Diversity and Fertility of Soils in Doi Inthanon Area, Chiang Mai Province

Wittaya Jindaluang, Somchai Anusontpornperm* and Irb Kheoruenromne

ABSTRACT

The diversity and fertility of 15 soils in the Doi Inthanon area of Chiang Mai province was studied using standard methods for field investigation and laboratory analysis, to characterize differences in their morphology, their physical and chemical properties and to assess their fertility levels. The soils occupied areas from 1,276 up to 1,563 m (above sea level, ASL) with slope ranging from 1 to 62%. Most soils were deep to very deep and acidic, with sand and silt dominating fine earth and a presence of an argillic horizon in all soils. They showed diversity in color, pH, presence of colluviated materials and depth of weathered materials within the profile. Their fertility levels were slightly different, but mostly medium in the upper part and medium or poorer in the layer between 30 and 100 cm. High organic matter content played an integral part in enhancing soil fertility level in all soils, combined with high amounts of available potassium in some soils. A small amount of bases and high values of exchangeable acidity signified the low base saturation percentage, which, in turn, had a negative impact on soil fertility levels in this area of Inthanon.

Key words: soil survey, highland soils, soil diversity, soil fertility, Doi Inthanon

INTRODUCTION

The Inthanon Royal Project Research Station is located in Doi Inthanon National Park, Chiang Mai province, within the North and West Continental Highlands (Moormann and Rojanasoonthon, 1972). Land surfaces are mainly slope complex (Dent, 1973) and were previously covered by native forests that were nearly all hill evergreen forest. Some areas have been converted to agriculture for a few decades, particularly those on valley floors and valley sideslopes. Based on information cited by Jindaluang (2008), there has been many soil studies in forest areas, however soil data after a change from forest to agricultural production appears scarce. Therefore, the purposes of this study were to characterize soils in the area both under crop production and native forests, and to assess the diversity of the soils and their fertility levels.

MATERIALS AND METHODS

Fifteen soils were chosen for the study. They were located in different substations as follows:

1. Khun Huai Haeng substation: ornamental plot (INT-1), coffee and kiwi plot (INT-2), plum plot (INT-3), pear plot (INT-4) and grape plot (INT-5)
2. Main station: vegetable plot (INT-6) and strawberry plot (INT-7)

Department of Soil Science, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.

* Corresponding author, e-mail: somchai.a@ku.ac.th

3. Pha Tung substation: area left idle (INT-8), strawberry guava plot (INT-9), peach plot (INT-10) and coniferous forest area (INT-11)

4. Mae Ya Noi substation: vegetable plot (INT-12), coffee plot (INT-13), apricot plot (INT-14) and hill evergreen forest area (INT-15).

Soil sampling from each genetic horizon at each site was carried out during periods of field investigation using standard soil survey and field sampling instruments (Kheoruenromne, 1987; Soil Survey Division Staff, 1993). Soil physical and chemical analyses were undertaken based on standard methods (National Soil Survey Center, 1996).

RESULTS AND DISCUSSION

Environmental condition and field morphology

All soils were located in a different landscape position at each site, starting from the narrow valley floor or lower footslope to the crestal slope and elevation, where soils occur, ranging from 1,276 up to 1,563 m (ASL). The slope at sampling sites was between 1 and 62%. Most soils were derived from colluvium and residuum of gneiss and granite, except for the soil in ornamental plot (INT 1) that was formed from intermountain local alluvium. Land uses differed from one place to another. The area has a humid subtropical climate (Peel *et al.*, 2007). The annual rainfall varies from 1,530 to 1,913 mm (Table 1).

Table 1 Environmental conditions of sites studied.

INT	Elevation (m)	Slope (%)	Rainfall (mm)	Physiography	Parent material	Land uses/ Natural vegetation
1	1,316	1	1,913	Narrow valley floor	Intermountain local alluvium	Ornamental plant plot
2	1,325	35	1,913	Lower sideslope	Colluvium over residuum derived from gneiss	Coffee and Kiwi plot
3	1,370	31	1,913	Middle sideslope of spur	Colluvium over residuum derived from gneiss	Plum plot
4	1,390	10	1,913	Shoulder slope of dissected spur	Colluvium over residuum derived from gneiss	Pear plot
5	1,362	35	1,913	Concave footslope of granite mountain	Colluvium over residuum derived from granite	Grape plot
6	1,276	2	1,703	Graded dissected footslope complex	Colluvium of gneiss mixed with granite	Strawberry plot
7	1,301	20	1,703	Footslope of granite mountain	Colluvium over residuum derive from granite	Vegetable plot
8	1,474	32	1,913	Middle footslope derived from gneiss	Colluvium over residuum	Idle plot
9	1,495	45	1,913	Lower backslope	Colluvium from gneiss	Strawberry guava plot
10	1,523	62	1,913	Upper backslope	Colluvium over residuum derived from gneiss	Peach plot
11	1,563	26	1,913	Crestal slope	Residuum derived from gneiss	Coniferous forest
12	1,405	10	1,530	Lower erosional footslope	Colluvium of gneiss	Vegetable plot
13	1,424	15	1,530	Middle erosional footslope	Colluvium of gneiss	Coffee plot
14	1,434	12	1,530	Upper middle erosional footslope	Colluvium of gneiss	Apricot plot
15	1,454	26	1,530	Upper erosional footslope	Colluvium of gneiss	Hill evergreen forest

Morphologically, the genetic horizon sequence of most soils, which were mainly Ap(A)-Bt-(BCrt or Crt), indicated development to some extent. An argillic horizon was a major diagnostic horizon for soil. All soils were deep to very deep. Soil texture was sandy loam to sandy clay, reflecting inherent characteristics derived from the parent rock material. The higher the elevation and the higher the position the soils occupied in the same landscape, the more reddish color they were. The lower subsoil in some profiles had mixed colors. This was due to differential weathering of parent rocks (Kheoruenromne, 1999; Buol *et al*., 2003). Topsoil thickness of most soils found on the mountain midslope was generally thinner than in other soils found on lower parts of the same mountain or crestal slope. This was indicative of erosion, which was more severe in the former than in the latter.

Physical properties of soils

Particle size distribution showed that the soils were mainly composed of sand and silt particles, reflecting their parent rock types, which were granite and gneiss (Figure 1). Clay content tended to increase with depth, while on the contrary, the amount of sand and silt tended to decrease with increasing depth. This indicated that the major processes involved were lessivage and elluviation, which can be identified by the presence of an argillic horizon in which clay coating and clay bridges are commonly found (Soil Survey Staff, 1999; Buol *et al*., 2003). The soils mainly had low to moderately low bulk density values in the topsoil (0.91-1.38 Mg m^{-3}) and low to moderate in the subsoil (0.93-1.53 Mg m^{-3}). This was due to greater amounts of organic matter in the topsoil than in the subsoil. In addition, translocation of clay downward to the subsoil created denser subsoil layers by filling up some pores (Foth, 1990), which resulted in a decrease of macropores in layers underneath surface horizon (Calvert *et al*., 1980; Potichan, 1991; Brady and Weil, 2008). This effect was also substantiated by the hydraulic conductivity values, which were generally more rapid in the topsoil (0.01-31.77 cm hr^{-1}) than in the subsoil (0.01-18.51 cm hr^{-1}) (Richie, 1981).

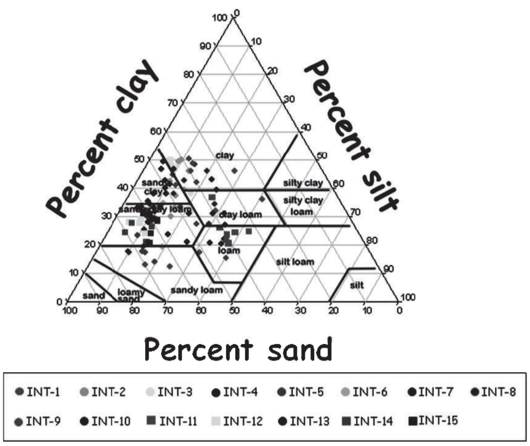

Figure 1 Particle size distribution of soils.

Chemical properties of soils

Soil pH of most soil profiles was extremely acid to strongly acid (pH 4.2-5.5), except for those soils from the main station (INT-6 and 7) that had a slightly higher pH, especially in the surface layers which were slightly acid (pH 6.4-6.5). This was due mainly to the application of lime. The net charge (ΔpH) of these soils was negative indicating the dominance of cation exchange in the soil system (Sanchez, 1976). The trend in soil pH (Figure 2) within the soil profile showed that some cations had been leached out of the soils to a measurable degree, but not completely, thus the pH tended to increase in the lower part of soil solum in most soils (Young, 1976; Kheoruenromne, 1999).

The organic matter content in these soils was mostly very high in the topsoil layer (46.33-83.38 g kg^{-1}) and moderate to moderately high down to a depth of 50 cm, with a decreasing trend to a greater depth (Figure 2). The higher content of organic matter in the upper compared with the lower part of the soil profile was due to accumulation and subsequent decay of plant residues, such as roots and above ground biomass, under cultivation or natural vegetation, in addition to the application of compost and manure (Sanchez, 1976; Virgo and Holmes, 1977; Vangai *et al.*, 1986; Magdoff and Weil, 2004). The amount of organic matter in these soils had a close relationship with the total nitrogen, so consequently, the trend of nitrogen distribution within the soil profile was similar to that of the organic matter.

All soils had very low levels of available phosphorus (0.01-0.83 mg kg^{-1}) throughout the soil profile (Figure 2). This may have been caused by the low pH of the soils, resulting in the release of considerable amounts of aluminium and iron oxides into the soil solution, which effectively fixed phosphorus into unavailable forms (Sanchez, 1976; Havlin *et al.*, 2005; Brady and Weil, 2008).

The available potassium content of the soils (Figure 2) varied from very low to very high (4.55-379.71 mg kg^{-1}) and decreased with increasing depth within the soil profile, due to the leaching process (West and Beinroth, 2000). The higher amounts of this plant nutrient in topsoil layers may have been due to heavy application of potassium fertilizers, particularly in the soils found under greenhouse cover (INT-1, 6 and 7) where leaching was diminished compared with those under normal conditions.

The extractable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) of most soils were very low to low in both topsoil and subsoil layers, except for the topsoil of the ornamental plant plot (INT-1), vegetable plot (INT-6), strawberry plot (INT-7), left-idle plot (INT-8) and strawberry guava plot (INT-9), where the amount was moderate to high, likely due to liming. In contrast, exchangeable

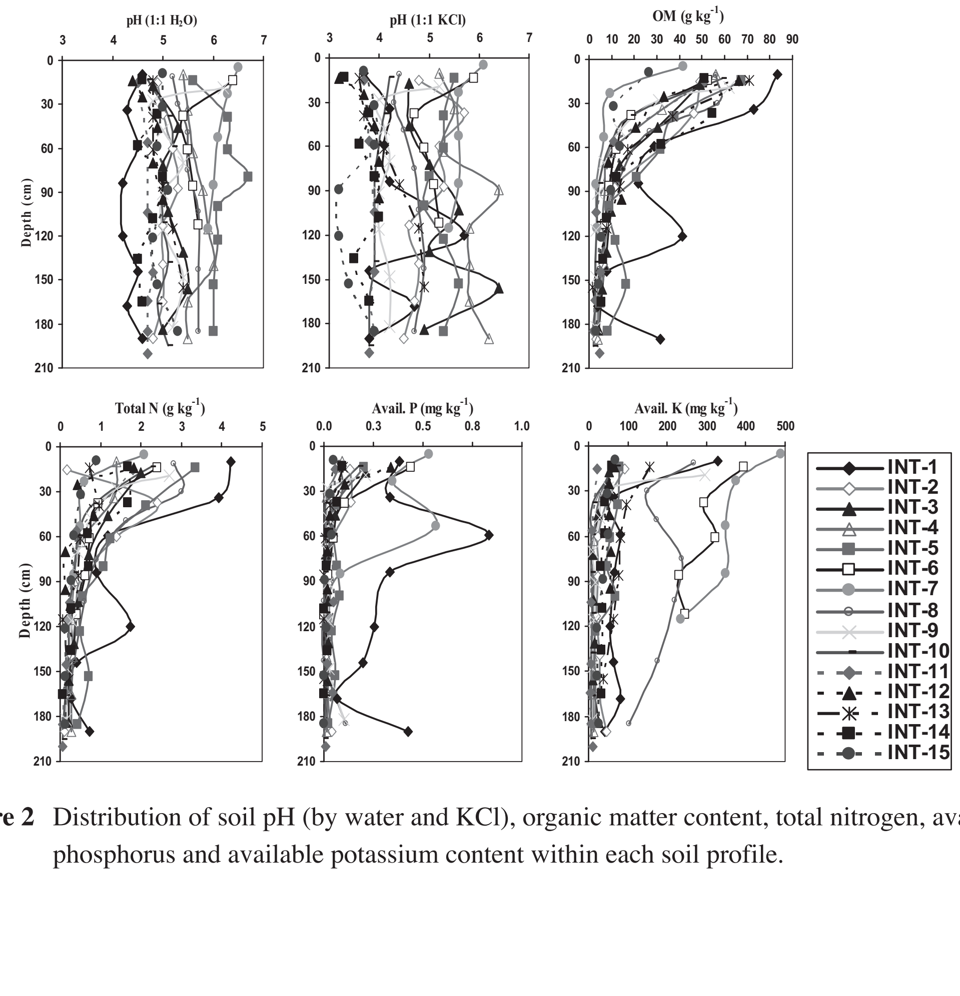

Figure 2 Distribution of soil pH (by water and KCl), organic matter content, total nitrogen, available phosphorus and available potassium content within each soil profile.

acidity values of these soils (Figure 3) were high to very high (10.50-39.73 cmol kg^{-1}) in the topsoil and moderate to very high (3.00-25.49 cmol kg^{-1}) in the subsoil. This indicated that Al^{3+} and H^{+} were dominant cations in these soils. However, the trend of this exchange property tended to decrease with depth, showing a contrast with the reverse soil pH trend that increased with depth (Foth, 1990; Tan, 1993). In addition, the release to the soil system of hydrogen ions from the decomposition of organic matter helped increase the value of exchangeable acidity, especially in the topsoil layers (Brady and Weil, 2008).

The cation exchange capacity of these soils (Figure 3) varied from very low to moderately high (2.12-17.36 cmol kg^{-1}). Notably, soils in the Mae Ya Noi substation had values lower than 10 cmol kg^{-1} in all subsoils, which was lower than in other sites. Generally, cation exchange capacity depends on the organic matter content, the amount of clay particles and the type of clay mineral (Sanchez, 1976; Young, 1976; Brady and Weil, 2008). Therefore, substantial amounts of organic matter in the upper part of most soils studied played an important role in high cation exchange capacity of this part of the soil profile. The increase in clay content with depth probably played no part in contributing to this soil property because the clay was generally composed of kaolinite, Fe oxides and Al oxides. These result in lower cation exchange capacity of subsoils (Buol *et al.*, 2003; Brady and Weil, 2008), which shows that the soils were rather highly developed (Magdoff and Weil, 2004). Consequently, extractable bases tended to decrease with depth as well.

H^{+}, $Al^{3+}$and base saturation percentages were all low (1.86-33.37%) in both topsoil and subsoil layers, with the exception of the soil used for growing vegetables in the greenhouse (INT-7) that had a moderate level (39.02-64.64%) of base saturation (Figure 3). The low base saturation percentage of most soils pointed to the highly leached condition of these soils, which in essence affected the low basic cation content (Lowe *et al.*, 1999; Bloom, 2000). Nevertheless, a slight increase in base saturation in the lower part of the soil profile in almost all soils suggested that the influence of leaching was not intense enough to remove all bases from the soil profiles (Sanchez *et al.*, 1983; Troeh and Thomson, 2005; Brady and Weil, 2008).

Diversity of soils

According to their morphological, physical and chemical properties, these soils could be classified into four different subgroups (Soil Survey Staff, 2006): Typic Haplohumults (INT-1, 6, 8, 9, 10, 12 and 13), Typic Palehumults (INT-2, 3, 4, 5 and 14), Typic Hapludults (INT-11 and 15) and Ultic Hapludalf (INT-7) (Soil Survey Staff, 2006).

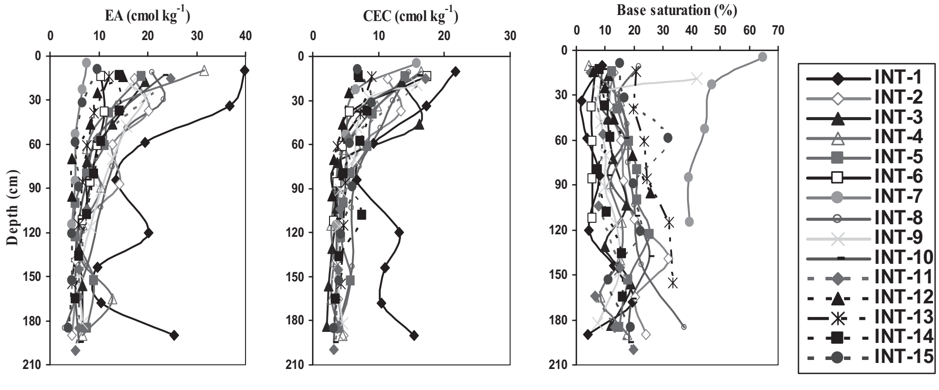

Figure 3 Exchange property of soils.

Due to the similar composition of granite and gneiss, which are the major parent rocks of soils in the area, the soils tended to have only slight differences in their textures (Buol *et al*., 2003). Soil development was rather similar, with an argillic horizon being a major diagnostic horizon of all soils (Soil Survey Staff, 2006). Variations in substrata were found in some soils, depending on their location in the landscape. Colluviated boulder rocks predominantly characterized the soils in the Mae Ya Noi substation, indicating severe past erosion or landslides. The mineral composition of gneiss found in the Mae Ya Noi substation was likely to be more acidic, resulting in the derived soils having a clearly lower pH than soils in other areas.

Morphologically, soils located in a more stable landscape compared to very steep slopes, for instance, on slightly more gentle slopes, appeared to be more reddish in color. Leaching played almost no part in soils under greenhouse conditions, such as in the ornamental plant plot (INT-1), strawberry plot (INT-6) and vegetable plot (INT-7), resulting in more accumulation of some bases and a higher base saturation percentage. The organic matter content in the upper 50 cm of soil profile suggested that accumulation might have already been considerable under the hill evergreen forest in the past. Thus, when it changed into agricultural production, in association with subsequent proper soil conservation and management, including the heavy input of organic materials, soil organic content was still acceptably high.

Soil fertility assessment

Soil fertility assessment was carried out using data from chemical analyses comprising organic matter content, available phosphorus and potassium, cation exchange capacity and base saturation percentage (Soil Survey Division, 1980).

It was found that soils in the Mae Ya Noi substation were slightly poorer in this context (Table 2). The cation exchange capacity and base saturation percentage negatively differentiated their fertility level from soils in other areas. The level of available phosphorus had no positive impact on the fertility level in all soils, due to its very low amount. Generally, high organic matter content and high available potassium of soils contribute to soil fertility (Foth, 1990), particularly in the top 30 cm layer.

CONCLUSION

Soils in Doi Inthanon area showed some diversity, such as in soil color and soil pH, and the presence of colluviated materials and the depth of weathered materials within the soil profile. Their fertility levels were slightly different, being mostly medium in the top 30 cm and similar or poorer in the deeper zone. Parent materials (colluvium and residuum of granite and gneiss) in association with topography influenced the development of these soils more than other factors. The soils were acidic, due to intense leaching under the humid subtropical climate and the acidity of the parent rocks. This also affected the loss of basic cations from the soil solum, giving low base saturation percentages in most soils. The ratio between Al^{3+} and H^+ varied within soil profiles and among soils from different substations, due to the variability in soil pH. The soils were classified as Typic Haplohumults, Typic Palehumults, Typic Hapludults and Ultic Hapludalf.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the Royal Project Foundation for funding support. They thank all staff from the Inthanon Royal Project Research Station for their contributions. Finally, the authors would also like to thank Associate Professor Dr Anchalee

Table 2 Fertility assessment of soils.

INT	Depth	OM		Avail.P		Avail.K		CEC		BS		Sum of	Rating[2/]
	(cm)	g kg^{-1}	Score[1/]	mg kg^{-1}	Score	mg kg^{-1}	Score	cmol kg^{-1}	Score	%	Score	score	
1	0-30	78.10	3	0.36	1	196.48	3	19.49	2	5.47	1	10	Medium
	30-100	25.29	2	0.58	1	73.35	2	8.00	1	5.77	1	7	Low
2	0-30	49.13	3	0.13	1	92.28	3	11.37	2	12.88	1	10	medium
	30-100	29.77	2	0.07	1	30.72	1	8.70	1	14.47	1	6	Low
3	0-30	21.90	3	0.21	1	51.68	1	13.49	2	11.02	1	8	Medium
	30-100	17.86	2	0.03	1	16.87	1	7.87	1	13.64	1	6	Low
4	0-30	56.13	3	0.09	1	66.00	2	16.49	2	4.44	1	9	Medium
	30-100	16.36	2	0.02	1	17.92	1	6.00	1	14.70	1	6	Low
5	0-30	67.27	3	0.20	1	78.67	2	14.11	2	12.41	1	9	Medium
	30-100	24.84	2	0.06	1	61.11	2	6.96	1	18.66	1	7	Low
6	0-30	52.74	3	1.01	1	394.74	3	17.36	2	56.21	2	11	Medium
	30-100	13.37	1	0.06	1	282.12	3	4.62	1	19.08	1	7	Low
7	0-30	25.67	2	0.44	1	432.68	3	11.24	2	55.87	2	10	Medium
	30-100	6.31	1	0.33	1	357.54	3	4.62	1	40.94	2	8	Medium
8	0-30	56.64	3	0.08	1	208.20	3	13.43	2	18.13	1	10	Medium
	30-100	16.96	2	0.02	1	209.53	3	7.79	1	18.67	1	8	Medium
9	0-30	61.87	3	0.21	1	296.82	3	15.75	2	41.91	2	11	Medium
	30-100	13.66	1	0.02	1	26.74	1	7.20	1	9.31	1	5	Low
10	0-30	58.73	3	0.18	1	71.13	2	16.00	2	9.12	1	9	Medium
	30-100	8.83	1	0.02	1	8.65	1	4.72	1	14.24	1	5	Low
11	0-30	50.96	3	0.06	1	6.33	1	17.09	2	4.89	1	8	Medium
	30-100	6.32	1	0.03	1	6.81	1	4.50	1	10.72	1	5	Low
12	0-30	66.13	3	0.34	1	66.37	2	7.12	1	5.76	1	8	Medium
	30-100	19.20	2	0.04	1	53.92	1	4.06	1	17.04	1	6	Low
13	0-30	70.95	3	0.10	1	154.63	3	8.99	1	20.79	1	9	Medium
	30-100	22.71	2	0.01	1	84.78	2	5.33	1	22.59	1	7	Low
14	0-30	52.86	3	0.08	1	50.45	1	7.62	1	8.98	1	7	Low
	30-100	17.31	2	0.01	1	36.16	1	6.50	1	9.90	1	6	Low
15	0-30	26.34	2	0.05	1	67.30	2	6.87	1	15.14	1	7	Low
	30-100	11.42	1	0.03	1	45.67	1	6.87	1	22.88	1	5	Low

[1/] OM (g kg^{-1}): <15 = 1, 15-35 = 2, >35 = 3; Avail.P (mg kg^{-1}): <10 = 1, 10-25 = 2, >25 = 3; Avail.K (mg kg^{-1}): <60 = 1, 60-90 = 2, >90 = 3, CEC (cmol(+) kg^{-1}): <10 = 1, 10-20 = 2, >20 = 3; BS(%): <35 = 1, 35-75 = 2, >75 = 3

[2/] Sum of scores from OM, Avail.P, Avail.K, CEC and BS: ≤7, low; 8-12, medium; ≥13, high.

Suddhiprakarn, the head of the Department of Soil Science, Faculty of Agriculture, Kasetsart University, Bangkok at the time of undertaking the research, for the provision of laboratory facilities.

LITERATURE CITED

Bloom, P.R. 2000. Soil pH and pH buffering, pp. B333-B352. *In* M.E. Sumner (ed.). **Handbook of Soil Science.** CRC Press, Florida.

Brady N.C. and R.R. Weil. 2008. **The Nature and Properties of Soils**. 14th ed. Prentice Hall, Inc., New Jersey. 965 pp.

Buol, S.W., R.J. Southard, R.C. Graham and P.A. McDaniel. 2003. **Soil Genesis and Classification.** The Iowa State Univ. Press., Amer. Iowa. 494 pp.

Calvert, C.S., S.W. Buol and S.B. Weed. 1980. Mineralogical characteristic and transformation of a vertical rock saprolite-soil sequence in the North Carolina piedmont. **Soil Sci. Soc. Amer. Proc.** 44: 1096-1103.

Dent, F.J. 1973. **An Approach to Soil Survey in Hilly Marginal Land of Northern Thailand.** Soil Surv. Div., Dept. of Land Development, Min. of Agr. and Cooperative, Bangkok.

Foth, H.D. 1990. **Fundamentals of Soil Science.** John Wiley and Sons, Inc., New York. 402 pp.

Havlin, J.L., J.D. Beaton, S.L. Tisdale and W.L. Nelson. 2005. **Soil Fertility and Fertilizers: An Introduction to Nutrient Management**. 6th ed. Prince-Hall Inc., Upper Saddle River, New Jersey. 528 pp.

Jindaluang, W. 2008. **An Analysis of soils Factors Influencing Crop Production in Inthanon Area.** M.S. Thesis, Kasetsart University, Bangkok.

Kheoruenromne, I. 1987. **Soil Survey Laboratory Manual.** Department of Soil Science, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand. 182 pp.

Kheoruenromne, I. 1999. **Soil Survey: Concepts, Principles and Techniques**. Kasetsart University Press, Bangkok. 733 pp.

Lowe, C.A., F.O.R. Akamigbo and J.S.C. Mbagwu. 1999. Chemical and mineralogical propertirs of soil in southeastern Nigeria in relation to aggregate stability. **Geoderma** 92: 111-123.

Magdoff, F and R.R. Weil. 2004. **Soil Organic Matter in Sustainable Agriculture**. CRC press, Washington D.C. 416 pp.

Moormann, F.R. and S. Rojanasoonthon. 1972. **Morphology and Genesis of Gray Podzolic Soils in Thailand.** Ph D. thesis, Oregon State University.

National Soil Survey Center. 1996. **Soil Survey Laboratory Methods Manual**. Soil Survey Invest. Rept. No 42, Version 3.0. U.S. Dept. of Agr., U.S. Government Printing Office, Washington D.C. 735 pp.

Peel, M. C., B.L. Finlayson and T.A. McMahon. 2007. Updated world map of the Köppen-Geiger climate classification. **Hydrol. Earth Syst. Sci.** 11: 1633-1644.

Potichan, A. 1991. **Morphology, Genesis and Characteristics of Skeletal Soils in Sakon Nakhon Province, Northeast Thailand.** Ph.D. Thesis, University of the Philippines.

Richie, J. L. 1981. Soil and Water Available. **Plant and Soil** 58: 327-338.

Sanchez, P.A. 1976. **Properties and Management of Soils in the Tropics.** John Wiley and Sons, Inc., New York. 630 pp.

Soil Survey Division Staff. 1993. **Soil Survey Manual.** USDA Handbook No. 18, USDA, Washington DC. 437 pp.

Soil Survey Division Staff. 2006. **Key to Soil Taxonomy.** 10th ed. U.S. Dept. of Agr., U.S. Government Printing Office, Washington D.C. 298 pp.

Soil Survey Division. 1980. **Handbook of Soil Suitability Classification for Field Crops.** Handbook No.28, LDD, Bangkok.

Tan, K.H. 1993. **Principle of Soil Chemistry**. 2nd ed. Macel Dekker, Inc., Madison Avenue, New York. 362 pp.

Troeh, F.R. and L.M. Thompsom. 2005. **Soil and Soil Fertility**. 6th ed. Blackwell Publishing Professional, Iowa. 489 pp.

Vangai, S., I. Kheoruenromne and A. Sukthumrong. 1986. Soil organic matter, crop residue and green manure management, pp. 237-249. *In* M. Latham (ed.). **The First Regional Seminar on Soil Management under Humid Conditions in Asia.** Bangkok, Thailand.

Virgo, K.J. and D.A. Holmes. 1977. Soil and landform features of mountainous terrain in South Thailand. **Geoderma** 18: 207-225.

West, L.T. and F.H Beinroth. 2000. Ultisols, pp. E358-E372. *In* M.E. Sumner (ed). **Handbook of Soil Science.** CRC Press, Florida.

Young, A. 1976. **Tropical Soils and Soil Survey.** Cambridge Univ. Press, London. 468 pp.