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THE FERTILITY AND MANAGEMENT IMPERATIVES OF THE DEGRADED UPLAND SOILS OF EBONYI STATE, SOUTHEAST NIGERIA

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ABSTRACT

Soil fertility evaluation of some continuously cultivated Upland Soils in Ebonyi State, Southeast Nigeria, was assessed to determine their levels of degradation, as a basis for soil health management to increase their productivity. Results showed that the soils are generally fine loam, very strongly acidic (average pH 4.9), and soils with very low base saturation of below 60 %. They are low in organic matter (OM) (< 2 %), total Nitrogen (N) (< 0.15 %) exchangeable potassium (K) (< 2 Cmol/ kg), sodium (Na) and available phosphorus (P) (17-39 mg/ kg), but medium to moderate in exchangeable calcium (Ca) and magnesium (Mg) (0.4-4.8;0.3-4.8) respectively. The overall result indicates that the soils are of very low fertility, and requires adequate fertility restoration for improved soil health. The application of lime, organic and mineral fertilizers was recommended to improve their productivity and boost crop yields.

Key Words: Soil degradation, Soil Fertility, Upland soils, Soil productivity, Crop yields, Ebonyi state.

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INTRODUCTION

Soil degradation is defined as the process which lowers the current or future capacity of the soil to produce goods or services. It implies long-term decline in soil productivity and its environment-moderating capacity (Blum, 1998; Lal, 2001). Two categories of soil degradation are recognised. The first is soil degradation due to displacement of soil material, such as soil erosion by wind or water. The second is in situ soil degradation due to chemical processes like loss of nutrients and organic matter, salinisation, acidification, and pollution and due to physical processes such as compaction, water- logging and subsidence (Oldeman, 1994).

Soil resources are degraded at an unprecedented rate in Ebonyi state due to various human activities. Thousands of hectares of agricultural land have become unproductive due to physical and chemical degradation. The problem is much more serious due to the fact that the soils are prone to degradation because of the inherent properties of their shale parent material and the prevalent climatic conditions.

Soil erosion appears to be the most widespread process of land degradation studied in the state. Other important soil degradation processes including loss of nutrients and organic matter, salinisation, acidification, pollution, and compaction have received less attention. There is a need for more data on the physical and chemical characteristics of degraded lands in the state to aid in the formulation of appropriate soil management strategies to support sustainable crop production in these threatened lands.

This study therefore assessed the structure and chemical properties of some degraded soils in the various localities in Ebonyi state with a view to ascertain the status of the soils health and formulate site specific soil management strategies needed, which in turn require detailed knowledge of the properties and limitations of the degraded soils.

MATERIALS AND METHODS

Location: The investigation covered upland soils located within Latitude 7^{o} 30$^{/}$ E and Longitude 5^{o} 40$^{/}$N and 6^{o} 45$^{/}$ N. The area lies within the southeast low-rainforest and derived Savanna zone of Nigeria. The soil is characterized by shale parent materials and of shallow depth (FDALR, 1985), with intermittent water logging conditions. The soil is noted with high temperature, with mean monthly atmospheric temperature ranging between 24^{o} and 28^{o}. The rainy season begins about May and ends around November, whereas the dry season starts about October and ends around April. The rainfall pattern is bimodal with peaks in the months of July and September. Annual rainfall ranges between 1500 mm and 2000 mm.

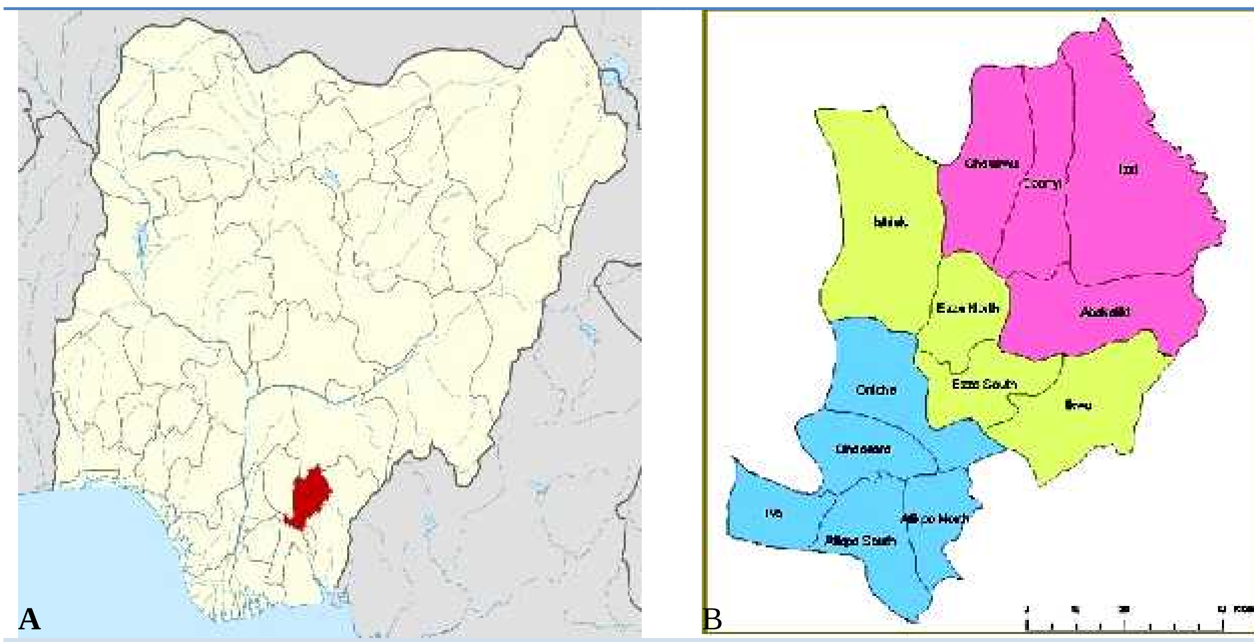

Figure 1: Location Map showing (A) Map of Nigeria indicating the study area and (B) Enlarged Map of Ebonyi State, indicating the LGAs (the study area).

Design: The study was a survey exercise covering most of the continuously cultivated upland soils of Ebonyi state. It involved all the thirteen local government areas in the state (Figure 1). The number of communities chosen for sampling in each local government was purposively selected, based on the size and extent of farming activities. Sixteen sampling sites were randomly chosen at each location for sample collection.

***Field Study*:** Soil samples were collected at 0-40 cm depth representing effective rooting zone and being mindful of the soils shallow depth. The samples from each location were thoroughly mixed and a Representative sample bagged individually, and analyzed separately. The average values of each parameter measured at sixteen sites of each location assumed the data for the location.

Laboratory Methods: The soil samples collected from the different locations were analyzed separately in the laboratory for the texture and chemical properties respectively. The soil particle size distribution was determined by the hydrometer method (Gee and Bouder 1989). The chemical characteristics were determined and interpreted using the method as outlined in Adepetu, (2000).

Data analysis: The data generated were statistically analyzed using summary and descriptive statistics, according to SAS 2006 version.

RESULTS AND DISCUSSION

Texture of the Degraded Soils

Table (2a and b) shows particle size distribution of the degraded soils. There are variations in the soil textural classes which could be attributed to either differences in topography and landforms, soil formation processes, land use or levels of soil degradation. Generally, the textural classes ranged from Silt to clay. Apart from soils at Nwedda, Ishieke, Inyimagu, Umuezoka, Owutu and Isu locations, the silt content of the soils is generally higher than sand and clay contents. The predominance of silt separate indicates that the water holding capacity of the soils is high. The textural classes indicate that the soils are likely to be heavy and prone to compaction. The very low organic matter content of the soils (i.e. < 2 percent) will contribute to soil compaction that can lead to the unfavourable growth of crops. The soils that represent the study area had been observed to have high soil bulk density, and soil compaction is believed to be an important limiting factor in crop production especially in intensively cultivated lands of the state (FDALR, 1985, Ogbodo and Chukwu, 2011).

Table 1a: Soil Texture under Derived Savanna Zone

LGA	Locations	SAND (%)	SILT (%)	Clay (%)	Textural Class
EZZA –NORTH	IDEMBIA	18	8	2	SiL
	AMEKA	14	82	4	SiL
	EZZAMA	13	57	30	SCL
	AMUZU	35	26	39	ClL
IKWO	ECHARA	13	63.4	23 .6	SiL
	OKPUITUMO	30	64	6	SiL
	EKA-AWOKE	22	74	4	SiL
	NDUFU- ECHARA	36	35.4	28.6	CL
	EKPA- OMAKA	49	46	5	L
ISHIELU	NKALAHA	22	75	3	SiL
	NTEZI	32	62	6	SiL
	OKPOTO	43	52	5	SiL
	UMUHUALI	21	74.6	4.4	SiL
	NKALAGU	30	53.4	16.6	SiL
	EZILLO	15.8	72.4	11.8	SiL
IZZI	IGBEAGU	19	76	5	SiL
	AGBAJA	24	70	6	SiL
	NDIECHI- EZZA	23	65	22	SiL
	INYIMAGU	20	45.4	34.6	ClL
	NDIEZE	28	50	22	L
OHAUKWU	EZZAMGBO	16	83	1	SL
	AMIKE- EZZAMGBO	14	84	2	SL
	EFFIUM	16	67.4	16.6	SiL
	OKPOSHI- ESHI	15.4	69.2	15.4	SiL
	NTURAKPA	29	70	1	SiL
ABAKALIKI	AMEGU	42	53	5	SiL
	NWEDDA	18.4	23.4	58.2	CL
	AMACHI	22.8	74	3.2	SiL
	NDIEGU-I SHIEKE	26	69	5	SiL
EBONY	ISHEIKE	20	33.4	46.6	CL
	NKALIKI- UNUHU	29	66	5	SiL
	OGUZORONWEYA	27	65	8	SiL
EZZA-NORTH	OGBOJI	20	80.1	9.9	SiL
	UMUOGHARA	14	82	4	SL
	UMUEZEOKA	14	51.4	34.6s	ClL

SL=Silt; CL=Clay; SiL= Silty Loam; L= Loam; ClL= Clay Loam; SCL= Silty Clay Loam.

Table 1b: Soil Texture under Low Rainforest Savanna Zone

LOCATIONS		Sand (%)	Silt (%)	Clay (%)	Textural Calss
Afikpo-North	Unwana	11	77.4	11.6	SiL
	Amasiri	14	83	3	SiL
	Ozizza/Ibii	23	75	2	SiL
	Akpo	21	75	4	SiL
	Nkpoghoro	11	78	11	SiL
	Ohaisu	15	79	6	SiL
	Itim	23	73	4	SiL
	Opi	39	56	5	SiL
Afikpo-South	Ebunwana	25	73	2	SiL
	Amangwu	66.6	18.4	15	SiL
	Owutu	46	21.5	32.5	L
	Oso	41	55	4	SiL
Iivo	Akaeze	32	63	5	SiL
	Ishiagu	28	70	2	SiL
	Ihie	33	62	5	SiL
	Okue	16	75	9	SiL
Ohaozara	Ugwulangwu	27	65	8	SiL
	Okposi	24.4	71	4.6	SiL
	Mgbom-na Chara	24	71	5	SiL
	Uburu	30	60	10	SiL
Onicha	Oshiri, igboeze	30	30	5	SiL
	Abaomege, Isu	26	69	5	SiL
	Ukawu	26	49	25	L
		14	51.4	34.6	SCL
		23	70	7	SiL

SL = Silty; CL = Clay; SiL = Silty Loam; L = Loam; CIL = Clay Loam; SCL = Silty Clay Loam

Fertility of the degraded upland soils

Chemical properties of the soils of the study locations are presented in tables 2a and b. The chemical properties of the soils indicate that the soils are low in fertility, which would pose a great constraint to crop production. In fact the soil fertility indicators like soil pH, organic matter and nutrient contents, show that the degraded soils have low fertility status. Soil pH values range from 4.1 to 5.9 with an average of 4.9 indicating very strongly acidic condition. The soil acidification observed can be attributed to human activities particularly intensive cultivation of the soils without addition of nutrients and application of inorganic fertilizers to the soil without organic matter, or liming. This practice is considered as a contributor to the widespread occurrence of acid soils in the state (Ogbodo, 2013a; b). Organic matter contents range from 0.17 percent (very low) to 1.99 percent (low) with an average of 1. 3 (very low). The area is also marked by high rainfall (1,500 – 2,000mm) per annum and high temperatures (FDALR, 1985), and also prone to annual bush burning; situations that favour high rate of organic matter decomposition accounting for the low organic matter content. All the soils have multiple nutrient deficiencies which are below the favourable amount of nutrient for crop production in degraded upland soils (Landon, 1991). This can be attributed to the generally low nutrient content of the parent rocks (shale) and to the strongly acidic chemical condition of the soils. Total N contents range from 0.05 (very low) to 0.28 % (moderate) with an average value of 0.21 percent (low), available P from 0.27 to 39.4 with average value of 15.12 (low), whereas K ranged from 0.05 to 0.41, with an average value of 0.19 (very low). The low available P in some locations corroborated the work of Ogbodo (2013) in acid soils of the state. The exchangeable Na is also low (<0.70 Cmol/kg), (Landon, 1991). These values apparently reflect the direct effect of the land use and other human activities. Generally, exchangeable Ca is medium (0.4 – 4.8 Cmol/kg), while exchangeable Mg is moderate to high (0.3 – 4.8 Cmol/kg). Most of the soils have exchangeable Ca and Mg contents above the critical values of 0.4 and 0.5 cmol kg^{-1}, suggesting that the elements are not a major problem in the degraded soils (Landon, 1991). Cation exchange capacity of the soils is very low which is partly due to their low organic matter contents, and which is reflective of the soils inability to retain nutrients. Ogbodo 2013a and b reported that those soils of these areas which represent these degraded soils are generally characterized by low cation exchange capacity, low base saturation, high P retention and depletion of nutrient reserves or soil impoverishment, depletion of organic matter and associated soil acidification combined with aluminium toxicity. This situation greatly determines agricultural production in Ebonyi state where what obtains is that subsistence farmers don’t practice the use of organic manures and fertilizers are expensive, so unaffordable to them.

Table 2a: Soil Chemical characteristics under the Derived Savanna Zone

LGA	Locations	pH	OM	N	P	K	Ca	Mg	Na	CEC	EA	BS
		(H_20)	(%)	(%)	(mg/g)			Cmolkg^{-1}				(%)
EZZA –NORTH	IDEMBIA	4.9	1.03	0.10	5.00	0.38	1.38	0.70	0.18	6.45	3.58	40,93
	AMEKA	4.8	1.37	0.09	4.50	0.08	1.35	0.56	0.10	4.89	2.80	42.74
	EZZAMA	4.7	1.24	0.05	6.00	0.12	1.oo	0.75	0.16	6.15	4.15	33.00
	AMUZU	5.1	1.24	0.14	4.80	0.12	0.60	0.56	0.10	6.23	4.85	22.15
IKWO	ECHARA	5	1.89	0.15	18.30	0.16	1.15	0.91	0.15	7.80	5.09	30.39
	OKPUITUMO	4.9	1.06	0.13	13.10	0.35	2.18	1.00	0.16	8.65	5.07	42.66
	EKA-AWOKE	5.1	1.02	0.11	18.30	0.23	2.43	1.25	0.21	9.03	4.72	45.63
	NDUFU- ECHARA	4.5	1.7	0.25	18.40	0.32	1.6	1.6	0.17	9.37	3.12	39.38
	EKPA- OMAKA	5.4	1.7	0.25	18.40	0.13	1.54	0.90	0.11	5.37	3.12	49.91
ISHIELU	NKALAHA	4.3	1.06	0.27	20.70	0.13	1.10	0.30	0.20	13.00	11.27	13.31
	NTEZI	4.7	1.37	0.07	37.80	0.14	2.10	0.91	0.19	9.83	6.83	33.37
	OKPOTO	4.8	1.37	0.07	37.80	0.13	1.10	0.89	0.17	8.92	5.68	25.67
	UMUHUALI	5.1	1.58	1.18	7.30	0.12	1.63	0.91	0.16	6.19	3.80	45.57
	NKALAGU	5.8	1.13	0.1	34.10	0.12	2.60	2.00	0.14	8.98	1.04	54.00
	EZILLO	5.1	1.86	0.12	4.40	O.11	2.10	0.19	0.12	5.72	3.20	44.10
IZZI	IGBEAGU	4.9	1.29	0.12	4.80	0.14	1.23	0.61	0.17	7.78	5.63	27.64
	AGBAJA	4.9	1.58	0.09	15.00	0.13	2.01	0.53	0.12	5.24	2.45	53.24
	NDIECHI- EZZA	4.8	1.1	0.06	7.10	0.30	1.50	0.95	0.33	8.25	3.18	36.24
	INYIMAGU	5.3	1.75	0.18	14.20	0.09	2.30	0.81	0.23	8.24	4.81	41.63
	NDIEZE	5.1	1.39	0.18	26.80	0.30	1.30	0.58	0.16	6.14	0.88	38.11
OHAUKWU	EZZAMGBO	4.9	1.4	0.12	8.70	0.22	2.3	0.82	0.15	7.49	3.60	46.60
	AMIKE- EZZAMGBO	5	1.15	0.05	3.90	0.30	1.56	0.85	0.28	7.15	4.23	41.82
	EFFIUM	5.2	1.34	0.21	38.50	0.10	3.80	1.12	0.25	9.96	0.80	52.91
	OKPOSHI- ESHI	5.5	0.87	0.17	20.10	0.31	2.60	1.60	0.15	8.16	3.50	57.11
	NTURAKPA	5.5	1.03	0.14	7.80	0.40	2.10	1.30	0.10	10.70	6.80	36.45
ABAKALIKI	AMEGU	4.9	1.58	0.14	17.90	0.12	0.40	0.30	0.11	9.00	18.07	10.33
	NWEDDA	5.6	1.99	0.13	27.00	0.08	2.40	1.60	0.13	7.69	0.48	54.75
	AMACHI	4.7	1.79	0.08	11.00	0.10	1.70	0.11	0.11	4.12	2.10	49.03
	NDIEGU-I SHIEKE	4.7	1.44	0.20	8.40	0.16	0.80	4.00	0.11	9.00	17.55	56.33

EBONY	ISHEIKE	5.2	1.44	0.17	28.70	0.10	4.80	4.80	0.15	18.07	1.12	54.51
	NKALIKI- UNUHU	4.9	1.5	0.11	18.10	0.11	2.60	0.70	0.21	6.42	2.80	56.39
	OGUZORONWEYA	4.9	1.1	0.13	27.50	0.17	1.54	0.92	0.15	6.09	3.31	45.65
EZZA-NORTH	OGBOJI	4.6	1.13	0.15	5.60	0.34	1.48	0.80	0.16	5.45	3.59	51.00
	UMUOGHARA	4.8	1.43	0.19	4.80	0.18	1.33	0.65	0.12	4.19	2.86	50.11
	UMUEZEOKA	5	1.32	0.08	38.20	0.17	4.00	2.40	0.14	12.21	0.80	55.55
	Mean	4.99	1.38	0.17	16.66	0.19	1.90	1.11	0.16	7.94	4.48	42.27

Table 2b: Soil Chemical characteristics under the Low Rainforest Zone

LGA	LOCATIONS	pH **(H_20)**	OM **(%)**	N **(%)**	P **(mg/g)**	K	Ca	Mg **Cmolkg^{-1}**	Na	CEC	EA	BS **(%)**
AFIKPO-NORTH	UNWANA	4.9	0.34	0.22	5.08	0.15	1.16	0.82	0.01	4.50	2.40	47.56
	AMASIRI	4.9	0.17	0.27	0.27	0.26	1.70	0.30	0.15	6.00	3.59	40.17
	OZIZZA/IBII	4.5	1.18	0.30	6.80	0.13	1.40	1.30	0.15	5.30	12.02	56.23
	AKPO	4.7	0.93	0.28	14.10	0.12	0.90	0.60	0.15	5.22	6.25	33.91
	NKPOGHORO	5.9	1.57	0.10	28.60	0.17	2.00	1.20	0.10	6.24	0.72	55.61
	OHAISU	4.8	1.75	0.08	16.90	0.22	1.90	0.90	0.17	7.50	4.33	42.53
	ITIM	4.9	1.28	1.18	2.60	0.13	0.90	0.60	0.22	8.50	5.65	21.77
	OPI	4.8	1.4	0.20	8.40	0.14	0.50	0.40	0.11	5.90	17.55	19.14
AFIKPO – SOUTH	EBUNWANA	4.7	1.44	0.20	8.40	0.16	0.80	0.40	0.11	5.90	17.55	24.92
	AMANGWU	4.9	1.72	0.17	10.40	0.19	3.10	1.00	0.21	9.00	4.50	50.00
	OWUTU	5	1.41	0.08	35.40	0.17	4.00	1.60	0.15	15.20	10.48	38.95
	OSO	5.3	1.13	0.14	5.70	0.19	2.30	0.70	0.22	9.50	5.49	35.89
IIVO	AKAEZE	4.9	1.44	0.18	8.06	0.14	1.15	0.63	0.14	5.94	3.69	34.68
	ISHIAGU	4.9	1.07	0.11	4.40	0.14	0.95	0.14	0.11	6.43	4.82	20.84
	IHIE	4.7	1.53	0.12	5.20	0.30	1.20	0.65	0.17	5.83	3.60	39.80
	OKUE	5.3	1.51	0.18	28.01	0.10	1.82	0.98	0.25	6.19	1.04	51.48
OHAOZARA	UGWULANGWU	4.9	1.10	0.13	37.50	0.17	1.54	0.92	0.15	6.09	3.10	45.65
	OKPOSI	5	1.65	0.20	2.50	0.13	4.00	2.40	0.15	11.56	0.88	57.79
	MGBOM- NA CHARA	5.3	1.79	0.25	39.40	0.07	2.80	2.00	0.14	9.95	3.04	50.35
	UBURU	4.7	1.17	0.11	2.60	0.15	1.40	0.30	0.11	4.59	2.68	42.70
ONICHA	OSHIRI	4.9	0.10	0.10	5.00	0.38	1.38	0.70	0.18	6.45	5.58	40.93
	IGBOEZE	5.2	1.06	0.11	7.30	0.40	1.50	0.60	0.15	5.10	4.35	51.96
	ABAOMEGE	4.9	1.96	0.23	12.60	0.05	1.09	0.36	0.12	3.02	1.40	53.64
	ISU	5.4	1.06	0.03	24.80	0.41	2.40	1.60	0.12	8.41	0.88	53.23
	UKAWU	5	1.13	0.10	19.2	0.32	1.20	0.80	0.09	9.61	7.20	25.08
	Mean	4.98	1.24	0.20	13.57	0.19	1.72	0.88	0.15	7.12	5.31	41.39

Loss of nutrients and organic matter

Almost all the soils of the state belong to Ultisols (FDALR, 1985; 1990) which are strongly weathered and soils which have generally low contents of essential plant nutrients. Farmers practices including seasonal bush burning, removal of crop residues, intensive and continuous cropping, non application of inorganic lime and inadequate manure application result in loss of nutrients and soil organic matter and therefore hasten the degradation of these inherently less fertile soils. The low content of essential nutrients in the soils is also attributable to soil erosion, leaching and nutrient mining by the growing plants, while erosion and decomposition are the causes of the low organic matter content. The loss of organic matter is of particular concern because organic matter plays a major role in the productivity of soils especially these soils that are Ultisols which are strongly weathered. This is because organic matter is the reservoir of plant nutrients from where they are slowly released to the soil solution. The soil organic matter constraint also influenced the low pH, cation exchange capacity, base saturation and poor structure of the soils. Loss of nutrient and organic matter are also commonly observed in these areas because low-input agriculture is practiced. In spite of the fact that the soils are of low fertility, farmers do not practice adequate fertilization or practice use of inorganic fertilizers alone without organic manure or complimentary use of organic and inorganic fertilizers. There is also soil degradation resulting from deforestation, and slash and burn farming practices which is accompanied by a decrease in quantity and quality of organic substances and non-cellulosic sugars in the soil. Many soils around the state are also degraded due to pollution arising from the accumulation of various types of wastes and toxic materials from mining activities (Ogbodo, 2006, Ezeh et al 2007, Ezeh and Chukwu 2011), and households (Ogbodo 2011) and agricultural activities (Ogbodo 2013a). Because of the fact that the state is rich in mineral resources, mining has probably caused more extensive and severe soil pollution than manufacturing activities.

Management options for the degraded soils

The degraded condition of the soils is a major problem for agriculture because of the various chemical and physical constraints they possess. Because the properties of degraded soils widely vary, soil management strategies should be site specific. This requires that every degraded soil has to be attended to in terms of its properties and constraints. Conservation farming must be introduced and adopted by the farmers. Reforestation should be widely promoted as a traditional approach to rehabilitating the degraded soils. Reforestation projects in the past have not been very successful due to, among other factors, the use of exotic tree species which are difficult to establish in infertile degraded upland soils. An alternative approach is agro-forestry, involving the use of indigenous tree species that are available locally in combination with some food crops. Such approach had proved effective in the restoration of degraded lands in Philippines, (Asio & Milan, 2002).

CONCLUSION

Based on soil fertility ratings (Landon 1991), the study locations suffer multiple nutrient deficiencies. The soil pH and organic matter are very low. Available P is low, total N is low and exchangeable K is also low. Similarly, the soils cation exchange capacity and base saturation are low. The low organic matter content and the nature of the parent materials accounted for these observations. The multiple nutrient deficiencies of the soils were also attributed to soil acidity, and nutrient mining by crops. To improve the soil productivity and enhance agricultural transformation in the area, the practice of retaining crop residue on the soil, application of organic manure, mineral fertilizers and liming should be adopted.

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