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Soil Property Variations Under Different Land Use/ Cover Types In Traditional Agricultural Landscape In Northeast India

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Abstract Clearing of forests and their subsequent conversion into croplands greatly influence soils in terms of its water holding capacity, structure stability and compactness, nutrient supply and storage as well as its biological life. Consequently, many agricultural soils in the tropics are now below their potential levels. In this paper we are reporting that there is expansion of agricultural land use in Northeast India at the expense of forest area in order to meet increasing human population and market demands. New land use/ cover types are also being introduced for commercial and well as subsistence purpose. On the other hand fallow period of shifting agriculture has been reduced. We suggest that a minimum fallow period of seven years is necessary sufficiency of soil nutrients and vegetation in this humid subtropical mountain landscape of Northeast India.

1. INTRODUCTION

The importance of agroecosystems as a sink for CO_2 has been recognized since increased yields, decreased tillage and increased residue inputs lead to accumulations of soil carbon (Civeira, 2011). Understanding the effect of land management practices on soil property changes is quite important for the prediction of soil behaviour and its response to different management options (Ketema and Yimer, 2014).Intensive cropping promotes high levels of nutrient

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extraction from soils without natural replenishment (Alam and Salahin, 2013). Clearing of forests and their subsequent conversion into croplands deprives soils its water holding capacity, structure stability and compactness, nutrient supply and storage as well as its biological life (Vitorello et al., 1989; Sombroek et al., 1993; Wairiu and Lal, 2003; Rasiah et al., 2004). Consequently, many agricultural soils in the tropics are now below their potential levels (Sombroek et al., 1993). Studies in the tropics have shown significant changes in soil organic carbon (SOC) following conversion of natural forest into cultivation, and these changes have been shown to affect soil fertility (Brown and Lugo, 1990; Piccolo et al., 1994; Tiessen et al., 1994; Fernandes et al., 1997; Neill et al., 1997; Dominy et al., 2002, Ramakrishnan, et al., 2003). Lugo et al. (1986) and Lepsch et al. (1994) have also indicated that forested lands converted into cultivated areas in tropical regions undergo important changes in soil properties, including loss of organic matter, increase in bulk density and decrease in pH and exchangeable cations.

Understanding change on soil properties due to land use/cover change in regional to global scale is important aspect for framing land management policies. Land use change, mainly through conversion of natural vegetation to cropland and/or grazing, may influence many natural phenomena and ecological processes (Turner, 1989), leading to a remarkable change in soil properties. Solomon et al. (2002) reported a significant reduction in SOC after conversion of humid tropical forests to maize (*Zea mays*) cultivation in the south-eastern Ethiopia, with SOC stocks ranging from 58.3 to 63.9 Mg C ha^{-1} in forest soils and 33.9 to 39.7 Mg C ha^{-1} in cultivated soils. Similarly, Lemenih and Itanna (2004) found significantly lower soil carbon (C) and total nitrogen (N) stocks in cropland soils than the soil C and total N stocks under the natural vegetation in the south central part of Ethiopia.Apart from an initial reconnaissance (Weinert and Mazurek, 1984) and recent report on soil property variations under natural vegetations at different topographic aspects (Yimer et al., 2006a,b), there has been no study conducted so far to address the impact of conversion of native forests into agricultural lands.

Forest cover of India as per State of Forest Report 2013 assessment is 697,898 sq km which is 21.23 per cent of the geographical area of the country reflecting an increase of 5,871 sq km from 2011 assessment (FSI, 2013). Further there is an increase forest cover of 2,396 sq km in tribal districts of India. Of the 15 states/union territories of India having forest cover of more than 33 per cent of the geographical area, all the states of Northeast India figure in the list with an average of 70.03 per cent. However, with respect of forest cover in 2011, except in the state of Assam where there is no net decrease or increase, only one state; Meghalaya recorded increase in are. Most of the reasons for change are attributed to shifting agriculture and biotic pressures on the forest.Of late, Northeast has become an area of particular concern due to the rapid land conversion practices, sensitivity to human impact and poor agricultural managements in the traditional shifting agricultural areas with fragile tropical mountain and hill ecosystems containing diverse gene reserves and an important source of water draining to the lowlands of the Assam valley and Bangladesh. The main aim of this study was to assess the important physico-chemical properties of soils under different land use systems and changesin Domong and Yogong village landscape.

2. METHODS

2.1 Study area

The study was conducted in two representative traditional shifting agricultural villages located at 28º10´N to 28º30´N latitude and 94º40´E to 95º00´E longitude at the altitudinal range of 600-1600 masl. This area falls under the south western region of the Dihang-Dibang Biosphere Reserve which constitutes an area of 5,112 km^2 in the districts of West Siang, Upper Siang and Dibang valley of Arunachal Pradesh (Figure 1). Both the study sites are inhabited by ‘Adi’ community of Tibeto-Mongoloid race; one of the major tribes of Arunachal Pradesh. The study sites are located in a tropical humid environment with 4 distinct seasons in a year, namely, spring (March-April), summer (May-August), autumn (October-November) and winter (December-February). The mean annual minimum and maximum temperature varies between 12^0C and 37^0C respectively. More than 80% of the rainfall occurs during monsoon (May-September) registering about 60-80% relative humidity. The area experiences occasional winter rainfall too. Though soil survey of the region has not been carried out, some generalization can be made based on the information available for the state. Arunachal Pradesh can be divided into four distinct zones: (a) snow-capped mountains (> 5500 m amsl.) (b) lower Himalayan ranges (3500-5500 m amsl.) (c) the sub-himalayan Siwalik hills (700-3500 m amsl.) (d) the eastern Assam plains. Soils occurring in these physiographic zones are inceptisols, entisols, ultisols and alfisols. The remaining soils can be classified as miscellaneous. Soils of warm perhumid eastern Himalayan ecosystem with a thermic temperature regime are highly acidic inceptisols and entisols. Soils of warm perhumidsiwalik system with a hyperthermic temperature regime are also entisols and inceptisols with a high to moderate acidic conditions.

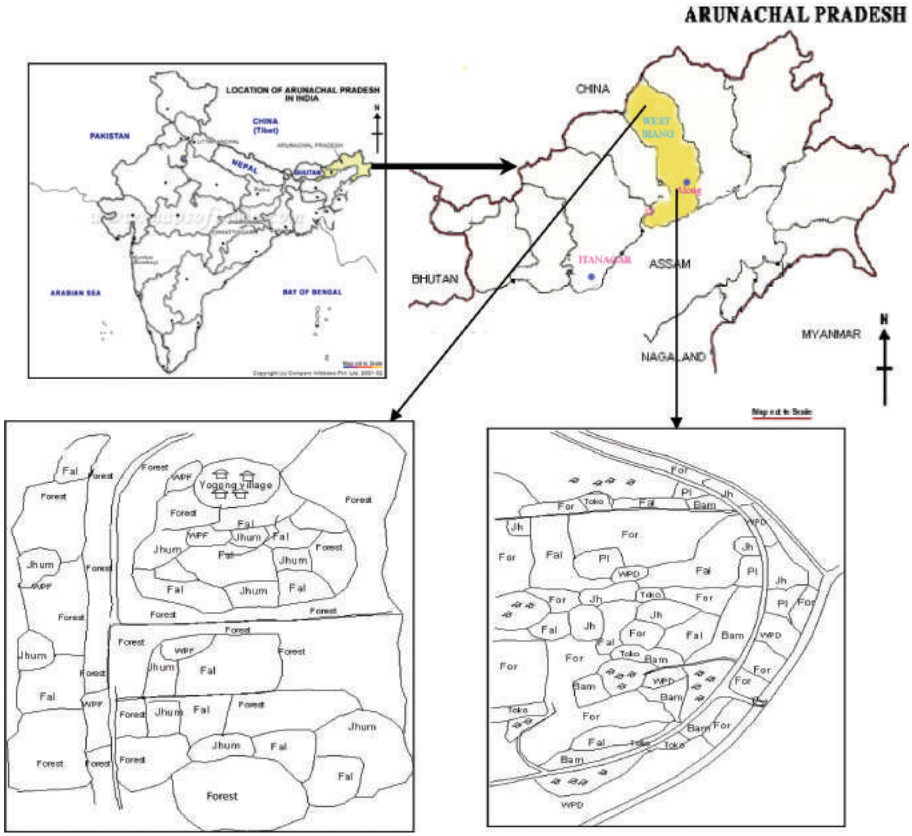

Figure 1: The study sites

3. SOIL SAMPLES

To assess the soil characteristics in relation to land use land cover change, three replicates of soil samples from all land use types from both the representative village landscapes were collected at 0-30 cm depth using steel corer (6.5 cm inner diameter) and brought to the laboratory. Samples of each replicate were mixed thoroughly and sieved through 2 mm mesh screen after proper drying in the sun. Soil pH was measured in 1: 2.5 fresh soil-water (w/v) suspensions with an electric digital pH meter (Decibel). Texture was determined by Bouyoucos hydrometric method (Allen et al., 1989). Organic carbon and total nitrogen were determined by using CHNSO analyser. Available phosphorus was determined colorimetrically (Labmed colorimeter) by molybdenum blue method after extracting soil samples with 0.03 N ammonium fluoride in 0.025 N HCl (Olsen and Sommers, 1982).

4. RESULTS

4.1 Physical properties of soil

All soils samples were assigned to sandy loam texture class based on the particle size distribution using the soil textural triangle (Table 1-2). In both the village landscapes, the sand content consistently increased with increase in jhum period but decreased as the length of fallow increased. Wet paddy fields on slope have more sand content than wet paddy fields in valley and least disturbed forests in Domong has less sand content than more disturbed. However in the case of forests of Yogong, it was found to be just reverse. Among plantation types in Domong village landscapes, toko has the largest sand content followed by orange, bamboo, banana and timber, respectively. Similar trend was observed in Yogong village too. The proportion of silt and clay in the soil of both village landscapes was also similar. The sand, silt and clay content range from 64.68 to 76.77%, 11.42 to 17.82 % and 11.30 to 19.07%, respectively, in Domong village and 63.10 to 71.74%, 13.81 to 20.58% and 13.10, respectively, in Yogong village landscapes. Soil pH did not show much variation between the two village landscapes. All soil samples were found to be acidic; pH ranging from 4.86 to 6.8 (Table 1-2).

4.2 Chemical properties of soil (organic carbon, total nitrogen and available phosphorus).

In these two village landscapes, content of organic carbon, total nitrogen and available phosphorus was maximum in both the soil profiles in first year jhum followed by 7th year fallow, 2nd year jhum and forests which have more or less similar content. Wet paddy field has comparatively low content of C and N but more P. Among plantations, soils of bamboo and timber plantation have high content of all these nutrients as compared to orange, toko and banana plantations. In the case of jhum fallow, concentration of CNP is increases with increase in fallow period (Figure 2). To test significant difference among the land uses and between land uses ANOVA and t-test respectively, were applied (Table 3-9).

5. DISCUSSION

Soil texture in all land uses was consistent in both village landscapes. The sand content increases with increase in jhum crop period in both the village landscapes but decreases with increase in jhum fallow period. In contrast, both silt and clay contents decrease with increase in jhum crop period but increase as the jhum fallow period increases. Eyre (1968) reported that loss of finer soil particles, *i.e.,* clay component, increases the proportion of sand in soil during the early developmental stages after disturbance in terrestrial ecosystem. In

Table 1: Soil pH, clay, silt, sand, organic carbon, total nitrogen and available phosphorus in Domong village landscape

Land use	Class	pH	Clay	Silt	Sand	Organic carbon	Total nitrogen	Available phosphorus
Jhum cropland	1st year jhum	5.05±0.08	15.98±1.72	14.79±2.82	68.80±1.92	2.23±0.38	0.19±0.03	7.87±0.90
	2nd year jhum	5.30±0.05	11.30±1.88	13.01±1.29	74.02±1.67	1.88±0.09	0.16±0.01	5.17±0.51
	3rd year jhum	6.30±0.06	11.53±0.75	11.70±0.69	76.77±1.03	1.85±0.11	0.16±0.01	4.42±0.56
Jhum fallow	1st year fallow	5.15±0.08	15.56±2.10	13.67±0.93	70.77±1.29	2.13±0.36	0.20±0.03	4.75±0.77
	3rd year fallow	5.18±0.10	17.06±1.75	16.56±1.76	66.38±2.89	2.16±0.37	0.19±0.03	4.60±0.68
	7th year fallow	4.96±0.09	16.39±1.10	16.42±1.01	67.19±1.75	2.72±0.23	0.20±0.03	7.15±1.06
Plantation	Bamboo	5.48±0.07	18.10±1.92	16.57±1.08	65.33±2.73	2.04±0.13	0.20±0.03	6.42±1.02
	Banana	5.96±0.07	19.07±1.24	15.71±1.01	65.22±0.33	1.86±0.06	0.15±0.01	6.35±0.26
	Orange	5.02±0.11	15.98±0.40	17.45±0.90	66.57±1.04	1.85±0.03	0.19±0.01	4.00±0.58
	Timber	5.35±0.03	18.61±0.40	16.71±0.93	64.68±1.25	2.49±0.47	0.23±0.02	5.00±0.81
	Toko	5.68±0.18	14.25±0.95	11.42±0.50	74.32±0.46	1.89±0.25	0.16±0.01	5.50±1.73
Forest	Least disturbed	4.86±0.01	14.35±1.16	17.82±1.57	67.83±2.43	2.30±0.42	0.15±0.03	4.01±0.49
	Disturbed	5.12±0.04	14.31±0.86	16.36±1.02	69.33±1.87	2.28±0.45	0.19±0.03	6.72±0.70
Wet paddy fields (WPF)	WPF in valley	6.02±0.03	15.09±0.65	16.51±0.70	68.40±0.54	1.50±0.22	0.12±0.01	5.92±0.77
	WPF on slope	6.16±0.06	14.66±2.10	15.81±0.94	69.53±1.32	1.25±0.12	0.11±0.01	5.34±0.45

Table 2.: Soil pH, clay, silt, sand, organic carbon, total nitrogen and available phosphorus in Yogong village landscape

Land use	Class	pH	Clay	Silt	Sand	Organic carbon	Total nitrogen	Available phosphorus
Jhum cropland	1st year jhum	4.95±0.06	16.05±2.24	17.26±1.18	66.88±1.06	4.25±1.05	0.35±0.11	6.80±0.50
	2nd year jhum	5.54±0.12	15.41±0.96	15.99±0.68	68.60±0.75	2.87±1.60	0.27±0.12	4.96±0.52
Jhum fallowland	1st year fallow	6.54±0.08	14.45±0.61	13.81±0.91	71.74±0.71	3.66±0.03	0.33±0.03	3.29±1.06
	3rd year fallow	5.99±0.04	18.45±1.21	15.61±0.56	65.94±0.76	2.79±0.31	0.30±0.03	4.70±1.62
	7th year fallow	5.94±0.05	16.32±0.08	20.58±0.94	63.10±0.90	3.64±0.19	0.34±0.03	7.02±0.30
Forest	Least disturbed	5.10±0.14	15.07±0.40	15.88±0.66	69.05±0.43	3.31±0.29	0.31±0.04	5.99±0.40
	Disturbed	5.43±0.06	13.10±0.57	16.15±0.62	70.75±0.96	3.44±0.05	0.26±0.01	6.62±0.63
Wet paddy fields (WPF)	WPF in valley	5.87±0.07	18.51±0.75	17.35±0.43	64.14±0.52	2.36±0.26	0.23±0.01	5.85±0.91
	WPF on slope	5.90±0.09	18.36±1.88	16.87±0.58	64.77±1.38	2.00±0.45	0.19±0.03	5.08±1.43

Table 3: ANOVA for organic carbon, total nitrogen and available phosphorus in Domong and Yogong village landscapes

		Domong						Yogong					
	Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	**F crit**	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Organic carbon	Between Groups	5.7518	14	0.4108	4.9898	0.0001	2.0374	11.9492	8	1.4936	3.2416	0.0182	2.5102
	Within Groups	2.4701	30	0.0823				8.2939	18	0.4608			
	Total	8.2219	44					20.2431	26				
Total nitrogen	Between Groups	0.0441	14	0.0031	6.1530	0.00002	2.0374	0.0706	8	0.0088	2.5111	0.0499	2.5102
	Within Groups	0.0153	30	0.0005				0.0632	18	0.0035			
	Total	0.0594	44					0.1338	26				
Available phosphorus	Between Groups	56.7920	14	4.0566	5.9892	0.00002	2.0374	34.5896	8	4.3237	4.9968	0.0022	2.5102
	Within Groups	20.3194	30	0.6773				15.5752	18	0.8653			
	Total	77.1114	44					50.1648	26				

Table 4: t-test for organic carbon of 0-30 cm soil among different land uses in Domong village

t-Test: Paired Two Sample for Means

	J-1 vrs J-2		**J-1 vrs J-3**		**J-2 vrs J-3**		**Fal-1 vrs Fal-3**		**Fal-1 vrs Fal-7**		**Fal-3 vrs Fal-7**	
	Var1	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var1***	***Var 2***	***Var 1***	***Var 2***
Mean	2.2313	1.8833	2.2313	1.852	1.8833	1.852	2.1333	2.158	2.1333	2.72	2.1577	2.72
Variance	0.1463	0.0077	0.146322	0.0121	0.0077	0.0121	0.1277	0.134	0.1277	0.0516	0.1336	0.052
Observations	3	3	3	3	3	3	3	3	3	3	3	3
Pearson Correlation	-0.5580		-0.3275		0.9668		0.5156		0.5833		0.9967	
Hypothesized Mean Difference	0		0		0		0		0		0	
df	2		2		2		2		2		2	
t Stat	1.3781	S	1.5235	NS	1.6029	NS	-0.1185	NS	-3.4938	S	-6.9413	S
P(T<=t) one-tail	0.1511		0.1335		0.1251		0.4583		0.0365		0.0101	
t Critical one-tail	2.9200		2.92		2.9192		2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.3021		0.2671		0.2501		0.9165		0.0731		0.0201	
t Critical two-tail	4.3027		4.3027		4.3027		4.3027		4.3027		4.3027	
	Ora vrs Bam		**Bam vrs Ban**		**Or vrs Tim**		**Ora vrs Tok**		**Ora vrs Ban**		**Bam vrs Tim**	
Mean	1.854	2.039	2.039	1.8613	1.854	2.494333	1.854	1.886	1.854	1.8613	2.039	0.225
Variance	0.001	0.0181	0.0181	0.0031	0.0010	0.2237	0.0010	0.062	0.0010	0.0031	0.0181	4E-04
Observations	3	3	3	3	3	3	3	3	3	3	3	3
Pearson Correlation	-0.6261		0.9828		-0.0687		0.9204		-0.7594		0.0982	
Hypothesized Mean Difference	0		0		0		0		0		0	
df	2		2		2		2		2		2	
t Stat	-2.04344	NS	3.8098	S	-2.3290	NS	-0.2547	NS	-0.1537	NS	23.4102	S

Continues Table 4

	J-1 vrs J-2		J-1 vrs J-3		J-2 vrs J-3		Fal-1 vrs Fal-3		Fal-1 vrs Fal-7		Fal-3 vrs Fal-7	
	Var1	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var1***	***Var 2***	***Var 1***	***Var 2***
P(T<=t) one-tail	0.0889		0.0313		0.0726		0.4114		0.4460		0.0009	
t Critical one-tail	2.9200		2.9200		2.9192		2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.1772		0.0626		0.1453		0.8228		0.8919		0.0018	
t Critical two-tail	4.3027		4.3027		4.3027		4.3027		4.3027		4.3027	
	Bam vrs Toko		**Tim vrs Toko**		**Tim vrs Ban**		**Toko vrs Ban**		**For-U vrs For-D**		**WPF Va vrs Sl**	
Mean	2.039	1.8863	2.4943	1.8863	2.4943	1.8613	1.8863	1.861	1.6357	1.9507	1.4997	1.252
Variance	0.0181	0.0621	0.2246	0.0620	0.2237	0.0031	0.0621	0.003	0.0292	0.0832	0.0495	0.015
Observations	3	3	3	3	3	3	3	3	3	3	3	3
Pearson Correlation	-0.8811		-0.4533		0.7012		-0.9534		-0.8847		-0.9874	
Hypothesized Mean Difference	0		0		0		0		0		0	
df	2		2		2		2		2		2	
t Stat	0.7084	NS	1.6809	NS	2.5157	NS	0.1431	NS	-1.2210	NS	1.2520	**NS**
P(T<=t) one-tail	0.2761		0.1174		0.0641		0.4497		0.1732		0.1686	
t Critical one-tail	2.9120		2.9200		2.9200		2.9120		2.9120		2.9200	
P(T<=t) two-tail	0.5521		0.2349		0.1283		0.8993		0.3465		0.3371	
t Critical two-tail	4.3027		4.3027		4.3027		4.3027		4.3027		4.3027	

* *Var, Variable, J-1, jhum 1st year; J-2, jhum 2nd year; J-3, jhum 3rd year; Fal-1, fallow of 1st year; Fal-3, fallow of 3rd year, Fal-7, fallow of 7th year, Ora, orange plantation; Bam, bamboo plantation; Tim, timber plantation; Tok, toko plantation; Ban, banana plantation; For-U, forest undisturbed, For-D, forest disturbed; WPF-V, wet paddy field in valley; WPF-S, wet paddy field on slope.*

Table 5: t-test for total nitrogen content in 0-30 cm of soil in different land uses in Domong village

t-Test: Paired Two Sample for Means

	J-1 vrs J-2		**J-1 vrs J-3**		**J-2 vrs J-3**		**Fal-1 vrs Fal-3**		**Fal--1 vrs Fal-7**		**Fal-3 vrs Fal-7**	
	Var 1	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***
Mean	0.1913	0.1577	0.1913	0.1583	0.1577	0.1583	0.1987	0.1900	0.1987	0.198	0.19	0.198
Variance	0.0009	3.0E-05	0.0009	7.2E-05	3.0E-05	7.2E-05	0.0009	0.0008	0.0009	0.0010	0.0008	0.0010
Observations	3	3	3	3	3	3	3	3	3	3	3	3
Pearson Correlation	-0.5355		-0.4607		0.9963		-0.5017		0.8360		-0.8941	
Hypothesized Mean Difference	0		0		0		0		0		0	
Df	2		2		2		2		2		2	
t Stat	1.7375		1.6317		-0.3780		0.2946		0.0641		-0.2352	
P(T<=t) one-tail	0.1122		0.1222		0.3709		0.3980		0.4774		0.4180	
t Critical one-tail	2.9200		2.9200		2.9200		2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.2244		0.2443		0.7418		0.7961		0.9547		0.8360	
t Critical two-tail	4.3027		4.3027		4.3027		4.3027		4.3027		4.3027	
	Ora avrs Bam		**Ora vrs Tim**		**Ora vrs Tok**		**Ora vrs Ban**		**Bam vrs Tim**		**Bam vrs Tok**	
Mean	0.1937	0.1963	0.1937	0.2250	0.1937	0.1573	0.1937	0.1543	0.1963	0.2250	0.1963	0.1573
Variance	8.2E-05	0.0009	8.2E-05	0.0004	8.2E-05	0.0001	8.2E-05	7.4E-05	0.0009	0.0004	0.0009	0.0001
Observations	3	3	3	3	3	3	3	3	3	3	3	3
Pearson Correlation	0.0436		0.5196		0.0240		-0.9821		0.8763		-0.9977	
Hypothesized Mean Difference	0		0		0		0		0		0	

Continues Table 5

	J-1 vrs J-2		**J-1 vrs J-3**		**J-2 vrs J-3**		**Fal-1 vrs Fal-3**		**Fal--1 vrs Fal-7**		**Fal-3 vrs Fal-7**	
	Var 1	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***	***Var 1***	***Var 2***
Df	2		2		2		2		2		2	
t Stat	-0.1459		-3.0089		4.1830		3.8673		-3.1134		1.5735	
P(T<=t) one-tail	0.4487		0.0475		0.0263		0.0304		0.0448		0.1281	
t Critical one-tail	2.9200		2.9200		2.9200		2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.8974		0.0950		0.0527		0.0608		0.0895		0.2563	
t Critical two-tail	4.3027		4.3027		4.3027		4.3027		4.3027		4.3027	
	Bam vrs Ban		**Tim vrs Toko**		**Tim vrs Ban**		**Toko vrs Ban**		**For-U vrs For-D**		**WPF-V vrs WPF- S**	
Mean	0.1963	0.1543	0.2250	0.1573	0.2250	0.1543	0.1573	0.1543	0.1473	0.1850	0.1207	0.1057
Variance	0.0009	7.4E-05	0.0004	0.0001	0.0004	7.4E-05	0.0001	7.4E-05	0.0011	0.0008	0.0002	0.0002
Observations	3	3	3	3	3	3	3	3	3	3	3	3
Pearson Correlation	-0.2309		-0.8417		-0.6711		0.1645		-0.9943		-0.9281	
Hypothesized Mean Difference	0		0		0		0		0		0	
Df	2		2		2		2		2		2	
t Stat	2.1536		3.6656		4.4447		0.3780		-1.0795		0.9993	
P(T<=t) one-tail	0.0821		0.0335		0.0235		0.3709		0.1966		0.2115	
t Critical one-tail	2.9200		2.9200		2.9200		2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.1641		0.0670		0.0471		0.7418		0.3932		0.4229	
t Critical two-tail	4.3027		4.3027		4.3027		4.3027		4.3027		4.3027	

* *Var, Variable, J-1, jhum 1st year; J-2, jhum 2nd year; J-3, jhum 3rd year; Fal-1, fallow of 1st year; Fal-3, fallow of 3rd year, Fal-7, fallow of 7th year, Ora, orange plantation; Bam, bamboo plantation; Tim, timber plantation; Tok, toko plantation; Ban, banana plantation; For-U, forest undisturbed, For-D, forest disturbed; WPF-V, wet paddy field in valley; WPF-S, wet paddy field on slope.*

Table 6: t-test of available phosphorus in 0-30 cm depth of soil in different land uses in Domong village landscapes
t-Test: Paired Two Sample for Means

	J-1 vrs J-2		**J-1 vrs J-3**		**J-2 vrs J-3**		**Fal-1 vrs Fal-3**		**Fal-1 vrs Fal-7**		**Fal-3 vrs Fal-7**	
	Var 1	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***
Mean	7.8700	5.1715	7.8700	4.4172	5.1715	4.4172	4.7526	4.6007	4.7526	7.1476	4.6007	7.1476
Variance	0.8103	0.2571	0.8103	0.3136	0.2571	0.3138	0.5975	0.4646	0.5975	1.1155	0.4646	1.1155
Observations	3	3	3	3	3	3	3	3	3	3	3	3
Pearson Correlation	-0.8365		0.9865		-0.9150		-0.305		0.9110		0.1150	
Hypothesized Mean Difference	0		0		0		0		0		0	
Df	2		2		2		2		2		2	
t Stat	3.4542	S	16.6354	S	1.2510	NS	0.2236	NS	-8.7339	S	-3.7089	S
P(T<=t) one-tail	0.0373		0.0018		0.1687		0.4219		0.0065		0.0328	
t Critical one-tail	2.9200		2.9200		2.9200		2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.0746		0.0036		0.3374		0.8438		0.0129		0.0656	
t Critical two-tail	4.3027		4.3027		4.3027		4.3027		4.3027		4.3027	
	Ora vrs Bam		**Ora vrs Tim**		**Ora vrs Toko**		**Oravrs Ban**		**Bam vrs Tim**		**Bam vrs Toko**	
Mean	4.0111	6.7187	4.0111	5.9237	4.0111	5.3354	4.0111	6.4168	6.7186	5.9237	6.7186	5.3354
Variance	0.2374	0.4832	0.2374	0.5939	0.2374	0.2068	0.2374	1.0399	0.4832	0.5939	0.4832	0.2068
Observations	3	3	3	3	3	3	3	3	3	3	3	3

Continues Table 6

	J-1 vrs J-2		J-1 vrs J-3		J-2 vrs J-3		Fal-1 vrs Fal-3		Fal-1 vrs Fal-7		Fal-3 vrs Fal-7	
	Var 1	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***
Pearson Correlation	-0.7204		0.7843		-0.9270		0.9562		-0.9953		0.4075	
Hypothesized Mean Difference	0		0		0		0		0		0	
Df	2		2		2		2		2		2	
t Stat	-4.2657	S	-6.7297	S	-2.4806	NS	-7.2861	S	0.9404	NS	3.6436	S
P(T<=t) one-tail	0.0254		0.0107		0.0656		0.0092		0.2232		0.0339	
t Critical one-tail	2.9200		2.9200		2.9200		2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.0508		0.0214		0.1313		0.0183		0.4463		0.0678	
t Critical two-tail	4.3027		4.3027		4.3027		4.30267		4.3027		4.3027	

	Bam vrs Ban		**Tim vrs Tok**		**Tim vrs Ban**		**Tok vrs Ban**		**For-U vrs For-D**		**WPF-Va vrs WPF-S**	
Mean	6.7187	6.4168	5.9237	5.3354	5.9237	6.4168	5.3354	6.4168	3.9979	5.5010	6.3543	4.9992
Variance	0.4832	1.0399	0.5939	0.2068	0.5939	1.0399	0.2068	1.0399	0.3375	2.9849	0.0665	0.6508
Observations	3	3	3	3	3	3	3	3	3	3	3	3
Pearson Correlation	-0.8918		-0.4943		0.9315		-0.7766		-0.6757		-0.2219	

Continues Table 6

	J-1 vrs J-2		J-1 vrs J-3		J-2 vrs J-3		Fal-1 vrs Fal-3		Fal-1 vrs Fal-7		Fal-3 vrs Fal-7	
	Var 1	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***	***Var 1***	***Var2***
Hypothesized Mean Difference	0		0		0		0		0		0	
Df	2		2		2		2		2		2	
t Stat	0.3131	NS	0.9514	NS	-2.0730	NS	-1.3355	NS	-1.2036	NS	2.6086	NS
P(T<=t) one-tail	0.3919		0.2209		0.0870		0.1567		0.1759		0.0604	
t Critical one-tail	2.9200		2.9200		2.9200		2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.7838		0.4418		0.1739		0.3134		0.3519		0.1209	
t Critical two-tail	4.3027		4.3027		4.3027		4.3027		4.3027		4.3027	

* *Var, Variable, J-1, jhum 1st year; J-2, jhum 2nd year; J-3, jhum 3rd year; Fal-1, fallow of 1st year; Fal-3, fallow of 3rd year, Fal-7, fallow of 7th year, Ora, orange plantation; Bam, bamboo plantation; Tim, timber plantation; Tok, toko plantation; Ban, banana plantation; For-U, forest undisturbed, For-D, forest disturbed; WPF-V, wet paddy field in valley; WPF-S, wet paddy field on slope.*

Table 7: t-test of organic carbon in 0-30 cm soil of different land uses in Yogong village landscape

t-Test: Paired Two Sample for Means

	J-1 vrs J-2		**Fal-1 vrs Fal-3**		**Fal-1 vrs Fal-7**	
	Var1	***Var2***	***Var1***	***Var2***	***Var1***	***Var2***
Mean	4.2517	2.8687	3.6553	2.7917	3.6553	3.6417
Variance	1.0950	2.5704	0.0008	0.0932	0.0008	0.0350
Observations	3	3	3	3	3	3
Pearson Correlation	-0.5328		0.1430		0.4941	
Hypothesized Mean Difference	0		0		0	
Df	2		2		2	
t Stat	1.0258	**NS**	4.9458	**S**	0.1354	**NS**
P(T<=t) one-tail	0.2064		0.0193		0.4523	
t Critical one-tail	2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.4128		0.0385		0.9047	
t Critical two-tail	4.3027		4.3027		4.3027	
	Fal-3 vrs Fal-7		**For-U vrs For-D**		**WPF-V vrs WPF-S**	
Mean	2.7917	3.6417	3.3107	3.4443	2.3627	1.9957
Variance	0.0932	0.0350	0.0814	0.0027	0.0668	0.2018
Observations	3	3	3	3	3	3
Pearson Correlation	0.9311		-0.1683		-0.1961	
Hypothesized Mean Difference	0		0		0	
Df	2		2		2	
t Stat	-9.9669	**S**	-0.7758	**NS**	1.1342	**NS**
P(T<=t) one-tail	0.0050		0.2595		0.1872	
t Critical one-tail	2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.0099		0.5191		0.3744	
t Critical two-tail	4.3027		4.3027		4.3027	

**Var, Variable, J-1, jhum 1st year; J-2, jhum 2nd year; J-3, jhum 3rd year; Fal-1, fallow of 1st year; Fal-3, fallow of 3rd year, Fal-7, fallow of 7th year, Ora, orange plantation; Bam, bamboo plantation; Tim, timber plantation; Tok, toko plantation; Ban, banana plantation; For-U, forest undisturbed, For-D, forest disturbed; WPF-V, wet paddy field in valley; WPF-S, wet paddy field on slope.*

Table 8: t-test of total nitrogen in 0-30 cm soil of different land uses in Yogong village landscape.

t-Test: Paired Two Sample for Means

	J-1 vrs J-2		**Fal-1 vrs Fal-3**		**Fal-1 vrs Fal-7**	
	Var1	***Var2***	***Var1***	***Var2***	***Var1***	***Var2***
Mean	0.3463	0.2687	0.3280	0.2967	0.3280	0.3433
Variance	0.0118	0.0144	0.0010	0.0008	0.0010	0.0007
Observations	3	3	3	3	3	3
Pearson Correlation	-0.8346		-0.1856		0.6204	
Hypothesized Mean Difference	0		0		0	
Df	2		2		2	
t Stat	0.6137		1.1546		-1.0108	
P(T<=t) one-tail	0.3010		0.1838		0.2093	
t Critical one-tail	2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.6019		0.3676		0.4185	
t Critical two-tail	4.3027		4.3027		4.3027	
	Fal-3 vrs Fal-7		**For-U vrs For-D**		**WPF-V vrs WPF-S**	
Mean	0.2967	0.3433	0.3063	0.2550	0.2307	0.1860
Variance	0.0008	0.0007	0.0017	0.0000	0.0000	0.0010
Observations	3	3	3	3	3	3
Pearson Correlation	0.6555		-0.5732		-0.9745	
Hypothesized Mean Difference	0		0		0	
Df	2		2		2	
t Stat	-3.4773		1.9607		2.1421	
P(T<=t) one-tail	0.0368		0.0945		0.0827	
t Critical one-tail	2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.0737		0.1890		0.1655	
t Critical two-tail	4.3027		4.3027		4.3027	

* *Var, Variable, J-1, jhum 1st year; J-2, jhum 2nd year; J-3, jhum 3rd year; Fal-1, fallow of 1st year; Fal-3, fallow of 3rd year, Fal-7, fallow of 7th year, Ora, orange plantation; Bam, bamboo plantation; Tim, timber plantation; Tok, toko plantation; Ban, banana plantation; For-U, forest undisturbed, For-D, forest disturbed; WPF-V, wet paddy field in valley; WPF-S, wet paddy field on slope.*

Table 9: t-test of available phosphorus in 0-30 cm soil of different land uses in Yogong village landscape

t-Test: Paired Two Sample for Means

	J-1 vrs J-2		**Fal-1 vrs Fal-3**		**Fal-1 vrs Fal-7**	
	Var1	***Var2***	***Var1***	***Var2***	***Var1***	***Var2***
Mean	6.7975	4.9631	3.2887	4.7010	3.2887	7.0192
Variance	0.2532	0.2753	1.1314	2.6159	1.1314	0.0885
Observations	3	3	3	3	3	3
Pearson Correlation	0.2337		-0.9995		0.9517	
Hypothesized Mean Difference	0		0		0	
df	2		2		2	
t Stat	4.9922	S	-0.9125	NS	-8.2211	S
P(T<=t) one-tail	0.0189		0.2289		0.0072	
t Critical one-tail	2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.0379		0.4578		0.0145	
t Critical two-tail	4.3027		4.3027		4.3027	
	Fal-3 vrs Fal-7		**For-U vrs For-D**		**WPF-V vrs WPF-S**	
Mean	4.7010	7.0192	5.9893	6.6238	5.8466	5.0839
Variance	2.6159	0.0885	0.1581	0.4024	0.8314	2.0313
Observations	3	3	3	3	3	3
Pearson Correlation	-0.9609		-0.9821		0.9789	
Hypothesized Mean Difference	0		0		0	
df	2		2		2	
t Stat	-2.1077	NS	-1.0694	NS	2.3411	NS
P(T<=t) one-tail	0.0848		0.1984		0.0720	
t Critical one-tail	2.9200		2.9200		2.9200	
P(T<=t) two-tail	0.1696		0.3968		0.1441	
t Critical two-tail	4.3027		4.3027		4.3027	

* *Var, Variable, J-1, jhum 1st year; J-2, jhum 2nd year; J-3, jhum 3rd year; Fal-1, fallow of 1st year; Fal-3, fallow of 3rd year, Fal-7, fallow of 7th year, Ora, orange plantation; Bam, bamboo plantation; Tim, timber plantation; Tok, toko plantation; Ban, banana plantation; For-U, forest undisturbed, For-D, forest disturbed; WPF-V, wet paddy field in valley; WPF-S, wet paddy field on slope.*

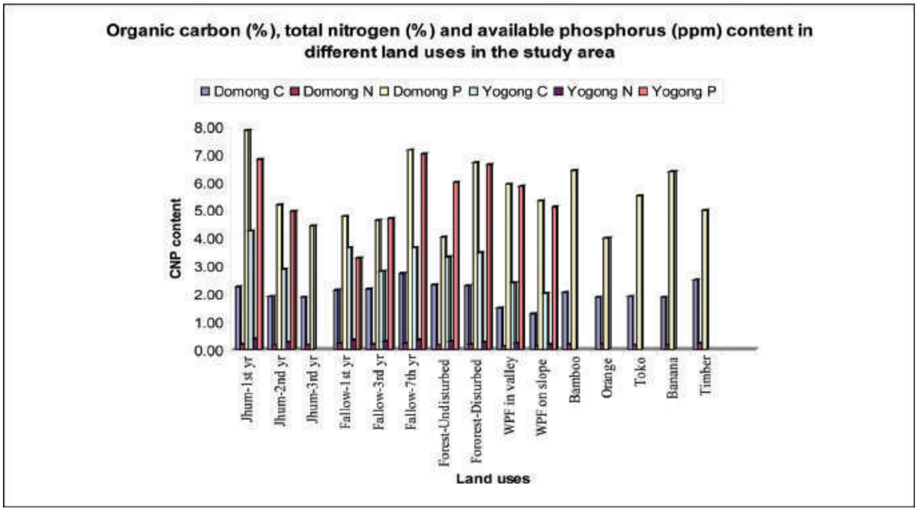

Figure 2: Organic carbon (%), total nitrogen (%) and available phosphorus (ppm) content in different land uses in Domong and Yogong village landscapes

wet paddy fields in both the study villages, the content of sand, silt and clay was uniform so is also in plantation and forest although slightly higher content in sand was found in wet paddy fields on slope (WPF-S) and disturbed forest (For-D) as compared to wet paddy field in valley (WPF-V) and undisturbed forest (For-U).As compared to other land uses, plantation of all kinds except toko plantation has lower content of sand but higher content of finer particles, *i.e.,* silt and clay. This may be attributed to plantation having fewer disturbances and less erosion as compared to other land uses. Toko plantations, on the other hand, are mostly located at the open areas and jhum fallow which facilitates greater degree of erosion of finer particles.

The soil pH was found to be acidic throughout all land uses. In Domong village landscape, lowest pH (most acidic) was observed in undisturbed forest followed by fallow of 7th year, orange plantation and jhum of 1st year respectively and highest pH was found in jhum of 3rd year followed by wet paddy fields on both slope and valley and banana plantation respectively. In Yogong village landscape, highest pH value was observed in fallow of 1st year followed by fallow of 3rd year, fallow of 7th year, and wet paddy fields respectively and lowest value of pH was observed in jhum crop field of 1st year followed by undisturbed forest, disturbed forest, jhum of 2nd year and wet paddy field in valley respectively. Across the land uses except fallow of seven years, there is not much significant variation indicating that a minimum of seven years is necessary to retain sufficient nutrient in shifting agriculture practice.

Roder et al. (1993), depending on the vegetation cover developing during the fallow period, categorized shifting agriculture in higher elevations of Bhutan into grass fallow and bush fallow systems. The grass fallow system is used at elevations ranging from 2500 to 3800 m amsl which are generally poor in available phosphate. These soils are used as grazing land during fallow period and the vegetation cover consists mainly of grasses and short shrubs interspersed with blue pine (*Pinuswallichiana*). Soil organic carbon and total nitrogen were reduced from 3.3 and 0.17 to 0.8 and 0.08%, respectively. Such and closely similar slash-burn practices observed elsewhere (Ramakrishnan et al., 2003) are not observed in the study area.

An increase in population pressure may be reflected in terms of a number of changes shifting cultivation landscapes in highlands of Chiapas including (a) conversion of a mosaic landscape where a variety of forest successional stages coexist with fertile cropland to a more homogeneous landscape characterized by larger crop fields, smaller and more isolated forest patches, and shorter fallow periods (b) removal of timber/wood before burning the slash (c) selective extraction of oak firewood since the early stages of fallow period favouring pine dominance. Pines and oaks differ in their morphology, resprouting ability, shade tolerance, life history and colonizing ability. Oaks are mostly logged at pre-reproductive age for firewood, while pines are allowed to grow up to commercial timber sizes attainable after their reproductive maturity. Pines have similar lignin contents but substantially less N and P concentrations in their green foliage and fresh or partially decomposed litter than oaks (Zublena et al., 1991; Magill and Aber, 1998). It is expected that soil fertility in pine-dominated secondary forests may be lower than in similarly aged oak-dominated stands (Duryea et al., 1999; Galindo-Jaimes et al., 2002) and pine dominance may reduce crop yields (Garcia-Barrios and Gonzalez-Espionosa, 2004). Garcia-Barrios and Gonzalez-Espionosa, (2004) concluded that human induced pine dominance could be a self-reinforcing process which has catalyzed the decline of shifting agriculture as well as soil degradation in the region. Around the study area, such practices were not observed. People removed wood from the plot after cultivation was abandoned and removed timber of only large dying trees.

Burning is also credited with increasing pH and decreasing aluminum saturation, a significant agronomic benefit on acid soils (Ahn, 1974; Ewel et al., 1981; Sanchez et al., 1983; Christanty, 1986). To minimize the loss of nitrogen and sulfur during burning, temperatures can be reduced. However, lower temperature burns also result in lowered transfer of biomass nutrients to the soil because of limited breakdown of organic matter and ash complexes (Andriesse and Koopmans, 1984). Zinke et al. (1978) found that although calcium, phosphorus and potassium are returned primarily through residual ash, nitrogen and organic matter are added by forest fallow. Notably, because of the size of many slash-and-burn rotation systems, erosion in areas within or outside of the agroecosystem may result in sediment deposition within the agroecosystem. For example, the Dayaks of Borneo sometimes plant swamp rice at the base of steep swiddens (Dove, 1985), thereby taking advantage of the deposition of eroded sediments and associated nutrients.

Results from village-level models developed by Sankhayan and Hofstad (2001) suggest that forest degradation could be best retarded through introduction of improved agricultural techniques and marketing (*viz.,* higher cotton prices, increased rural wages and reduced charcoal prices). Agricultural intensification is important in that it can result in higher rates of carbon sequestration (Woomer et al., 1997; IPCC, 2000) and it reduces agricultural expansion which is a key driver for removal of forested land, which is the major carbon stock in many regions. Intensification may be of two types: capital led intensification involving increase in non-labour inputs such as fertilizers and capital deficient intensification which utilizes the inputs of family or hired labour but without channeling the surplus labour towards capital inputs. In this study area where the agricultural fields are located at hilly terrain, soil nutrient can be managed more effectively by soil erosion control measures through improved agricultural techniques employed in neighbouring states like Meghalaya by construction of bunds, bench terraces and contour trenching.

6. CONCLUSION

Shifting agriculture system in Northeast India, unlike most traditional shifting cultivation systems (Raintree and Warner, 1986), does not maximize returns on labour, but is perhaps the only possibility for the highland farmers to produce their staple food under the prevailing conditions. One ha of buckwheat produced with this system may release 30-90 t of CO_2 during the burning process. With a fallow period of 15-20 years this system would accumulate 0.4 -1.0 t of C/ha/year. Fallow periods of 15-20 years are required for the system to be sustainable.

Although vegetation, land management and cropping patterns in the present study area is different from the scenarios reported in studies referred in the preceding paragraph, there is a resemblance in perception of local people that sustainability demands fallow periods longer than 10 years. The yields in shifting agriculture as well as in wet paddy cultivation system of the study area are markedly higher than the yields in similar agricultural systems in other parts of the north-eastern India and elsewhere. If 15 t/ha of rice is taken as the maximum possible yield in the present study area (Turner and Haygarth, 2001), there is immense scope of increasing the yields in wet paddy fields. While shifting agriculture is valued as an agricultural production system resilient to climatic fluctuations, yielding a food for a balanced diet, enforcing social integration and equity and providing a buffer zone between human habitations and natural ecosystems rich in large mammals, wet paddy cultivation is valued for its high productivity.

With the kind of warm and humid climatic factors prevailing in the study area where regeneration of vegetation is fast with broadleaved plant, a minimum seven fallow years would be ideal period for recuperation of sufficient soil nutrients in this agroecosystem landscape.

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