Annals of Tropical Research 22[1&2]:78-88 (2000)
ViSCA, Leyte, Philippines

Nutrient status of soils in the rain forest of Mt. Pangasugan, Leyte, Philippines

Sabine Zikeli[1], Victor B. Asio[2] and Reinhold Jahn[1]

[1]*Institute of Soil Science and Plant Nutrition, University of Halle-Wittenberg, 06108 Halle (Saale), Germany*
[2]*Institute of Tropical Ecology, Visayas State College of Agriculture, Baybay 6521-A Leyte, Philippines*

ABSTRACT

Zikeli S., V.B. Asio and R. Jahn. 2000. Nutrient status of soils in the rain forest of Mt. Pangasugan, Leyte, Philippines. *Ann. Trop. Res.* 22[1&2]:78-88.

Soils under rain forests are until now poorly understood. This study was conducted to determine if nutrient status is a limiting factor in the rain forest soils of Mt. Pangasugan in Leyte, Philippines. Four sampling sites at varying elevations in a representative catena were studied. In each site, three soil profiles representing the upper, middle and lower slopes were sampled. Soil samples were analyzed for OM, N, P, K, Ca and Mg. Results showed that, except phosphorus, the nutrients are not limiting in the rain forest soils studied. Phosphorus appears limiting despite the fact that some amount of it is brought into the ecosystem by rain. Results also showed a generally high spatial variability of the nutrient status of the soils in the study site.

Keywords: Andosols. Alisols. catena. nutrient status. rain forest. tropical soil.

INTRODUCTION

Soils under rain forests are generally considered to be infertile. This classical view has until now influenced research and management of this fragile tropical ecosystem. In a recent review of the subject, Bruijnzeel (1998) pointed out that this view of tropical rain forest as being perched

Correspondence: V.B. Asio. Address: Institute of Tropical Ecology, Visayas State College of Agriculture, Baybay 6521-A Leyte, Philippines. Fax: 0063: 053-335-2652. E-mail: asio@philwebinc.com

on a nutrient-poor substrate is an overgeneralization and that the extent of extremely infertile soils in the tropics is smaller than previously assumed. Likewise, Sanchez and Logan (1992) criticized this view and pointed out that there are fertile as well as infertile soils in the tropics. Tropical soils are highly variable (Harrassowitz, 1930; Moormann, 1972) depending upon the parent rock, geomorphic surface, vegetation, and human influence. Thus, soils under rain forests could range from highly weathered infertile type to the relatively young fertile type on alluvial and volcanic sediments (Jordan, 1985; Longman and Jenik, 1987).

While the nutrient characteristics of highly weathered rain forest soil types have been widely studied, very limited research has been done on the nature of the younger types which are common on volcanic landscapes of Insular Asia like the Philippines. Likewise, very little is known concerning the nature of rain forest soils in the Philippines since most soil studies in the past dealt with agricultural soils. Except for the previous pedo-ecological study by Asio and co-workers (Asio, 1996; Asio *et al.*, 1998; Jahn and Asio, 1998), no other research dealing on the nutrient characteristics of the forest soils in Mt. Pangasugan has been published. Our hypothesis was that nutrient status is not a limiting factor in the rain forest soils of Mt. Pangasugan considering the fact that the area is underlain by relatively young andesitic-basaltic pyroclastics, and based on our observation that upland crops are grown successfully in shifting cultivation fields inside the forest reserve.

MATERIALS AND METHODS

Study area

The study area is the mid-western slope of Mt. Pangasugan forest reserve in Leyte, Philippines (Fig. 1). The geology of the area is characterized by Pliocene-Pleistocene andesitic to basaltic pyroclastics. The soils in the upper slopes are classified as Andosols (Andisols) and in the lower slopes as Alisols (Ultisols). Some chemical properties of representative soil profiles in the area are given in Table 1. Annual rainfall, determined in the lowland at 5 m elevation, is 2600mm although our actual observation indicates that the mountain has a considerably higher rainfall than the lowland area. Average temperature is

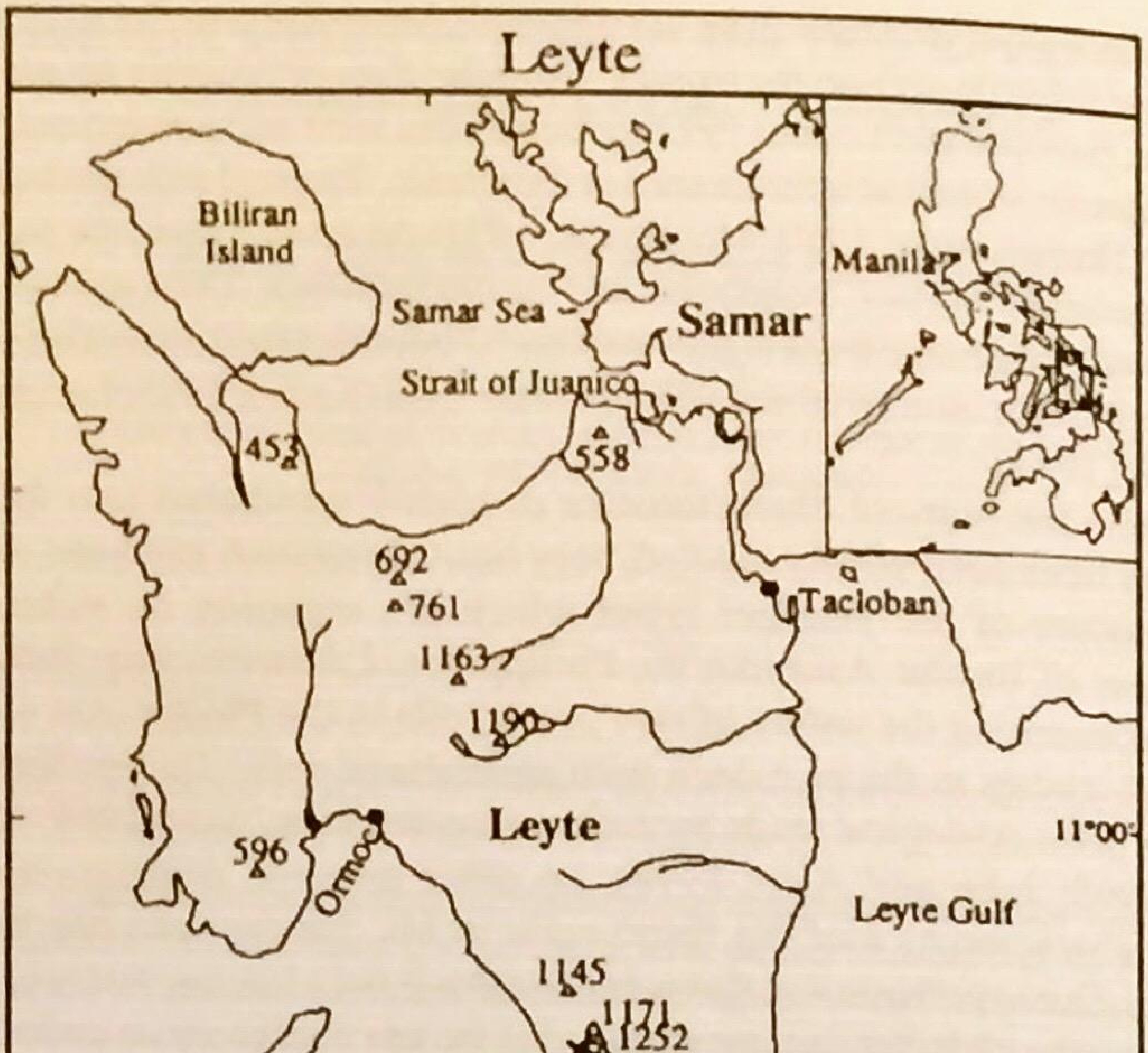

Figure 1. Location of the study site (marked X)

Table 1. Soil chemical properties for selected soil profiles in the study sites

Site	Depth (cm)	pH CaCl$_2$	pH H$_2$O	CEC$_{eff}$* cmol$_c$/kg	BS$_{eff}$** %	Al-saturation %	P-retention %
1 Alisol	0-15	4.2	4.4	8.85	88.8	10.5	61.0
	15-26	4.1	4.6	7.48	70.2	29.4	71.0
	26-50	4.1	4.6	7.58	51.1	48.8	72.0
	50-76	4.0	4.5	9.17	33.5	58.9	75.0
	76-100	4.0	4.6	9.10	28.5	59.3	76.0
2 Andosol	0-25	4.3	4.9	28.8	72.5	21.9	90.0
	25-55	4.3	5.1	31.3	73.8	20.3	89.9
	55-90	4.3	5.1	32.5	72.7	21.1	91.0
	90-122	4.4	5.1	32.5	83.6	12.7	83.5
3 Andosol	0-20	4.2	5.0	24.1	51.8	38.1	>99.9
	20-40	4.3	5.0	20.2	50.0	38.6	>99.9
	40-63	4.3	5.9	20.8	57.3	31.5	>99.9
	63-90	4.4	5.2	21.6	67.8	23.8	>99.9
	90-100	4.4	5.3	21.4	72.0	20.6	>99.9
4 Andosol	0-45	4.7	5.0	18.6	62.8	26.7	>99.9
	45-90	4.5	5.1	15.0	70.5	21.8	>99.9
	90-130	4.0	5.1	14.0	61.9	27.0	>99.9
	130-150	3.9	5.0	18.0	45.2	39.2	>99.9

* effective Cation Exchange Capacity determined by summation of cations
** effective Base Saturation based on effective CEC

28°C and the temperature regime is classified as isohyperthermic. The forest is of the Dipterocarp type. Detailed information on the vegetation in the site is found in Langenberger (2000).

Sampling and laboratory analysis

A catena starting at about 100 m asl and extending up to 500 m asl was chosen. The aerial length of the catena was approximately 2 km. Four sampling sites were then selected at 100-200 m asl (site 1), 370-400 m asl (site 2), 430-460 m asl (site 3) and 470-520 m asl (site 4). In each sampling site, three soil profiles representing the upper, middle and lower slopes were sampled.

Bulk soil samples were collected from the genetic horizons of each soil profile, air dried and sieved to pass a 2 mm sieve. Organic matter (OM) was analyzed following the Walkley-Black method on samples ground to <0.25 mm (Nelson and Sommers, 1982), total N by Kjeldahl method, available P by Bray No. 2 and available Ca and Mg by ammonium lactate extraction all according to Schlichting *et al.* (1995). Available K was analyzed by the HCl extraction method of Houba *et al.* (1989) and bulk density by the core method (Schlichting *et al.*, 1995). Samples of fresh rock and saprolites were collected from representative soil profiles and analyzed for total P, K, Ca and Mg using X-ray fluorescence spectrophotometry.

Quantification of OM, total N, available P, K, Ca and Mg was done by calculating the amount of nutrients for three uniform depths (0-20, 20-40, 40-60 cm) using their corresponding bulk density values. The use of uniform depths in the quantification was necessary to allow better comparison among the sites. The 60 cm depth was considered since it was the average thickness of the soils in the area. The 40 to 60 cm range is also commonly used for the quantification of nutrients in soils of tropical rain forests (see Nykvist, 1997).

RESULTS AND DISCUSSION

Table 2 shows that the total OM in the 60 cm depth ranged from 1.1 kg m^{-2} in the midslope of site 1 (Alisol) to 6.1 kg m^{-2} in the lower slope of site 4 (Andosol). The OM values for the Andosols were lower than those reported for cooler subtropical climates (Shoji *et al.*, 1992). Results also showed that OM was generally higher in the upper 0-20 cm layer than in the lower 20-40 and 40-60 cm layers although for some profiles the difference between the OM in the upper and lower layers were only slight. Variation in the amounts of OM was considerable within each site (i.e., between upper, middle and lower slopes) and between sites. Total N was moderately high in the soils ranging from 0.2-0.4 kg m^{-2} in the Andosols to 0.4-0.6kg m^{-2} in the Alisols. These values fall within the range of total N values from several rain forest soils reviewed by Nykvist (1997). Very observable also was the less variation of total N between sites compared to OM. Available P was very low (0.042-0.20 g m^{-2}) in all the soils in the catena. Variations within a site and between sites were evident from the values both for the different layers and for the whole 60 cm soil depth. Total

Table 2. Amounts of OM, total N and available P, K, Ca & Mg of the soils in the rain forest of Mt. Pangasugan, Leyte (recalculated to uniform depths of 0-20, 20-40 & 40-60 cm)

Site	Soil type	Physiographic position	Depth (cm)	OM	N	P	K	Ca	Mg
				------ kg m^{-2}------		mg m^{-2}	--------------- g m^{-2} ---------------		
(1) 100-200 m asl	Humic Alisol	upper slope	0-20	0.7	0.3	0.060	13.9	97.7	71.2
			20-40	0.4	0.2	0.034	9.9	60.1	47.9
			40-60	0.3	0.1	0.050	6.5	59.4	39.0
			Total	*1.4*	*0.6*	*0.144*	*30.3*	*217.2*	*158.1*
	Humic Alisol	midslope	0-20	0.6	0.2	0.056	12.0	265.4	87.5
			20-40	0.3	0.1	0.030	8.1	147.0	95.3
			40-60	0.2	0.1	0.030	7.0	43.9	64.9
			Total	*1.1*	*0.4*	*0.116*	*27.1*	*456.3*	*247.7*
	Humic Alisol	lower slope	0-20	0.7	0.2	0.011	19.1	386.0	101.2
			20-40	0.4	0.1	0.056	8.8	ND	80.6
			40-60	0.2	0.1	0.038	6.3	ND	85.4
			Total	*1.3*	*0.4*	*0.105*	*34.2*	-	*267.2*
(2) 370-400 m asl	Haplic Andosol	upper slope	0-20	0.9	0.1	15.1	6.8	60.5	33.3
			20-40	1.0	0.1	14.1	6.8	58.0	32.1
			40-60	1.0	0.0	13.1	6.8	55.6	30.8
			Total	*2.9*	*0.2*	*42.3*	*20.4*	*174.1*	*96.2*
	Haplic Andosol	midslope	0-20	1.5	0.1	18.9	2.8	52.6	62.3
			20-40	1.0	0.1	15.5	6.8	40.7	44.9
			40-60	0.9	0.0	12.2	5.4	36.7	39.1
			Total	*3.4*	*0.2*	*46.6*	*15.0*	*130.1*	*146.3*
	Haplic Andosol	lower slope	0-20	2.6	0.1	52.6	18.0	107.2	114.2
			20-40	1.4	0.1	47.4	14.5	121.6	125.2
			40-60	1.2	0.1	45.4	14.7	121.9	123.4
			Total	*5.2*	*0.3*	*145.4*	*47.2*	*350.7*	*362.8*

ND = no data

Table2. *(continued)*

Site	Soil type	Physiographic position	Depth (cm)	OM	N	P	K	Ca	Mg
				------ kg m^{-2}------		mg m^{-2}	-------------- g m^{-2} --------------		
(3) 430-470 m asl	Haplic Andosol	upper slope	0-20	1.8	0.1	45.1	11.2	15.8	25.8
			20-40	1.8	0.1	46.1	13.9	28.7	30.3
			40-60	1.7	0.0	42.3	18.3	114.2	40.5
			Total	*5.3*	*0.2*	*133.5*	*43.4*	*158.7*	*96.5*
	Haplic Andosol	midslope	0-20	2.7	0.1	59.9	102.5	128.3	52.7
			20-40	0.8	0.0	39.1	28.1	63.6	47.9
			40-60	0.3	0.0	15.8	18.3	26.8	20.6
			Total	*3.8*	*0.1*	*114.8*	*148.9*	*218.7*	*121.2*
	Haplic Andosol	lower slope	0-20	1.6	0.0	38.7	29.8	82.4	37.5
			20-40	1.6	0.0	38.7	29.8	82.4	37.5
			40-60	2.5	0.1	126.7	50.4	221.8	101.1
			Total	*1.3*	*0.1*	*204.1*	*110.0*	*386.7*	*176.1*
(4) 480-525 m asl	Haplic Andosol	upper slope	0-20	2.7	0.1	39.1	30.9	27.0	17.0
			20-40	2.5	0.1	38.9	31.1	27.3	16.9
			40-60	0.7	0.0	37.3	33.3	30.5	16.3
			Total	*5.9*	*0.2*	*115.2*	*95.3*	*84.8*	*49.2*
	Haplic Andosol	midslope	0-20	0.9	0.1	51.9	36.0	47.2	20.8
			20-40	0.9	0.1	51.9	36.0	47.2	20.8
			40-60	0.9	0.1	42.5	58.8	31.8	17.0
			Total	*2.7*	*0.3*	*146.3*	*130.8*	*126.2*	*58.4*
	Haplic Andosol	lower slope	0-20	2.8	0.1	32.9	12.9	8.9	8.9
			20-40	1.9	0.1	34.5	34.0	8.5	8.8
			40-60	1.4	0.1	35.9	28.6	8.3	9.2
			Total	*6.1*	*0.3*	*103.3*	*75.4*	*25.7*	*26.9*

values of available bases at 60 cm depth ranged from 15 to 149 g m^{-2} for available K, 25 to 456 g m^{-2} for available Ca and from 27 to 267 g m^{-2} for available Mg. These values are much higher than for several rain forest soils reviewed by Nykvist (1997). Considerable variations in the values of these essential elements occurred both within and between sites.

The high amount of OM of rain forest soils is generally known (Jordan, 1985; Longman and Jenik, 1987). However, this is only generally true for the surface horizons. Results of this study revealed that OM accumulation in the rain forest soils were still considerable at 60 cm soil depth. This could be due to the moderate rooting density even in deeper soil horizons. Preservation of OM due to the effect of short-range-order clay minerals such as imogolite and allophane in the Andosols and of iron oxides in the Alisols help explain this observation. In our previous study (Jahn and Asio, 1998), we found that the Andosols contained significant amounts of imogolite, ferrihydrite and allophane while the Alisols contained high amounts of hematite and goethite. The high total N is attributable to the high OM since more than 95 per cent of soil N comes from OM (Pagel *et al.*, 1982). The low available P is due to the following reasons: low pH and very high P retention of the soils (Table 1), and low P content of the andesitic parent rock (Table 4). The ability of the native vegetation to cope with this limited P condition, could be explained by an enhanced availability of P due to mycorrhizal association. Jordan (1985) reported that such association is important for P nutrition in P deficient soils of rain forest ecosystems. Moreover, considerable amount of P could have come from aeolian addition in the form of dust and ashes from burning activities in nearby shifting cultivation fields as well as from the communities in the lowland area about 2 km away. This is indicated by the composition of the rain water collected in the middle portion of the study area (Table 3). The high amounts of available K, Ca and Mg are due to the relatively high contents of these elements in the parent rock (Table 4) and to the aeolian input especially in the case of K (Table 3). The soils in the upper part of the catena are relatively young and still contain in their profile considerable amounts of slightly weathered rock fragments which could serve as source of these elements in question. The soils in the lower portion of the catena, although more intensively weathered, still showed high amounts of K, Ca and Mg probably due to the lateral transport of these nutrients from the upper slopes. Such occurrence is common in humid landscapes (Stahr, 1990; Asio, 1996) and appears to occur in the study area as indicated by the high amounts of these elements in the stream water collected below the study site (Zikeli, 1998).

Table 3. Nutrient contents of rainwater collected at 480 m asl

Sampling period	pH	Mg	Ca	K	P	NH_4^+	NO_3^-
		(mg/l)					
10/10-10/15/98	6.1	0.06	0.19	1.03	1.23	1.04	0.98
10/15-11/03/98	6.3	0.09	0.30	0.92	1.38	0.92	0.92
11/03-11/15/98	5.9	0.02	0.08	1.21	1.22	0.90	1.08

Table 4. Amounts of P, K, Ca and Mg in the fresh and weathered rocks (saprolite) below the solum in the study site

		P	K	Ca	Mg
		g/kg			
holocene andesite	fresh	1.06	12.90	59.70	18.50
	saprolite	0.81	10.30	38.60	11.80
pleistocene andesite/ basalt	fresh	1.68	11.80	68.90	22.10
	saprolite	0.32	0.30	0.90	2.80

The results of the study also indicate a relatively high variation of the nutrient status of the soils studied. This is supported by the study of Pasayloon (2000) who, using one of the profiles in site 1, found significant microscale spatial variation of several chemical soil properties. High spatial soil variability of soils under rain forests is considered as a major factor contributing to the high species diversity in this ecosystem (Longman and Jenik, 1987). Soil variability is probably due to the effect of geologic, pedologic and biologic processes which have been going on in the study area for a long time.

CONCLUSION

From the results of the study, it can be concluded that the hypothesis that nutrients are not limiting in the area is correct except for phosphorus. This element is limiting in the soil despite the considerable contribution coming from dusts and ashes probably from nearby human activities. There is generally high spatial variability of the nutrient status of the soils in the rain forest of Mt. Pangasugan.

ACKNOWLEDGMENTS

The authors thank the German Academic Exchange Service (DAAD) for the financial support. In addition, this paper was prepared by the authors while V.B. Asio was a visiting scientist in Halle (May-June 1999) made possible by a scholarship grant from the DAAD. The authors likewise thank Gerhard Langenberger, a PhD candidate (Forest Science) from Freiburg University, who was very helpful during our field work in Leyte.

REFERENCES

ASIO V.B. 1996. Characteristics, weathering, formation and degradation of soils from volcanic rocks in Leyte, Philippines. *Hohenheimer Bodenkundliche Hefte* 33. (Published PhD Thesis, University of Hohenheim) Stuttgart, Germany.

ASIO V.B. and Z.S. CHEN. 1998. Study of andesite weathering in Northern Taiwan using micromorphological approaches. *Taiwan Journal of Forest Science.* 13:259-269.

ASIO V.B., R. JAHN, K. STAHR and J. MARGRAF. 1998. Soils of the tropical forests of Leyte, Philippines. II. Impact of different land uses on status of organic matter and nutrient availability. In: *Soils of Tropical Forest Ecosystems* (A. Schulte and D. Ruhiyat, eds.). Springer Verlag, Berlin-Heidelberg-New York, pp: 37-44

BRUIJNZEEL L.A. 1998. Soil chemical changes after tropical forest disturbance and conversion: the hydrological perspective. In: *Soils of Tropical Forest Ecosystems.* (A. Schulte and D. Ruhiyat, eds.). Springer Verlag, Berlin-Heidelberg-New York, pp: 45-61

HARRASSOWITZ H. 1930. Boeden der tropischen Regionen. In: *Handbuch der Bodenlehre.* III (E. Blanck, ed.). Verlag von Julius Springer, Berlin, pp: 362-436

HOUBA V.J.G., J.J. VAN DER ZEE, I. NOVOZAMSKAY and I. WALINGA. 1989. *Soil and Plant Analysis.* Part 5. Soil Analysis Procedures, Dept. Soil Science and Plant Nutrition, Wageningen

JAHN R. and V.B. ASIO. 1998. Soils of tropical forests of Leyte, Philippines. I. Weathering, soil characteristics, classification and site qualities. In: *Soils of Tropical Forest Ecosystems.* (A. Schulte and D. Ruhiyat, eds.). Springer Verlag, Berlin-Heidelberg-New York, pp: 29-36

JORDAN C.F. 1985. *Nutrient Cycling in Tropical Forest Ecosystems.* John Wiley and Sons, New York.

LANGENBERGER G. 2000. Forest vegetation studies on the foothills of Mt. Pangasugan, Leyte, Philippines. TOB Publication F-II/10e. Tropenökologisches Begleitprogram, GTZ, Eschborn, Germany.

LONGMAN K.A. and J. JENIK. 1987. *Tropical Forests and its Environment* (2^{nd} edn.). Longman Scientific and Technical, Essex

MOORMANN F.R. 1972. Soil microvariability. In: *Soils of the Humid Tropics*. National Academy of Science, Washington, D.C. pp: 45-49

NELSON D.W. and L.E. SOMMERS. 1982. Total carbon, organic carbon and organic matter. In: *Methods of Soil Analysis. Part II: Chemical and microbiological properties*. (A.L. Page *et al.*, eds.). Amer. Soc. Agron. Inc. and Soil Sci. Soc. Amer., Madison, Wisconsin, pp: 539-594

NYKVIST N. 1997. Total distribution of plant nutrients in a tropical rain forest system, Sabah, Malaysia. *Ambio* **26**:152-157

PAGEL H., J. ENZMANN and H. MUTSCHER. 1982. *Pflanzennaehrstoffe in tropischen Boeden- ihre Bestimmung und Bewertung*. VEB Deutscher Landwirtschaftsverlag, Berlin

PASAYLOON L.A.G. 2000. *Micro-scale spatial variability of some properties of a forest soil in Mt. Pangasugan*. B.Sc. Thesis. ViSCA, Baybay, Leyte.

SANCHEZ P.A. and T.J. LOGAN. 1992. Myths and science about the chemistry and fertility of soils in the tropics. In: *Myths and Science of Soils of the Tropics*. SSSA Special Publication No. 29, Madison, Wisconsin, pp: 35-46

SCHLICHTING E., H.P. BLUME and K. STAHR. 1995. *Bodenkundliches Praktikum*. (2nd edn.). Blackwell, Berlin

SHOJI S., M. NANZYO and R.A. DAHLGREN. 1992. *Volcanic Ash Soils. Genesis, properties and utilization*. Developments in Soil Science 21, Elsevier, Amsterdam

STAHR K. 1990. Transport processes in soils and landscapes. *Ernst Schlichting Memorial Workshop. Hohenheimer Arbeiten*, Ulmer, Stuttgart, pp: 58-68

ZIKELI S. 1998. Nutrient status and nutrient cycles of the tropical rain forest, Mt. Pangasugan, Leyte, Philippines. Diplomarbeit, Martin Luther University, Halle, Germany.