study area. Five replicates of the samples were collected at a depth of 0-20 cm at each site. These samples were then analyzed at the Soil Survey Laboratory, Directorate of Soil and Water Conservation, Kohima, Nagaland. The soil quality parameters such as pH (pH meter), mineralizable N (Kjeldahl method), available P (spectrophotometer), available K (flame photometer), SOM and SOC (Walkley-Black method) were analysed.

Based on the soil test values for different nutrients, soils were classified into three categories *viz* low, medium and high nutrient status (Table 1). Using these fertility classes as proposed by [20], Nutrient Index was calculated using the following equation (1).

$$\text{Nutrient Index (NI)} = \frac{(NL * 1 + NM * 2 + NH * 3)}{NT} \quad (1)$$

Where, NL, NM and NH are number of samples falling in low, medium and high classes of nutrient status, respectively and NT is total number of samples analyzed for a given area.

Table 1. Soil fertility ratings based on soil test values

Soil test	Low	Medium	High
N [alkaline permanganate method (kg ha^{-1})[a]]	<280	280 to 560	>560
P [Olsen's method in alkaline soil (kg ha^{-1})[a]]	<10	10-25	>25
K [Neutral N, ammonia acetate method(kg ha^{-1})[a]]	<108	108-280	>280
SOC [as a measure of available N (%)[a]]	<0.5	0.5-0.75	>0.75
SOM [% of Organic Carbon][b]	< 1	1.0-1.5	>1.5%

Source: a-Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India (2011); b-[18]

Descriptive statistics in the form of mean, minimum, maximum, median, standard deviation (SD), range, skewness and kurtosis were determined. All data were analyzed using SPSS software and MS Excel. Statistical comparisons of soils under different land use systems were performed by one-way analysis of variance (ANOVA). Land use class was the factor and soil fertility indicators are the dependents. Significant F-values were obtained and statistical significance was determined at a level $p<0.05$.

4. Results and Discussions

Soil parameters such as pH, N, P, K, SOC and SOC were studied in three land use systems *viz* Natural Forest, Jhum Fallow and Paddy Field. Results show that, all the measured soil parameters varied under the influence of the three land use systems (Table 3).

4.1. Statistical Descriptions

The descriptive statistics (Table 2) of the soil nutrients studied suggested that they were all normally distributed with the values of the skewness of the various variables analysed lying within the range of -1 to +1. Skewness values of soil properties in the Paddy Field showed low deviation from normal distribution.

Table 2. Summary of the Statistics for Selected Soil Nutrients in Different Land Uses in Khonoma

Variables	Unit	Land use	Mean	Min	Max	Median	S.D	Range	Skewness	Kurtosis
pH	-	NF	5.14	4.6	5.6	5.2	0.37	1	-0.47	0.58
		JF	4.82	4.5	5.2	4.8	0.25	0.7	0.56	0.79
		PF	5.52	5.1	5.8	5.6	0.31	0.7	-0.55	-1.91
N	Kg ha^{-1}	NF	202.55	190.45	215.77	200.56	10.54	25.32	0.24	-2.01
		JF	159.49	157.12	162.05	159.52	1.93	4.93	0.14	-0.95
		PF	47.34	42.14	50.17	48.16	3.36	8.03	-1.06	-1.06
P	Kg ha^{-1}	NF	14.1	12.04	16.4	14.39	1.97	4.36	-0.06	-2.62
		JF	17.18	14.92	18.99	17.57	1.77	4.07	-0.39	-2.28
		PF	11.77	10.98	12.4	11.9	0.55	1.42	-0.57	-0.57
K	Kg ha^{-1}	NF	109.31	92.4	124.32	108.36	14.37	31.92	-0.01	-2.59
		JF	130.68	127.82	133.28	130.14	2.19	5.46	-0.06	-1.31
		PF	48.63	45.68	52.12	48.72	2.46	6.44	0.36	-0.23
SOC	%	NF	2.85	2.61	2.99	2.89	0.16	0.38	-0.86	-0.48
		JF	2.37	1.76	2.99	2.46	0.55	1.23	-0.13	-2.72
		PF	1.03	0.94	1.12	1.06	0.08	0.18	-0.34	-2.81
SOM	%	NF	6.7	6.62	6.81	6.7	0.06	0.19	0.51	2.06
		JF	4.08	3.03	5.15	4.24	0.95	2.12	-0.14	-2.71
		PF	1.78	1.62	1.93	1.82	0.14	0.31	-0.30	-2.79

NF - Natural forest; PF - Paddy field; JF - Jhum fallow; S.D - Standard deviation; (n=15)

4.2. Soil Nutrients in the Three Land Use Systems

The soils of the three study sites are acidic with a mean pH of 5.16 in water since a pH value of 6.5 and less is considered acidic. The acidic soil reaction can be attributed to decomposition of SOM which releases organic acids leading to leaching of bases from the exchange complex under the prevailing high rainfall and hilly topography. Statistically significant difference (0.015 at $p<0.05$) on soil pH due to land use was found in the three sites (Table 3). The pH of the different land use follows the order Jhum Fallow > Natural Forest > Paddy Field. The pH of the soil at the study sites ranged from 4.6 to 5.6; 4.5 to 5.2 and 5.1 to 5.8 in Natural Forest, Jhum Fallow and Paddy Field respectively. The soils of the region are highly acidic and forest production on acid soils that are poor in basic cations is limited by mineral deficiencies [27]. The pH range of most productive agricultural soils is between 5.5 and 7.5 [30]. The pH of Paddy Fields in the study is found to be within this range and thus accounts for continued production of good crops with the use of Farm Yard Manure (FYM) and nutrient wash-out from the hill slopes without the use of fertilizers.

N is a commonly limiting nutrient for plant growth in tropical soils and its availability is important to soil fertility [12]. N is found to be present in the highest amount in Natural Forest as compared to the other land use studied [14]. In the present study, amount of N in kg ha^{-1} follows the order Natural Forest (202.55)> Jhum Fallow (159.49)>Paddy Field (47.34) and is significantly different among the three land use type at $p<0.05$. The litter availability in Natural Forest and Jhum Fallow increases resource availability on the forest floor that can be colonized, decomposed and mineralized by the microorganisms, and also retains moisture on the forest floor which may induce SOM decomposition and nutrient mineralization in the soil [12]. N cycling is altered by human activity [24]. There is a consistent finding that intact tropical forests with less human disturbance often harbours N in high supply relative to other essential nutrients [29]. N in the present study is in agreement with these findings with a mean of 202.55 kg ha^{-1} as compared to 14.1 kg ha^{-1} of P and 109.31 kg ha^{-1} of K. Many studies have reported increased N loss from forest ecosystems following the cutting of trees [12]. Very less amount of N (47.34 $kgha^{-1}$) in paddy fields can be attributed to the negligible number of trees grown, leading to lesser availability of SOM. Also burning of biomass and debris, a common practise in paddy fields reduces N stocks [9]. N are most susceptible to surface change, where physical changes such as removal of live vegetation and forest floor litter exacerbate erosion, runoff, and the leaching of mineral N not taken up by plant roots [13].

The available P content in Khonoma ranged between 11.77 and 17.18 kg ha^{-1}. Very little variation in the status of P was observed among the three land uses with (17.18±1.77) kg ha^{-1} in Jhum Fallow > (14.1±1.97) kg ha^{-1} in Natural Forest > (11.77±0.55) kg ha^{-1} in Paddy Fields. The less variability in the amount of available P in the soils from all the three land uses indicates that these parameters are less prone to changes in land use and cover [30]. Higher concentration of P in Jhum Fallows as compared to Natural Forest maybe attributed to rapid P cycling in young secondary forests by decomposition and the mineralization of more P-rich litter which help to maintain greater concentrations of P in these soils, until uptake and accumulation in living biomass removes P from this cycle [13]. Acidic soils fix P resulting in low available P in all land uses sampled in this study. P in soil is unavailable to plants because they are highly insoluble. Plant uptake, erosion, leaching and fixation can be accounted for lower amount of P from the soil system in all the land use types.

Table 3. ANOVA for Selected Soil Properties under Different Land Uses in Khonoma

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	1.228	2	.614	6.099	.015
	Within Groups	1.208	12	.101		
	Total	2.436	14			
N	Between Groups	64202.756	2	32101.378	762.692	.000
	Within Groups	505.075	12	42.090		
	Total	64707.831	14			
P	Between Groups	59.570	2	29.785	9.270	.004
	Within Groups	38.558	12	3.213		
	Total	98.128	14			
K	Between Groups	18117.712	2	9058.856	124.902	.000
	Within Groups	870.336	12	72.528		
	Total	18988.048	14			
SOC	Between Groups	8.834	2	4.417	38.920	.000
	Within Groups	1.362	12	.113		
	Total	10.196	14			
SOM	Between Groups	60.752	2	30.376	97.317	.000
	Within Groups	3.746	12	.312		
	Total	64.498	14			

Exchangeable K of soils of the Jhum Fallow (130.68 kg ha^{-1}) was significantly higher ($p < 0.05$) than the soils of Natural Forest (109.31 kg ha^{-1}) and Paddy Fields (48.63 kg ha^{-1}). In the present study, Jhum Fallow with the highest K content can be attributed to rapid recycling of soil nutrients from Alder trees. The different species of trees that thrives in the Natural Forests and Jhum Fallows may affect the availability of K in the soil. The larger number of Alder trees in Jhum Fallow might be responsible for the higher amounts of exchangeable K in jhum fallows. The K in soils of Natural Forests may be because of the contribution from an undisturbed ecosystem where there is a natural balance and no removal of residues that removes K [30]. Less use of FYM and no addition of chemical fertilizers in Paddy Fields may have resulted in low K content since the nutrient taken up by the crops were not replaced due to lack of SOM in Paddy Fields that can be replaced by litter fall from trees in Jhum Fallows and Natural Forests. The low level of K in paddy field is also due to poor recycling of nutrients from crop and grass residues due to grazing of livestock on crop residues remaining on the land after harvest. Therefore, in general the relatively low amount of K in cultivated land uses is likely as a result of the removal of vegetation.

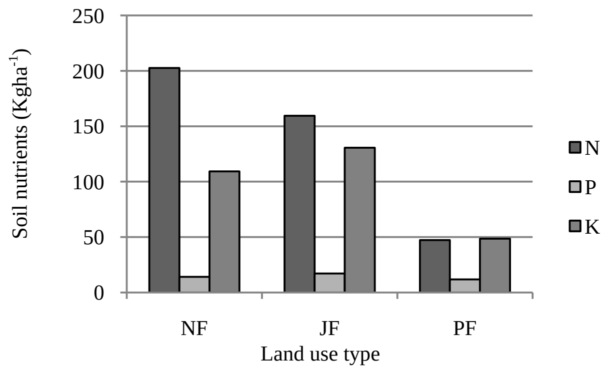

Figure 4. Variation in NPK in soils of Natural Forest (NF), Jhum Fallow (JF) and Paddy Field (PF)

SOM and SOC of Natural Forest soils are found to be higher than in the other land use types [8]. In the present study, SOC content was higher in Natural Forest (2.85%), followed by Jhum Fallow (2.37%) and least in soils of Paddy Fields (1.03%). Maintaining SOC levels in tropical soils was found to be more difficult because of its rapid oxidation under prevailing high temperatures. The lowest content of SOC in soils of the Paddy Field is due to the rapid decomposition and mineralization of SOM following the clearing of fields of the harvested crops and burning because of low temperature and low pH. Decomposition rates of SOM increases with increasing temperatures and pH. Therefore, proper management of SOC is important for sustaining soil productivity and ensuring food security as well as protection from land degradation.

SOM is widely regarded as the single most important indicator of soil fertility. The average SOM value ranged from (3.94 to 5.15) % in Natural Forest> (3.03 to 5.15) % in Jhum Fallow > (0.75 to 1.96) % in Paddy Fields. The SOM for Natural Forest showed higher value compared to that of the Jhum Fallow and Paddy Fields. This is because the soils under forest are not subjected to tilling and are not exposed to disturbances and erosion [2]. Less erosion is in turn due to sufficiently closed canopy and the availability of large amounts of ground cover in the form of leaf litter. Statistically significant differences in SOM of Natural Forest and Jhum Fallow from Paddy Fields can be attributed to various disturbances that negatively changes soil temperature, moisture, and aeration, and thus, enhance the decomposition of SOM [13]. Besides comparatively higher SOM in Jhum Fallow can be attributed to development of herbaceous layer over a short period of time that reduces soil erosion and increase in SOM content through biomass production. The amount of SOM is least in Paddy Fields as disturbances are more due to various activities involved in cultivation of crops without any fallow period. The increase in SOC oxidation is due to higher soil surface temperatures in arable soils as compared to soils under forests [9]. It is a well known fact that, the SOM is fundamental to the maintenance of soil health because it is essential to the optimal functioning of a number of processes important to sustainable ecosystems. SOM is a source and a sink of Carbon and Nitrogen and partly of Phosphorus and Sulphur [24].

4.3. Nutrient Index of Soils in Different Land Uses

The nutrient index values of selected soil nutrients *viz* N, P and K of the three land use were calculated based on the equation (1). These nutrient index values were then characterized as Nutrient Index category I, II and III (Table 4).

Table 4. Nutrient Index with Range and Remarks

Nutrient index	Range of soil nutrients	Fertility level
I	Below 1.67	Low
II	1.67 – 2.33	Medium
III	Above 2.33	High

The results of fertility status of the three macronutrients – N, P and K of the soil was determined for three land use categories and are summarized in Figure 5. The calculated values alongwith the corresponding nutrient index categories are given in Table 5. Soils are not rated on the basis of SOM content. This is because rapid changes SOM do not occur under normal crop management. N was found to have a high fertility status in Natural Forest and Jhum Fallow, while comparatively lesser but sufficient N fertility status was reported in Paddy Fields. Soils containing higher amounts of SOM generally are capable of releasing higher quantities of N [3]. In all the three land uses, P attained a medium value. The P values from this study indicate that there is sufficient available P in the soils of the three land uses tested. In Natural Forest and paddy fields K was found to be low while a sufficient amount of K with a medium fertility status found in Jhum Fallow.

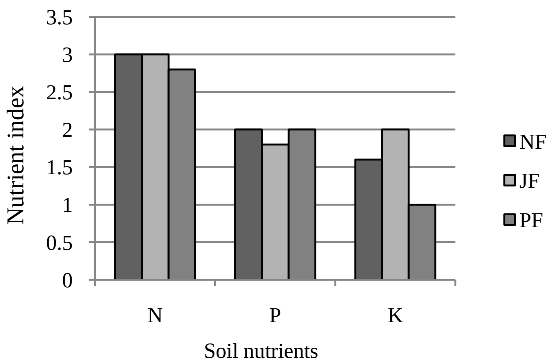

Figure 5. Soil nutrient index based on NPK levels for Natural Forest (NF), Jhum Fallow (JF) and Paddy Field (PF)

Only Paddy Fields was in agreement with the study of fertility status of soil under forest and cultivated land use system in a Nagaland, that nutrient availability status of N, P and K ranged from low to medium [28]. Natural Forest and Jhum Fallow in this study both showed high to low and high to medium fertility status respectively.

Table 5. Nutrient Index of Soils of Natural Forest (NF), Jhum Fallow (JF) and Paddy Field (PF) in Khonoma

Land use	Nutrients	NI values	NI	Fertility status
NF	N	3	III	High
	P	2	II	Medium
	K	1.6	I	Low
JF	N	3	III	High
	P	1.8	I	Medium
	K	2	II	Medium
PF	N	2.8	II	Medium
	P	2	II	Medium
	K	1	II	Low

4.4. Soil Fertility in Three Land Use Systems

Natural Forest was found to be richest in N, SOC and SOM while Jhum Fallow had the highest amount of P and K. The poorest in soil nutrients was found in Paddy Fields for all the soil nutrients analysed, where agricultural operation persists throughout the year without any fallow period and are cultivated devoid of any trees.

Higher amounts of SOC, SOM and N were found in Natural Forest soils in agreement with a study of soils in Nagaland [28]. There was less variation between Natural Forest and Jhum Fallow on the amount of these soil nutrients. The higher availability of soil nutrients and thus, soil fertility status in Natural Forest could be due to the fact that the forest floor is herbaceous and abundant in leaf litter that covers the soil surface and does not withhold plant nutrients for a long period in the standing biomass which may otherwise lead to a extended period of nutrient cycling. Also SOM in the forested land was higher than in the other land uses, since the soil in the Natural Forest was not tilled or exposed to erosion [2]. This can also account for the higher SOM value in Jhum Fallow than in Paddy Field since tillage and erosion is comparatively lesser in Jhum system. Forest soils are more sensitive to acidification by strong mineral acids. Soil fertility thus depends on the SOM supplied by the natural vegetation and the nutrient cycling. Comparatively lower soil fertility status was reported in regenerating Jhum Fallow than Natural Forest. This is due to higher soil acidity conditions in soils of Jhum Fallow. The higher pH and the amount of P and K in the Jhum Fallow can be attributed to the fact that, during the slash and burn operation in the Jhum fields, the ash deposited by the burning of biomass practice releases K and P, causing higher pH and available P. The higher amount of nutrients responsible for soil fertility in Jhum Fallows as compared to Paddy Fields can be because of the Alder trees intercropped in all the Jhum fields in Khonoma. In the absence of fast nutrient cycling trees such as the Alder tree, 10 years of fallow period is necessary for overall soil fertility improvement from a net transfer of nutrients back to the soil [19]. N fixing Alder trees contribute substantially to overall soil fertility on farmlands since many such trees are fast growing and produce high quality, high protein livestock fodder and green manure. This leads many tropic and sub tropic highlands to intensively develop and support large human populations where indigenous actinorhizal N-fixing trees are widely employed in agroforestry systems [31]. Besides fixing atmospheric N, the litter of the trees add to the soil P, K, Ca, and other nutrients [25]. Normally a Jhum field is cultivated for two years within a nine-year cycle, but the Alder system allows two harvests in two out of every four to five years [17]. In Khonoma Alder based Jhum fields, fallow period as short as 2 years are sufficient for cultivation [4]. The availability of SOC and other major soil nutrients such as N, P and K increase in post burning fallow periods from 3-4 years onward and soils exhibited consistent increase in fertility built up [6]. In addition, Jhum Fallows might have especially taken advantage of the residual effect of the wood ash from the slash-and-burn practice. The burning of forest residues practiced during land clearing is leading to considerable nutrient loss from the ecosystem. Approximately 50 kg N ha^{-1} was released in a 24-month period from litter fall in pure stands of Alder trees [22]. Total soil Nitrogen, available Phosphorus, exchangeable Potassium, exchangeable Calcium, and Organic Carbon have been shown to increase with age under stands of Alder trees [23].

The lowest SOC, SOM and Nitrogen level of soil was recorded in Wet Terrace Paddy fields. This is primarily attributed to fast oxidation of SOM, washing away of nutrient rich top soil with runoff water, rapid decomposition, poor recycling back of crop residues, continuous and intensive cultivation of crops without replenishment of nutrients through chemical fertilizers. Burning of crop residue and mismanagement of Farm Yard Manure can further lower values of SOC and N in Paddy cultivation. Continuous cultivation of soils reduces SOM by facilitating interactions of physical, chemical and biological soil processes that increases its decomposition rate. The puddling process in rice cultivation for transplanting the rice seedlings which breaks the soil aggregates and subjects the entrapped SOM fractions to further loss ultimately lead to poor soil structure. In paddy fields, exposure of the soil surface to heavy rains brings about erosion; plowing destroys and leads to rapid decomposition and mineralization of SOM, and intense leaching of nutrients thereby reducing the contribution of organic and microbial processes to nutrient cycling. The conversion of Natural Forest to cultivated land is manifested the most in the on-site loss of SOM causing a reduction in nutrient stock, CEC, and structure stability [9].

In general, the results of soil analysis revealed less availability of soil nutrients among the three different land uses. This can be attributed to the non use of chemical fertilizers in the study area. Only small scale Farm Yard Manures are used as soil additive for vegetable crops in Paddy Fields.

5. Conclusions

The conversion of Natural Forests into agriculture had resulted in changes in the availability of soil nutrients compared to soils in its natural state and shows statistically significant decreases in the amount of nutrients responsible for soil fertility. According to the soil fertility tests based on the calculated nutrient index of N, P and K, the soils of Natural Forest shows soil fertility status from high to low category; high to medium category for Jhum Fallow and medium to low category for Paddy Fields. Long-term continuous cultivation in the Wet Terrace Paddy cultivation system in Khonoma village significantly ($p<0.05$) decreased the SOM content in the soils. While Alder based Jhum practised with an interval of 2 years of cropping followed by 3-4 years or even a minimum of 2 years fallow period resulted in accumulation of substantial soil nutrients and does not show statistically significant difference in soil fertility indicators as compared to that of Natural Forest. This indicated that planting of well-adapted, native and fast-growing trees such as Alder trees can gradually improve the soil quality and rehabilitate degraded lands. In areas where agriculture depends on rainfall, attention should be focussed on conservation of soils on the hilly slopes by preventing deforestation and establishing appropriate forest cover and improving the existing forests. The decline of soil fertility is a major concern in relation to food production and the sustainable management of land resources [9]. These results confirms studies conducted around the world on the effect of land use on soil fertility and validate the finding that while agriculture significantly decrease soil fertility, degradation can be reversed and soil nutrient loss reclaimed by maintaining a period of fallow leading to subsequent regeneration of forest. The soils from Alder based Jhum Fallows in the present study showed soil properties similar to that of the Natural Forest. Sustained forest productivity requires the use of techniques which reduce nutrient export, increase nutrient accumulation in the biomass, increase efficiency of nutrient absorption and utilization and conservation of water in the system [27]. A balanced tree-crop combination is ideal for both production and maintenance of soil health [14].Thus we can conclude that, in the absence of proper management, the conversion of Natural Forest to cultivation leads to decrease in soil nutrients and thus, its fertility.

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