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Physico-chemical and biological properties of soil as affected by different land use system under different blocks of Wokha District of Nagaland

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Abstract
The Wokha District of Nagaland is located at 26.1°N 94.27^{0}E at an average elevation of 1,313 metres (4793 feet). It has a warm temperature climate. The average annual rainfall is 1940mm. The research was undertaken during 2018-2020.The surface soil samples (15 cm) were collected from five blocks of Wokha District under different land use system-forest, horticulture, rubber, paddy. The pH of the soils was found to be acidic in reaction and normal in total soluble salt concentration. The organic carbon was found to be high under forest land. The macronutrients were found to be low to medium under different land use system. CEC of forest soils was higher than horticulture, rubber, paddy land use system. The bulk density was found to be high in paddy and rubber land use system. Particle density and porosity was found to be high under forest land use. It was found that forest land use system had higher exchangeable acidity. The soil texture under different land system varied from clay to clay loam to loam. Higher soil microbial biomass carbon (SMBC) and soil respiration biomass was exhibited by forest soils.

Keywords: Organic carbon, soil microbial biomass carbon, soil respiration, soil texture

Introduction
Soil health can be defined as the continued capacity of soil to function as a vital living system, by recognizing that it contains biological elements that are key to ecosystem. Soil respiration under favorable temperature and moisture conditions are principally determined by substrate supply rather than by the pool size of Microbial Biomass Carbon, Soil respiration would be dependent on the replenishment of the labile substrate from the bulk organic C pool (Weijin Wang and Ram C Dalal 2003) [16]. Fertilizers being one of the earliest inputs a well-balanced scheduling for optimizing levels of fertilizers to derive maximum remunerative returns is important. For fertilizer recommendation very small amount (1 to 10 gm) of soil is used for each soil test. A proper soil testing will help the farmers have an idea about the soil properties and how they should manage the soil.

Materials and Methods
Wokha district of Nagaland is located at 26.1°N 94.27^{0}E at an average elevation of 1,313 metres (4793 feet). It has a warm temperature climate. The research was undertaken during 2018-2020. The average annual rainfall is 1940mm. The soil samples were collected from 5 blocks of Wokha district Nagaland *viz*., Wokha town, Wozhuro, Ralan, Sanis and Bhandari. The soil samples were analysed for pH in 1:2.5 soil water suspensions using glass electrode pH meter and EC using electrical conductivity meter, bulk density determined by measuring the volume of a known mass of soil sample that may have been passed through a sieve into a graduated cylinder, particle density by pycnometer method, porosity by Porosity (%) = (1-Bulk density/Particle density) x 100, organic carbon by Walkley and Black method, CEC by ammonium acetate, available nitrogen was determined by ordinary distillation method using alkaline potassium permanganate method, available phosphorus by Bray & Kurtz No. 1 method by using 0.03N NH_4F in 0.025N HCl, available potassium was extracted from the soil with neutral ammonium acetate and determined using flame photometer, available sulphur determined by turbidimetric measurement, exchangeable acidity measured by titration of soil extracts to a phenolphthalein endpoint at pH 8.3, soil microbial biomass carbon determined by fumigation-extraction method, soil respiration measured by determining O_2 consumption and/or CO_2 release.

Results and Discussion

Physico-Chemical Properties of soil

Soil Reaction (pH)

Irrespective of the land use system, the soils of Wokha district were found to be strongly to moderately acidic in reaction (table 1, 2, 3, 4). Patton (2015) [10] and Amenla *et al*. (2010) [2].

Electrical conductivity (EC)

The soil samples from different land use system fell under the class of having no deleterious effect on crops in terms of EC of soluble salts (table 1, 2, 3, 4). Due to heavy rainfall in these areas most of the soluble salts from the soil profile produced during weathering are washed off due to leaching. Sharma *et al*. (2012) [13].

Cation Exchange Capacity (CEC)

It was observed that CEC of forest soils was higher for the soils of Nagaland (Table 1, 2, 3, 4). Namai *et al*. (2016) [9]. This may be due to higher organic matter content in forest soils. Mishra *et al*. (2007) [8].

Bulk density

It is observed that paddy and rubber land use system had the highest bulk density (table 1, 2, 3, 4), this may be due to continuous tillage operation, low organic matter content in paddy field and conversion of forest for rubber cultivation.

Particle density

The PD of soil under forest LUS was found to be high in Wozhuru block with an average of 2.67gcm^{-3}and least in Ralan block with an average of 2.41gcm^{-3} (table 1). Under horticulture PD was found to be high in Wozhuru block with an average of 2.67gcm^{-3} (table 2). Under rubber PD was found to be low in Wozhuru block with an average of 2.26gcm^{-3} (table 3). Under paddy it was found to be high in Sanis block with an average of 2.50gcm^{-3} (table 4). It was found that forest showed highest particle density. Amenla *et al*. (2007) [1].

Porosity

The porosity of soil under forest LUS was found to be high in Sanis block with an average of 60.79% (table 1). Under horticulture porosity was found to be high in Bhandari block with an average of 61.47% (table 2). Under rubber porosity was found to be high in Wokha block with an average of 62.87% (table 3). Under paddy CEC was found to be high in Bhandari block with an average of 55.89% (table 4). The highest porosity was found to be in forest land use system. Debnath and Pattanaaik (2014) [3].

Organic carbon

The OC under forest LUS was found to be high in Sanis block with an average of 1.93% and least in Wokha block with an average of 1.55% (table 1). Under horticulture OC was found to be high in Ralan block with an average of 1.86% and least in Bhandari block with an average of 1.37% (table 2). Under rubber OC was found to be high in Bhandari block with an average of 1.77% and least in Wokha block with an average of 1.40% (table 3). Under paddy OC was found to be high in Bhandari block with an average of 1.68% and least in Wozhuru block with an average of 1.15% (table 4). It was found that forest land use system showed highest organic carbon content. Paul *et al*. (2011) [11].

Nitrogen

Available N under forest LUS was found to be high in Sanis block with an average of 408.59 kg/ha (table 1). Under horticulture it was found to be high in Wozhuru block with an average of 392.86 kg/ha and least in Bhandari block with an average of 334.50 kg/ha (table 2). Under rubber it was found to be high in Bhandari block with an average of 364.25kg/ha and least in Wokha block with an average of 300.22 kg/ha (table 3). Under paddy available N was found to be high in Sanis block with an average of 286.08 kg/ha (table 4). Available nitrogen was exhibited highest in forest land use system. Vishnu *et al*. (2017) [15].

Phosphorus

Available P under forest LUS was found to be high in Sanis block with an average of 14.13 kg/ha and least in Wokha block with an average of 12.21 kg/ha (table 1). Under horticulture available P was found to be high in Ralan block with an average of 11.60 kg/ha and least in Bhandari block with an average of 10.55 kg/ha (table 2). Under rubber available P was found to be high in Bhandari block with an average of 11.64 kg/ha and least in Wokha block with an average of 10.33 kg/ha (table 3). Under paddy available P was found to be high in Wokha block with an average of 10.29 kg/ha and least in Wozhuru block with an average of 8.72 kg/ha (table 4). It can be said that acidic soils have low to medium available phosphorus in soil this may be due to fixation of phosphorus with iron, manganese, aluminium of the soils. Leelavathi *et al*. (2009) [7]

Potassium

Available K of soil under different blocks of Wokha district under forest LUS was found to be high in Ralan block with an average of 369.86 kg/ha and least in Sanis block with an average of 283.46 kg/ha (table 1). Under horticulture available K was found to be high in Ralan block with an average of 264.26 kg/ha and least in Wozhuru block with an average of 156.26 kg/ha (table 2). Under rubber available K was found to be high in Sanis block with an average of 263.73 kg/ha and least in Bhandari block with an average of 230.93 kg/ha (table 3). Under paddy available K was found to be high in Ralan block with an average of 246.26 kg/ha and least in Wozhuru block with an average of 141.06 kg/ha (table 4). Available potassium was found highest in forest land use system, this may be due to higher organic carbon content in forest soil. Sharma *et al*. (2012) [13].

Sulphur

Available S of soil under forest LUS was found to be high in Wozhuru block with an average of 27.70 kg/ha and least in Sanis block with an average of 25.63 kg/ha (table 1). Under horticulture available S was found to be high in Ralan block with an average of 27.99 kg/ha and least in Sanis block with an average of 18.66 kg/ha (table 2). Under rubber LUS available S was found to be high in Bhandari block with an average of 26.02 kg/ha and least in Wozhuru block with an average of 23.89 kg/ha (table 3). Under paddy available S was found to be high in Ralan block with an average of 23.09 kg/ha and least in Sanis block with an average of 16.32 kg/ha (table 4). From the results it can be revealed that available sulphur under different land use system was found to be

medium to low in content in the soil. Kavita and Sujata (2015) [4].

Exchangeable acidity

Exchangeable acidity of soil under forest LUS was found to be high in Ralan block with an average of 2.91c mol (p+) kg^{-1} and least in Sanis block with an average of 2.08c mol (p+) kg^{-1} (table 1). Under horticulture exchangeable acidity was found to be high in Bhandari block with an average of 2.72c mol (p+) kg^{-1} and least in Sanis block with an average of 2.15c mol (p+) kg^{-1} (table 2). Under rubber exchangeable acidity was found to be high in Wozhuru block with an average of 2.63c mol (p+) kg^{-1} and least in Bhandari block with an average of 2.07 c mol (p+) kg^{-1} (table 3). Under Paddy exchangeable acidity was found to be high in Wozhuru and Ralan block with an average of 2.08c mol (p+) kg^{-1} and least in Wokha block with an average of 1.12c mol (p+) kg^{-1} (table 4). It was found that forest land use system had higher exchangeable acidity. Laxminarayana (2010) [6].

Mechanical analysis

It can be revealed that the soils of Wokha district under different land use system varied from clay to clay loam to loam soil texture (table 5). Soil texture varied under different land use system. Sitanggang *et al.* (2006) [14].

2) Biological Properties

Soil Respiration biomass

SRB under forest LUS was found to be high in Bhandari block with an average of 51.38 mg CO_2/g soil/24 hours (table 1). Under horticulture it was found to be high in Ralan block with an average of 50.48 mg CO_2/g soil/24 hours (table 2). Under rubber soil respiration biomass was found to be high in Wozhuru block with an average of 50.73 mg CO_2/g soil/24 hours (table 3). Under paddy soil respiration biomass was found to be high in Wozhuru block with an average of 49.62 mg CO_2/g soil/24 hours (table 4). It can be concluded that soil respiration biomass was found highest in forest land use system, this may be due to higher organic carbon because it can supply substrates to microbial substrates. Liming Lai *et al.* (2012) [5]. Soil respiration under favorable temperature and moisture conditions was principally determined by substrate supply rather than by the pool size of MBC (microbial biomass carbon). Weijin Wang and Ram C Dalal (2003) [16].

Table 1: Soil status of different blocks of Wokha district under Forest land use system

Blocks	pH	EC (dSm^{-1})	CEC [cmol (P^+) Kg^{-1}]	OC (%)	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	S ($kg\ ha^{-1}$)	PD ($g\ cm^{-3}$)	BD ($g\ cm^{-3}$)	Porosity (%)	Ex-acidity [c mol (p+) kg^{-1}]	SRB (mg CO_2/g soil/24 hours)	SMBC (µg/g soil)
Wokha	4.70	0.25	13.99	1.55	406.78	12.21	309.86	26.72	2.57	1.02	59.75	2.83	49.58	237.01
Wozhuru	4.51	0.2	15.39	1.81	398.94	13.50	292.93	27.70	2.67	1.05	60.38	2.67	50.73	293.97
Ralan	4.84	0.24	16.46	1.69	355.07	12.88	369.86	27.24	2.41	1.02	57.33	2.91	49.93	248.75
Sanis	4.83	0.23	15.63	1.93	408.59	14.13	283.46	25.63	2.64	1.02	60.79	2.08	49.87	254.54
Bhandari	4.89	0.24	15.26	1.89	356.49	13.47	320.8	27.31	2.57	0.94	60.34	2.94	51.38	315.42

Table 2: Soil status of different blocks of Wokha district under Horticulture land use system

Blocks	pH	EC (dSm^{-1})	CEC [cmol (P^+) Kg^{-1}]	OC (%)	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	S ($kg\ ha^{-1}$)	PD ($g\ cm^{-3}$)	BD ($g\ cm^{-3}$)	Porosity (%)	Ex-acidity [c mol (p+) kg^{-1}]	SRB (mg CO_2/g soil/24 hours)	SMBC (µg/g soil)
Wokha	4.85	0.23	12.97	1.41	359.71	10.86	208.26	21.89	2.45	1.08	54.35	2.16	50.28	267.71
Wozhuru	4.45	0.16	13.48	1.71	392.86	10.97	156.26	25.42	2.67	1.12	57.82	2.52	50.09	224.57
Ralan	4.71	0.24	13.72	1.86	376.08	11.60	264.26	27.99	2.28	1.06	53.24	2.52	50.48	280.41
Sanis	5.05	0.25	14.63	1.38	351.22	11.41	209.33	18.66	2.50	1.06	56.51	2.15	50.19	225.65
Bhandari	4.97	0.24	10.86	1.37	334.50	10.55	212.8	23.71	2.45	1.04	61.47	2.72	50.22	156.21

Table 3: Soil status of different blocks of Wokha district under Rubber land use system

Blocks	pH	EC (dSm^{-1})	CEC [cmol (P^+)Kg^{-1}]	OC (%)	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	S ($kg\ ha^{-1}$)	PD ($g\ cm^{-3}$)	BD ($g\ cm^{-3}$)	Porosity (%)	Ex-acidity [c mol (p+) kg^{-1}]	SRB (mg CO_2/g soil/24 hours)	SMBC (µg/g soil)
Wokha	4.79	0.19	11.14	1.40	300.22	10.33	235.46	23.89	2.46	1.02	62.87	2.49	49.58	233.68
Wozhuru	5.14	0.15	15.19	1.52	330.98	11.53	243.33	23.76	2.26	1.08	52.06	2.63	50.73	283.97
Ralan	5.07	0.18	13.95	1.68	362.78	11.48	242.13	24.81	2.46	1.06	56.61	2.28	49.93	248.09
Sanis	4.72	0.21	13.22	1.74	344.23	11.00	263.73	25.43	2.41	1.05	56.19	2.3	49.87	221.21
Bhandari	4.58	0.18	10.77	1.77	364.25	11.64	230.93	26.02	2.46	1.04	57.82	2.07	49.71	282.08

Table 4: Soil status of different blocks of Wokha district under Paddy land use system

Blocks	pH	EC (dSm^{-1})	CEC [cmol (P^+) Kg^{-1}]	OC (%)	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	S ($kg\ ha^{-1}$)	PD ($g\ cm^{-3}$)	BD ($g\ cm^{-3}$)	Porosity (%)	Ex-acidity [c mol (p+) kg^{-1}]	SRB (mg CO_2/g soil/24 hours)	SMBC (µg/g soil)
Wokha	4.45	0.12	11.26	1.22	236.36	10.29	159.73	17.46	2.33	1.07	53.46	1.12	49.8	132.03
Wozhuru	4.5	0.12	13.23	1.15	276.93	8.72	141.06	21.23	2.45	1.07	55.83	2.08	49.62	130.83
Ralan	4.72	0.12	12.24	1.31	284.38	10.27	246.26	23.09	2.23	1.16	47.52	2.08	49.54	158.97
Sanis	5.05	0.18	13.23	1.53	286.08	9.42	182.6	16.32	2.50	1.11	55.39	1.24	49.32	175.65
Bhandari	4.47	0.12	11.66	1.68	280.26	9.36	148.33	20.3	2.33	1.05	55.89	1.95	49.36	157.39

Table 5: Particle size distribution under different blocks of Wokha district as affected by different land use system

Name of block	%			Textural class
	Sand	Silt	Clay	
(a) Particle size distribution under Forest land use practice				
Wokha	31.71	35.78	32.51	L-CL
Wozhuru	31.61	27.51	40.87	CL-C
Ralan	28.34	50.27	38.14	CL
Sanis	27.48	39.58	32.92	CL
Bhandari	29.97	37.18	32.84	L-CL
(b) Particle size distribution under Horticulture land use practices				
Wokha	29.99	33.31	36.68	CL
Wozhuru	25.56	31.70	42.72	CL-C
Ralan	26.18	34.32	39.48	CL-C
Sanis	34.92	32.13	32.94	CL
Bhandari	30.33	33	36.66	CL
(c) Particle size distribution under Rubber land use practices				
Wokha	32.59	31.85	35.48	CL
Wozhuru	28.39	31.71	39.83	CL
Ralan	28.77	34.94	36.21	CL
Sanis	33.25	33.04	33.66	CL
Bhandari	34.4	33.06	32.46	CL
(d) Particle size distribution under Paddy land use practices				
Wokha	34.43	32.11	33.42	L-CL
Wozhuru	38.03	28.63	33.23	CL
Ralan	34.13	33.73	32.06	CL
Sanis	42.06	27.9	30	CL
Bhandari	34.33	32.93	32.66	CL

CL-Clay loam, L-Loam, C-Clay.

Soil microbial biomass carbon

Soil microbial biomass carbon under forest LUS was found to be high in Bhandari block with an average of 315.42 µg/g soil (table 1). Under horticulture soil microbial biomass carbon was found to be high in Ralan block with an average of 280.41µg/g soil. Under rubber LUS soil microbial biomass carbon was found to be high in Wozhuru block with an average of 283.97 µg/g soil and (table 3). Under Paddy LUS soil respiration biomass was found to be high in Sanis block with an average of 175.65 µg/g soil (table 4). Forest showed higher soil microbial biomass carbon (SMBC). This may be due to higher organic matter in the forest soil which allows higher microbial activity. Powlson *et al.* (1987) [12].

Conclusion

It can be said that the soils of Wokha district, Nagaland are acidic in reaction with EC having no deleterious effect on crops. Organic carbon was high in all the land use sytem. Soil Respiration Biomass (SRB) and Soil Microbial Biomass Carbon (SMBC) of soil had a was high under forest land use system. Due to little or no disturbance under forest land, it exhibited higher nutrient status, higher biological properties in comparison to horticulture, rubber, paddy land use system. The continuous tillage practice as well as due to improper management of farm waste in paddy land use system degraded the nutrient content. Turning of forest land into rubber cultivation degraded the soil nutrients as well as the biological properties. Therefore, it can be advised that with proper management and practices, the soil nutrients can be replenished.

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