



## Effect of land use systems on various soil properties under Mokokchung district of Nagaland

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### Abstract

A soil survey was conducted under Mokokchung district of Nagaland to study the effect of land use systems *viz.*, forest, kitchen, *jhum*, banana and tapioca on soil properties. From the experiment it was found that the pH of the different land use systems were strong to moderately acidic with normal electrical conductivity and low cation exchange capacity. On an average, the bulk density varied from 1.12 to 1.18 g cm<sup>-3</sup>, particle density varied from 2.29 to 2.37 g cm<sup>-3</sup> and porosity ranged from 49.77 to 51.05%. On the basis of nutrient index, the soils were found to be high in organic carbon content and medium in available N, P, K and S under the different land use systems. It was found that the effect of land use systems had a significant effect on soil physicochemical properties such as cation exchange capacity, bulk density, particle density and porosity, soil fertility properties such as organic carbon, available nitrogen, phosphorus and sulphur and soil acidity parameters such as total potential acidity, exchangeable acidity, exchangeable Al<sup>3+</sup>, exchangeable H<sup>+</sup> and extractable acidity.

**Keywords:** land use systems, nutrient index, physicochemical properties, fertility properties, acidity parameters

### Introduction

Soil is an important vital medium for healthy growth of plants by providing essential nutrients, giving life support and nutrition to all living organism and human beings. Healthy soil is essential for a productive, profitable and sustainable agriculture. The world is facing major challenges of deforestation, excessive use of fertilizer, pesticides and population expansion. These lead to poor soil fertility and productivity and decrease in soil quality thereby increasing soil degradation. Around 48-49 Mha of land in India under cultivation is acidic in reaction (Maji *et al.*, 2012) [18] which is detrimental to plant growth and productivity. Therefore, various types of soil acidity and physicochemical properties as well as soil fertility in such areas should be assessed to improve the soil health and suggest right packages of practices to the farming community. A vast area of land in Nagaland is acidic in reaction which adversely affects agriculture (Mishra *et al.*, 2017) [20]. This acidity is brought about by various land use systems resulting in soil degradation thereby affecting the soil physicochemical and biological properties of the soil. Proper land use system and planning can reduce the soil degradation and enhance the production and productivity of crops sustainably (Gomiero, 2016) [13]. The practice of shifting cultivation in this region also affects the soil adversely. The reduction in *jhum* cycle to accommodate the increasing population also hinders the soil to recover from the nutrient exhaustion and thus creates problem of poor soil health and crop production. Incorporation of proper management practices, right amelioration, recommendation of nutrient doses and soil test will improve the soil fertility, soil health and optimize the crop production. Therefore, this research was conducted to understand the physicochemical properties under various land use systems.

### Materials and methods

The experiment comprised of soil survey and analysis for assessment of the various soil physicochemical properties.

Soil samples were collected from 5 land use systems *viz.*, forest, kitchen, *jhum*, banana and tapioca from 12 different villages under Mokokchung district of Nagaland located at 26.33°N 94.53°E. This district receives an average rainfall of 2039 mm and an average temperature of 18.6°C. Altogether, 60 composite soil samples were collected at a depth of 0-15 cm with the help of a khurpi and spade. Stones, pebbles, and plant debris were carefully removed from the collected soil samples. The soil samples were air dried, sieved through a 2 mm sieve and analysed in the laboratory. Soil pH and electrical conductivity (EC) was determined as described by Richards (1954) [28], cation exchange capacity as described by Chapman (1965) [7], bulk density as described by Chopra and Kanwar (1976) [8], particle density and porosity as described by Baruah and Barthakur (1997) [4], organic carbon, available P and K as described by Jackson (1973) [14], available N as described by Subbiah and Asija (1956) [36], available S as described by Williams and Steinberg (1959) [38], total potential acidity, exchangeable acidity, extractable acidity and exchangeable Al<sup>3+</sup> as described by Baruah and Barthakur (1997) [4]. The exchangeable H<sup>+</sup> was estimated by the difference between exchangeable acidity and exchangeable Al<sup>3+</sup>. pH dependent acidity of the soil was calculated by subtracting exchangeable acidity from total potential acidity. Statistical analysis was done using Duncan Multiple range test by David B. Duncan in 1955 [11].

### Results and discussion

#### Physicochemical properties

##### Soil pH

The soil pH under different land use systems were 4.93, 4.81, 4.73, 4.68 and 4.69 for forest, kitchen, *jhum*, banana and tapioca land use system (Table 1). The highest acidity was found to be under banana land use system followed by tapioca, *jhum*, kitchen and forest land use system which were strong to moderately acidic in reaction irrespective of the different land use systems. The land use system also had

a non-significant effect on soil pH. The acidity of soil might be attributed to the heavy rainfall received in this region which leads to runoff and leaching of basic cations. Similar findings were also reported by Golla (2019) [12] and Bedassa (2010).

### Electrical conductivity (EC)

The Electrical Conductivity (EC) under various land use systems were 0.22 dSm<sup>-1</sup> for forest, 0.22 dSm<sup>-1</sup> for kitchen, 0.19 dSm<sup>-1</sup> for *jhum*, 0.20 dSm<sup>-1</sup> for banana and 0.20 dSm<sup>-1</sup> under tapioca land use system as shown in Table 1. The effect of land use systems was found to be non significant on soil EC. It has been found that there is no negative impact on the crops due to the EC of soluble salts content. This might be because of heavy rainfall causing leaching of soluble salts (Rajeshwar and Khan, 2007, Qian *et al.*, 2001 and Pariente., 2001) [27, 26, 25]. It is also evident that the forest soils have slightly higher EC values than the soils under the other land use systems. This might be due to the higher amount of organic matter in the forest soils which helps to retain the cations in the soil (Ross *et al.*, 2008) [29].

### Cation exchange capacity (CEC)

The CEC of the soil under various land use system were 18.1 cmol (p+) kg<sup>-1</sup> under forest, 15.3 cmol (p+) kg<sup>-1</sup> under kitchen, 14.3 cmol (p+) kg<sup>-1</sup> under *jhum*, 14.7 cmol (p+) kg<sup>-1</sup> under banana and 14.8 cmol (p+) kg<sup>-1</sup> under tapioca land use system as shown in Table 1. It was found that the CEC of the forest soils were higher as compared to the other land use systems. This might be due to the high organic matter content of the forest soils as reported by Rudramurthy *et al.*, (2007) [30]. The effect of land use systems on soil CEC was also found to be significant.

### Organic carbon

From the given data (Table 1), it can be observed that the organic carbon was significant for all the land use systems and was recorded as 3.11% under forest, 2.29% under kitchen, 2.03% under *jhum*, 1.86% under banana and 1.91% under tapioca land use system respectively. The nutrient index for organic carbon was calculated as 3 for all the five land use systems (Table 4) which indicated that the soils of Mokokchung district had high fertility status in terms of organic carbon as it fell under the high category of organic carbon as reported by Sarkar (2009) [32]. In general, OC was

found to be highest under forest land use system. Yitbarek *et al.* (2013) [39], Alaie *et al.* (2019) [1] and Namei *et al.* (2016) [24] also had reported similar findings. This may be a result of the contribution of the forest vegetation to the soil biomass through its decomposition into organic matter as reported by Tripathi *et al.* (2007) [37] who stated that the higher organic carbon content in the soil of forest land use system is due to the continuous addition of decayed vegetation in the forest.

### Bulk density

The bulk density of the soil under different land use systems was found to be significant. The bulk density recorded under forest land use systems were 1.11 g cm<sup>-3</sup>, 1.14 g cm<sup>-3</sup> under kitchen, 1.16 g cm<sup>-3</sup> under *jhum*, 1.15 g cm<sup>-3</sup> in banana and 1.15 g cm<sup>-3</sup> under tapioca land use system (Table 1). Many researchers have observed that the forest land upon conversion to cultivated land aggravates the fertility of the soil owing to high bulk density which is attributed to the low organic matter in the cultivated soils as opposed to low bulk density due to high organic matter content in the forest. Similar findings were reported by Athira *et al.*, 2019 and Amanuel *et al.*, 2018 [3, 2].

### Particle density

The effect of land use system on particle density was found to be significant. The particle density of the soils under different land use systems were 2.37 g cm<sup>-3</sup> (forest), 2.37 g cm<sup>-3</sup> (kitchen), 2.35 g cm<sup>-3</sup> (*jhum*), 2.29 g cm<sup>-3</sup> (banana) and 2.27 g cm<sup>-3</sup> (tapioca), respectively (Table 1). The particle density was found to decrease with increase in organic matter. The highest particle density was found in forest = kitchen followed by *jhum* > banana > tapioca. A similar observation was also made by Nabayi *et al.* (2021) [23].

### Porosity

The porosity of soil was found to be significant under the effect of different land use systems. The porosity of the soils under different land use systems were 53.05% (forest), 52.03% (kitchen), 50.49% (*jhum*), 49.82% (banana) and 49.53% (tapioca) (Table 1). In general, the highest porosity was exhibited by forest land use system followed by kitchen > *jhum* > banana > tapioca. Similar results were reported by Shougrakpam *et al.* (2010) [34] and Debnath and Pattanaik (2014) [10].

**Table 1:** Effect of land use systems on physicochemical properties of soil

Land Use	pH	EC (dSm <sup>-1</sup> )	Organic carbon (%)	CEC [cmol (p+) kg <sup>-1</sup> ]	Bulk density (g cm <sup>-3</sup> )	Particle density (g cm <sup>-3</sup> )	Porosity (%)
Forest	4.93 <sup>a</sup>	0.22 <sup>a</sup>	2.29 <sup>a</sup>	18.10 <sup>a</sup>	1.11 <sup>b</sup>	2.37 <sup>a</sup>	53.05 <sup>a</sup>
Kitchen	4.81 <sup>a</sup>	0.22 <sup>a</sup>	2.20 <sup>a</sup>	15.30 <sup>b</sup>	1.14 <sup>ab</sup>	2.37 <sup>a</sup>	52.03 <sup>a</sup>
<i>Jhum</i>	4.73 <sup>a</sup>	0.19 <sup>a</sup>	2.03 <sup>ab</sup>	14.30 <sup>b</sup>	1.16 <sup>a</sup>	2.35 <sup>a</sup>	50.49 <sup>b</sup>
Banana	4.68 <sup>a</sup>	0.20 <sup>a</sup>	1.86 <sup>b</sup>	14.70 <sup>b</sup>	1.15 <sup>a</sup>	2.29 <sup>b</sup>	49.82 <sup>b</sup>
Tapioca	4.69 <sup>a</sup>	0.20 <sup>a</sup>	1.91 <sup>b</sup>	14.80 <sup>b</sup>	1.15 <sup>a</sup>	2.27 <sup>b</sup>	49.53 <sup>b</sup>
Mean	4.77	0.21	2.06	15.44	1.14	2.33	50.98
SEm±	0.13	0.02	0.09	0.70	0.01	0.02	0.48
CD (P = 0.05)	NS	NS	0.24	1.99	0.03	0.05	1.36

**Note:** Small letters assigned after the mean values were separated by Duncan Multiple range test.

### Fertility status

#### Available nitrogen

The available nitrogen content of soils were 450.8 kg ha<sup>-1</sup>, 425.5 kg ha<sup>-1</sup>, 410.1 kg ha<sup>-1</sup>, 402.8 kg ha<sup>-1</sup>, 405.7 kg ha<sup>-1</sup> under forest, kitchen, *jhum*, banana and tapioca land use system,

respectively (Table 2). The nutrient index for available nitrogen recorded were 2.33, 2.16, 2.08, 2.08 and 2 for forest, kitchen, *jhum*, banana and tapioca land use systems, respectively which indicated that the soils of Mokokchung district had medium available nitrogen status (Table 4). In

general, the highest available nitrogen was exhibited under forest land use system followed by kitchen > *jhum* > tapioca > banana. The effect of land use systems on soil available nitrogen was found to be significant. The high available nitrogen in forest soils compared to other land use systems may be the result of higher organic carbon in the forest land use system which is in accordance with Tripathi *et al.*, (2007) [37].

#### Available phosphorus

The land use systems had a significant effect on the soil available phosphorus. The phosphorus content of various soil samples collected were 19.9 kg ha<sup>-1</sup>, 19.1 kg ha<sup>-1</sup>, 19.2 kg ha<sup>-1</sup>, 17.3 kg ha<sup>-1</sup> and 17.0 kg ha<sup>-1</sup> under forest, kitchen, *jhum*, banana and tapioca land use system (Table 2). The nutrient index for available phosphorus was 2 under all the five land use systems which indicated that the soils of the district are medium in available phosphorus status as shown in Table 4. In general, the available P was found to be higher in *jhum* than forest soils. This may be attributed to the addition of ash through the process of slash and burn. This in turn increases the soil pH, thereby increasing the pH leading to higher phosphorus availability. Similar findings were also reported by Motsara (2002) [22] and Kumar *et al.* (2020) [16].

#### Available potassium

The available potassium levels under forest, kitchen, *jhum*, banana and tapioca land use systems were 210.7 kg ha<sup>-1</sup>, 206.6 kg ha<sup>-1</sup>, 203.7 kg ha<sup>-1</sup>, 196.6 kg ha<sup>-1</sup> and 196.7 kg ha<sup>-1</sup> (Table 2). However, the land use systems had a non

significant effect on soil available potassium. The nutrient index for available potassium were 2.1, 2, 2.08, 2 and 2 under forest, kitchen, *jhum*, banana and tapioca land use system, respectively which indicates that the available potassium status of the soils of Mokokchung district is medium (Table 4). In general, the highest available potassium content was observed in forest land use systems which may be attributed to the high amount of organic carbon content in the forest soils which promote the availability of potassium in the forest soils. Similar observation was also reported by Singh *et al.*, (1999) [35] and Bhunia *et al.* (2016) [6].

#### Available sulphur

The available sulphur content of the different soil samples under various land use systems were 24.8 kg ha<sup>-1</sup>, 22.9 kg ha<sup>-1</sup>, 21.7 kg ha<sup>-1</sup>, 19.8 kg ha<sup>-1</sup> and 20.3 kg ha<sup>-1</sup> under forest, kitchen, *jhum*, banana and tapioca (Table 2). The available sulphur was found to be significant under the effect of different land use systems. The nutrient index for available sulphur was 1.91, 1.83, 1.66, 1.5 and 1.5 under forest, kitchen, *jhum*, banana and tapioca land use systems respectively (Table 4). This indicates that the soils of Mokokchung district are medium in available sulphur. In general, the available sulphur content followed the order: forest > kitchen > *jhum* > tapioca > banana. The highest available sulphur was observed in forest land use system due to the high amount of organic matter in forest soils. Similar results have been reported by Mishra *et al.*, (2007) [20] and Saren *et al.* (2016) [31].

Table 4: Nutrient index under different land use systems

Nutrient	Forest		Kitchen		Jhum		Banana		Tapioca	
	Nutrient index	Nutrient index class	Nutrient index	Nutrient index class	Nutrient index	Nutrient index class	Nutrient index	Nutrient index class	Nutrient index	Nutrient index class
Organic carbon	3.00	High	3.00	High	3	High	3.00	High	3.00	High
Av. N	2.33	Medium	2.16	Medium	2.08	Medium	2.08	Medium	2.00	Medium
Av. P	2.00	Medium	2.00	Medium	2	Medium	2.00	Medium	2.00	Medium
Av. K	2.10	Medium	2.00	Medium	2.08	Medium	2.00	Medium	2.00	Medium
Av. S	1.91	Medium	1.83	Medium	1.66	Medium	1.50	Medium	1.50	Medium

Table 2: Effect of land use systems on soil available nutrients

Land Use	Available N (kg ha <sup>-1</sup> )	Available P (kg ha <sup>-1</sup> )	Available K (kg ha <sup>-1</sup> )	Available S (kg ha <sup>-1</sup> )
Forest	450.80 <sup>a</sup>	19.90 <sup>a</sup>	210.70 <sup>a</sup>	24.80 <sup>a</sup>
Kitchen	425.50 <sup>ab</sup>	19.10 <sup>ab</sup>	206.60 <sup>a</sup>	22.90 <sup>ab</sup>
<i>Jhum</i>	410.10 <sup>b</sup>	19.20 <sup>ab</sup>	203.70 <sup>a</sup>	21.70 <sup>bc</sup>
Banana	402.80 <sup>b</sup>	17.30 <sup>b</sup>	196.60 <sup>a</sup>	19.80 <sup>c</sup>
Tapioca	405.70 <sup>b</sup>	17.00 <sup>b</sup>	196.70 <sup>a</sup>	20.30 <sup>bc</sup>
Mean	418.90	18.50	202.86	21.90
SEm±	12.02	0.74	12.82	0.86
CD (P = 0.05)	34.27	2.10	NS	2.46

Note: Small letters assigned after the mean values were separated by Duncan Multiple range test.

#### Nature of soil acidity

##### Total potential acidity

The total potential acidity was found to be significant under the effect of different land use systems where the values under forest, kitchen, *jhum*, banana and tapioca were 11.84, 12.09, 13.23, 13.11 and 12.56 cmol (p<sup>+</sup>) kg<sup>-1</sup>, respectively (Table 3). Similar findings were also observed by Mandal *et al.* (2013) [19] and Debnath *et al.* (2021) [9]. The total potential acidity was found to be higher in *jhum* soils followed by banana > tapioca > kitchen > forest.

##### pH dependent acidity

The pH dependent acidity of the soils under forest, kitchen, *jhum*, banana and tapioca were 9.47, 9.68, 9.82 and 9.71 cmol (p<sup>+</sup>) kg<sup>-1</sup> as shown in Table 3. The effect of land use systems on pH dependent acidity was found to be non significant. However, in general, the highest pH dependent acidity was observed under *jhum* followed by banana > tapioca > kitchen > forest land use system.

### Exchangeable acidity

The effect of land use systems on exchangeable acidity was found to be significant and was found to be 2.75, 2.81, 3.29, 3.11 and 3 cmol (p<sup>+</sup>) kg<sup>-1</sup> under forest, kitchen, *jhum*, banana and tapioca land use system, respectively (Table 3). The contribution of exchangeable acidity towards total potential acidity was low and it contributed to an extent of 15%, 15%, 16%, 16% & 15% in forest, kitchen, *jhum*, banana and tapioca land use systems, respectively. Similar findings have also been reported by Kidanemariam *et al.* (2012) [15] and Laxminarayana (2010) [17].

### Exchangeable aluminium

The exchangeable aluminium of soils was found to be significant under different land use systems, where the values under forest, kitchen, *jhum*, banana and tapioca land use systems were 1.89, 1.90, 2.30, 2.15 and 2.07 cmol (p<sup>+</sup>) kg<sup>-1</sup>, respectively (Table 3). Among the different land use systems, the highest exchangeable aluminium was observed in forest land use systems. The percent contribution of exchangeable Al<sup>3+</sup> towards total potential acidity were 10%, 10%, 11%, 11% and 11% in forest, kitchen, *jhum*, banana

and tapioca land use systems, respectively. From the present findings, it is evident that exchangeable Al<sup>3+</sup> made the major contribution towards total potential acidity and exchangeable acidity. Similar findings were also reported by Seyoum (2016) [33] and Mandal *et al.* (2013) [19].

### Exchangeable hydrogen

The exchangeable H<sup>+</sup> under forest, kitchen, *jhum*, banana and tapioca land use systems were 0.86, 0.91, 0.99, 0.96 and 0.98 cmol (p<sup>+</sup>) kg<sup>-1</sup> which was found to be significant as shown in Table 3. In general, the highest exchangeable H<sup>+</sup> was reported under *jhum* land use systems followed by tapioca > banana > kitchen > forest.

### Extractable acidity

The extractable acidity recorded were 3.38, 3.52, 4.05, 3.85 and 3.97 cmol (p<sup>+</sup>) kg<sup>-1</sup> under forest, kitchen, *jhum*, banana and tapioca land use systems as shown in Table 3. It was also found to be significant under different land use systems. In general, the highest extractable acidity was exhibited by *jhum* land use systems followed by tapioca > banana > kitchen > forest.

**Table 3:** Effect of land use systems on soil acidity parameters

Land Use	Total potential acidity [cmol (p <sup>+</sup> ) kg <sup>-1</sup> ]	pH dependent acidity [cmol (p <sup>+</sup> ) kg <sup>-1</sup> ]	Exchangeable acidity [cmol (p <sup>+</sup> ) kg <sup>-1</sup> ]	Exchangeable Al <sup>3+</sup> [cmol (p <sup>+</sup> ) kg <sup>-1</sup> ]	Exchangeable H <sup>+</sup> [cmol (p <sup>+</sup> ) kg <sup>-1</sup> ]	Extractable acidity [cmol (p <sup>+</sup> ) kg <sup>-1</sup> ]
Forest	11.84 <sup>b</sup>	9.47 <sup>a</sup>	2.75 <sup>c</sup>	1.89 <sup>c</sup>	0.86 <sup>b</sup>	3.38 <sup>c</sup>
Kitchen	12.09 <sup>b</sup>	9.68 <sup>a</sup>	2.81 <sup>bc</sup>	1.90 <sup>c</sup>	0.91 <sup>ab</sup>	3.52 <sup>bc</sup>
<i>Jhum</i>	13.23 <sup>a</sup>	10.09 <sup>a</sup>	3.29 <sup>a</sup>	2.30 <sup>a</sup>	0.99 <sup>a</sup>	4.05 <sup>a</sup>
Banana	13.11 <sup>a</sup>	9.82 <sup>a</sup>	3.11 <sup>a</sup>	2.15 <sup>ab</sup>	0.96 <sup>a</sup>	3.85 <sup>ab</sup>
Tapioca	12.56 <sup>ab</sup>	9.71 <sup>a</sup>	3.05 <sup>ab</sup>	2.07 <sup>bc</sup>	0.98 <sup>a</sup>	3.97 <sup>a</sup>
Mean	12.57	9.75	3.02	2.06	0.94	3.75
SEM±	0.38	0.52	0.09	0.07	0.03	0.15
CD (P = 0.05)	1.07	NS	0.25	0.20	0.09	0.42

**Note:** Small letters assigned after the mean values were separated by Duncan Multiple range test.

### Conclusion

It is observed that the soils under the different land use systems were strong to moderate in soil pH with normal EC levels. Higher CEC with low bulk density and sufficient pore space were observed in forest soils as compared to the other land use systems, which showed lower CEC and higher bulk density. The soils were high in OC content, medium in soil available nutrients such as N, P, K and S. On the basis of Nutrient Index, forest soils were found to have a higher nutrient status as compared to the other land use systems which followed the order forest > kitchen > *jhum* > banana > tapioca land use systems. The comparatively lower nutrient levels in the other land use systems may be due to changes in land use through conversion of forest lands into cultivated lands. The practice of *jhum* cultivation with short *jhum* cycle must have further led to the depletion of nutrients. The indiscriminate use of land for intensive cultivation has also added to soil acidity problems. This not only affects the soil health but also the productivity of crops. Therefore, it is advisable to adopt proper soil management practices such as liming for the reclamation of acidic soils as well as proper nutrient and crop management practices for enhancing the soil fertility and crop productivity.

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