MORPHOLOGY AND PROPERTIES OF SOME EXTREMELY ACID LOWLAND SOILS IN SOUTHERN THAILAND

สัณฐานวิทยาและคุณสมบัติของดินที่ลุ่มและเป็นกรดรุนแรงบางชนิด ในภาคใต้ของประเทศไทย

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ABSTRACT

A study on morphology and properties of some extremely acid lowland soils were carried out on three soils areas : Munoh series, Ra-ngae series and Thon Sai series in Narathiwat Province, southern Thailand. Method of soil characterization comprising pedon analysis and soil sample analysis based on standard method was applied.

Results of the study revealed that the three soils possess a similar profile model and morphology with that of acid sulfate soils in the Central Plain. However, these three soils are more sandy (sandy clay loam to loamy sand), richer in organic matter content (6.2-72.1 g/kg) and markedly lower in available potassium (10-35 mg/kg) than most of the acid sulfate soils in the Central Plain are. The base reserves in these soils are very low whereas their extractable *acidity is very high (up to 126.5 cmol/kg). The condition in these soils indicates a low buffering capacity and the effect of their acidity on crop cultivation is generally serious.*

บทคัดย่อ

ศึกษาสัณฐานวิทยาและคุณสมบัติของดินที่ลุ่มและเป็นกรดรุนแรงบางชนิด ในพื้นที่ของดิน 3 ชนิด คือ ชุดดินมูโนะ ชุดดินระแงะ และชุดดินต้นไทร ในจังหวัดนราธิวาสโดยใช้วิธีการกำหนดลักษณะของดิน ซึ่งประกอบด้วยการวิเคราะห์พีดอน (pedon analysis) และการวิเคราะห์ตัวอย่างดินโดยวิธีมาตรฐาน (soil sample analysis based on standard method) ผลการศึกษาพบว่าดินทั้ง 3 บริเวณมีลักษณะของหน้าตัดดินเป็นแบบ Apg-Bwg-Cg และสัณฐานวิทยาของดินคล้ายคลึงกับของดินเปรี้ยว (acid sulfate soils) ในบริเวณที่ราบภาคกลาง แต่ดินมีลักษณะเป็นทรายจัดกว่า มีปริมาณอินทรียวัตถุสูงกว่า (6.2-72.1 ก./กก.) และมีโพแทสเซียมที่เป็นประโยชน์ต่ำกว่าดินลักษณะเดียวกันในภาคกลางมาก (10-35 มล./กก.) ปริมาณธาตุประจุบวกที่เป็นด่างสำรอง (base reserves) ในดินเหล่านี้มีปริมาณต่ำ ในขณะที่มีค่าของกรดที่สกัดได้สูงมาก (126.5 เซนติโมล/กก.) สภาพภายในของดินเหล่านี้แสดงว่ามีความต้านทานต่อการเปลี่ยนแปลงต่ำ (Low buffering capacity) และความเป็นกรดของดินมีผลเสียรุนแรงต่อการปลูกพืชโดยทั่วไป

INTRODUCTION

Extremely acid lowland soils have been known, in general, as acid sulfate soils. Many studies have been conducted on these soils in the Lower Central Plain where their extensive area exists.[1,4,6] However, these soils can also be found along the Southeast Coast and in the coastal areas of Peninsular Thailand[8] in association with Organic Soils (Histosols)[12,13] where accumulation of organic materials in the soils is uncommonly excessive.[13] Some of these extremely acid lowland soils appeared to have recently passed through a stage of being Organic Soils before developing further, due to drainage and oxidation, to become mineral acid sulfate soils.[13] Therefore, one can expect to see some layers of the organic materials preserved in the profiles of acid sulfate soils in these two areas (Southeast Coast and Peninsular Thailand). A similar situation was reported also for some acid sulfate soil profiles in the Central Plain.[3] Under a tropical monsoonal grading towards tropical rain forest climatic regime[7], acid sulfate soils in the Southeast Coast and Peninsular Thailand can be expected to develop faster than the ones in the Central Plain due to a higher and better distribution of rainfall. This should have some bearing on their characteristics and utilization.

This research summarized results of the three expected to be acid sulfate soils in southern Thailand to provide basic data on their morphology, physical; characteristics and chemical properties to be used in their fertility capability classification and land utilization planning.

MATERIALS AND METHODS

Soil characterization method was applied. This comprised field investigation of soils and laboratory analysis of soil samples according to standard analytical techniques.[10] Field investigation included a general survey of the soil areas to obtain relevant information on their general settings and characteristics, and a pedon analysis[5,11] was carried out in a 1.5x2x2 m (width x length x depth) soil pit after being chosen as the best representative area for each soil. Soil samples for laboratory analysis were collected from soil genetic horizons identified by pedon analysis procedure . Three pedons were studied. One was in Munoh soil series area at Karuko Village, Karuwor Nua Subdistrict, 150 m northeast of a drainage canal, approximately 500 m southwest of Khao Tan Yong. Other two pedons were in the farm experimental areas, Royal Development Study Center at Phikunthong Village, Karuwor Nua Subdistrict. All areas of the study are in Muang Narathiwat District, Narathiwat Province. Laboratory analyses of soil samples were carried out at Soil Laboratory, Department of Soil Science, Faculty of Agriculture, Kasetsart University, Bangkok, and Soil and Fertilizer Applied Research Laboratory, Central Laboratories and Greenhouse Complex, Kasetsart University Research and Development Institute, Kamphaeng Saen Campus, Nakhon Pathom Province.

RESULTS AND DISCUSSIONS

Results of the study on these extremely acid soils comprise three parts. They are profile characteristics and morphology, physical properties and chemical properties. The chemical properties of the soils are subdivided into two parts. One deals with the reaction and major plant nutrients of the soils. Another emphasized the soil exchange properties and soil acidity.

Profile characteristics and morphology

Profile models of the soils are shown in Figure 1. It was found that they have a similar stage of profile development. The top 80 cm section of the soils was found to undergo chemical change sufficiently. A striking feature in the profile is the contrasting materials between the upper section and the section approximately below the depth of 80 cm, and the condition persist in all of them. The change of materials was also found again for some profiles (P2 and P3) in the substratum below the 120 cm depth. This can be interpreted as the influence of the episodic sedimentation, geologically, in the area, and the finer materials in the upper section are the most recent ones, deposited in the backswamp of along the coastline.[13]

Field analysis results indicate the general characteristics of these soils as shown in Table 1. These soils have thick surface layers. They are very deep and poorly drained soils on a generally flat terrain of deltaic environment. All of them show features of alluvium overlying brackish and marine deposits. It seems that these general characteristics can be applied to most, if not all, of the acid sulfate soils in southern Thailand.

Morphology of these extremely acid lowland soils is summarized in Table 2. Most of morphological characteristics of these soils conform well with the general features of lowland soils in southern Thailand. Nevertheless, few relevant features should be noted. One which indicates them as acid sulfate soils is the straw yellow mottles (2.5Y 8/6-8/8) occurring in Bwg2 of all profiles and continuing downwards to 2Cg1 (10 YR 7/8) in P1 (Monuh series area). This indicates the presence of jarosite, a characteristic feature of acid sulfate soil. The depth where these jarosite mottles were found coincided in all profiles, from slightly deeper than 50 cm to approximately 100 cm. The second feature is the low field pH values in the upper part of the profiles (=pH 4) whereas the lower substrata have higher pH values. This suggests the poor development of these acid sulfate soils where oxidation in the lower part of the profile is not effective. The general condition indicated by the field pH values suggests the more serious acidic problem in Munoh and Ra-ngae series areas. Other features that should be noted for these soils are the presence of decayed plant materials, mica flakes and sand patches in some layers of the soil profile. These features can be considered as indicators of mixed deltaic environment influenced by riverine alluvium. The weak and semi-massive structure, and the nearly ripe condition at depth of these soils confirm that they are generally poorly developed soils.[2]

Physical properties

One of the most important physical characteristics of poorly developed soils is the soil texture. Data on particle size distribution (USDA grading) and textural class of these soils are shown in Table 3. These data were based on mechanical analysis of the fine earths fraction only. It is obvious that sand and silt are abundant in the profiles of these soils whereas high amount of clay can be found in the upper part of their profiles only. The trend of particle size distribution with depth also confirms the finding on morphological analysis that these soils have contrasting parent materials. The abundance of silt sized particles in the profile also suggests deposition in an estuarine environment. In addition, the excessive amount of sands in the lower part of the profile may have some impact on nutrient supplying ability of these soils in the long run for cultivation of economic crops.

Chemical properties

Chemical properties of the soils can be devided loosely into two parts. One is on their reaction and availability of plant major nutrients. Another is on their exchange properties and their acidity.

Reaction and availability of plant major nutrients

Table 4 summarizes data on soil reaction and major available nutrients of these soils. The pH values of these soils indicate that their soil system has a negative delta pH. Therefore, the system favors the exchange of cations[9].

The pH values in water of Bwg2 in Pedons 1 and 2 confirm that the soils can be considered acid sulfate soils. However, Bwg2 in Pedon 3 (in Thon Sai series area) has a higher pH value to be considered a characteristic of a sulfuric horizon though its morphology appears to justify the criteria for it. Actually, in some studies, it was found that layer with jarosite mottles can have a pH value (air dry basis) higher than 3.5.[4] All soils appear to have very low pH values at depth and their general pH values (in all horizons) are very low. They can be considered as extremely acid soils.

These soils have relatively high organic matter content. One of the most interesting, but not so surprising, characteristics of these soils is the high organic matter content in the deeper horizon (Cg). This is not only indicating the poorly developed status of the soils but also contradicting the concept of cambic horizon. It seems quite normal for lowland tropical soils, rich in organic matter, with a change of drainage condition to be drier, would develop to have properties in some of their genetic horizons to justify the criteria of cambic horizon except for their organic matter content. More studies are needed on this aspect. The high organic matter content in the surface layer of these soils, nevertheless, is beneficial for crop cultivation. Available phosphorus values in these soils, particularly in their surface layers are generally in acceptable lavel for crop practices but their trend with depth has a poor relationship with the trend of organic matter. This may suggest a different form of organic material in these soils from that of the ones in upland soil condition. Available potassium in these soils is low. The values of available potassium, even in the surface soils, are too low for effective crop cultivation and this is a major difference between chemical properties of these acid sulfate soils in southern Thailand and that of the ones in the Central Plain.[6]

Exchange properties and acidity of soils

Data on extractable bases (EB) including calcium, magnesium, sodium and potassium as shown in Table 5 illustrate very well the scarcity of bases in these soils. This is also a different feature of acid sulfate soils in southern Thailand as compared to the ones that had been studied in the Central Plain. Though the sum of extractable cations can be very high, particularly in the lower part of the profile, most of the cations extractable appear to be acid cations. This is confirmed by the values of soil extractable acidity (EA) where its major components are hydrogen and aluminum. This condition affects the base saturation of the soils appreciably. All soils have generally low to extremely low percentage base saturation (PBS) values. For example, surface soil of Pedon 1 (in Munoh series area) has a base saturation value of only 0.87% where as the EA value in the surface layer of this profile is 59.5 cmol/kg. The relationship among the extractable bases, extractable acidity and percentage base saturation of these soils indicate acidity problem in these soils very clearly. With a generally sandy nature and low base saturation percentage, these soils have a poor buffering capacity and can be affected by acidity strongly in crop cultivation.

CONCLUSION

Based on the results of field analysis and laboratory analytical data, the extremely acid lowland soils or the acid sulfate soils in southern Thailand can be considered to have similar profile characteristics with that of acid sulfate soils in the Central Plain. However, these soils are generally more sandy, richer in organic matter but much lower in available nutrients and base saturation. Data obtained in this study appear to indicate a poorer but more rapid rate of development in these soils as compared to the ones in the tropical savanna climatic regime. Though further study on their potential for crop practice is needed before a firmer conclusion can be drawn, their physical and chemical properties, as found, indicate that they lack buffering capacity. Therefore, crop cultivation on them, to be successful, may need a slightly different approach of soil management from that has been used for the acid sulfate soils in the Central Plain.

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Table 1. General characteristics of some extremely acid lowland soils in southern Thailand

Thickness of surface horizon (cm)	Effective depth (cm)	Profile development	Slope %	Relief	Physiographic position/ drainage	Parent materials and land use
Pedon 1 (in Munoh series area)						
12-25	150+	Apg-Bwg-2Cg	<2	Flat	Low rise on deltaic flat/poorly drained	Alluvium overlying brackish and marine deposits, left fallow under grasses
Pedon 2 (in Ra-ngae series area)						
18	150+	Apg-Bwg-2Cg-3Cg	<2	Flat	Low rise on deltaic flat/poorly drained	Alluvium overlying brackish and marine deposits, rice and grasses
Pedon 3 (in Thon Sai series area)						
25-31	150+	Apg-Bwg-2Bwg-3Cg	<2	Slightly undulating	Rise on deltaic flat/poorly drained	Alluvium overlying brackish deposits, raised bed for field crops

Table 2. Morphology of some extremely acid lowland soils in southern Thailand

Horizon	depth (cm)	Matrix color / Mottles	Texture	Structure	Consistance D	Consistance M	Consistance W	Filed pH	Boundary	Others
Pedon 1 (in Munoh series area)										
Apg	0-12/25	10YR3/1 / 10YR6/8 (2%)	SGSiL	2f-m SBK and ABK	SH	SF	SS and SP	4.5	A and W	Common traces of dead roots and few small sand pockets
Bwg 1	25-45/56	10YR5/3 (70%), 10YR6/4 (25%) / 7.5YR3/4 (5%)	SiL	1c ABK (semi-massive)	—	F	SS and P	4.0	C and W	Common large brown silt and very fine sand pockets
Bwg 2	56-75/100	10YR6/3 (60%), 10YR5/2 (30%) / 10YR5/8 (8%), 2.5YR8/6 (2%)	FSCL	1f-m SBK	—	F	SS and P	4.0	A and W	Common very fine sand patches and fine mica flakes, common traces of dead roots
2Cgl	100-128	5YR4/1(88%), 10YR6/3 (10%) / 10YR7/8 (2%)	SL	1c ABK (semi-massive)	—	F	S and P	4.0	G and S	Common fine mica flakes
2Cg2	128-200+	5YR4/1 (95%), 5YR5/1 (5%)	SL	1c ABK (nearly ripe)	—	F	S and P	6.5	—	Common fine mica flakes and few very fine sand patches

Table 2. (cont.)

Horizon	depth (cm)	Matrix color / Mottles	Texture	Structure	Consistance D	Consistance M	Consistance W	Filed pH	Boundary	Others
Pedon 2 (in Ra-nage series area)										
Apg	0-18	10YR4/1 / 10YR4/4 (2%)	L	2 m-c ABK	VH	SF	SS and P	4.0	A and S	Few rock fragments and mica flakes
Bwg1	18-50/55	10YR6/2 / 10YR3/2 (5%), 10YR4/6 (2%)	SCL	2 m-c ABK	VH	SF	SS and SP	4.0	C and W	Few fine mica flakes
Bwg2	55-85/92	10YR4/2 (80%), 10YR7/4 (10%) / 2.5YR8/6 (5%), 10YR4/6 (5%)	VFSCL	2m-c SBK	—	SF	SS	4.0	A and W	Common patches of uncoated sands and common mica flakes
2Cg1	92-130	5YR4/1	SL	1c ABK (semi-massive)	—	F	S and P	6.5	A and S	Common fine sand patches and common very fine mica flakes
3Cg2	130-200+	2.5Y4/0	LS	1c ABK (semi-massive)	—	F	S and P	8.0	—	Many shell fragments and few fine mica flakes

Table 2. (cont.)

Horizon	depth (cm)	Matrix color / Mottles	Texture	Structure	Consistance D	Consistance M	Consistance W	Filed pH	Boundary	Others
Pedon 3 (in Thon Sai series area)										
Ap	0-25/31	10YR3/2 7.5YR4/6 (2%)	FSL	2f-m SBK	SH	SF	SS and SP	5.5	A and W	Common traces of decayed plant remains and few fine mica flakes
Bwg1	31-60	2.5Y7/2 (96%), 10YR3/2 (2%) 7.5YR5/8 (5%)	SCL	2f-m SBK and ABK	—	SF	SS and SP	5.5	G and S	Common dark brown vertical elongated and patches and few fine mica flakes
Bwg2	60-90/95	2.5YR7/2 (48%), 10YR4/3 (48%) 2.5YR6/8 (2%) 75YR5/6 (2%)	SCL	lc ABK (semi-massive)	—	F	SS and SP	4.5	A and W	Common large dark brown vertical elongated sand patches and few fine mica flakes
2Bwg3	95-133	10YR3/2(80%), 10YR6/3 (20%)	SL	lc ABK (semi-massive)	—	F	SS and SP	4.5	A and S	Common decayed plant remains and common mica flakes
3Cg	133-170+	2.5Y4/0 (90%), 10YR4/1 (10%)	LS	Massive	—	F	SS	6.5	—	Abundant dead roots and plant remains, common sand patches with H_2S odor

Texture SG = slightly gravelly, VF = very fine, F = fine, LS = loamy sand, SL = sandy loam, L = loam, SiL = silt loam, SCL = sandy clay loam

Structure 1 = weak, 2 = moderate, 3 = strong, SBK = subangular blocky structure, ABK = angular blocky structure, c = coarse, m = medium, f = fine

Consistence D = dry : SH = sligtly hard, H = hard ; M = moist: SF = slightly firm, F = firm; W = wet : SS = slightly sticky, S = sticky, SP = slightly plastic, P = plastic

Boundary A = abrupt, C = clear, G = gradual, S = smooth, W = wavy

Table 3. Physical characteristic of some extremely acid lowland soils in southern Thailand

Horizon	Depth (cm)	Particle size distribution (g/kg) Sand	Silt (USDA Grading)	Clay	Textural Class[1/]
Pedon 1 (in Munoh series area)					
Apg	0-12/25	198	642	160	SiL
Bwg1	25-45/56	247	545	208	SiL
Bwg2	56-75/100	542	242	216	SCL
2Cg1	100-128	531	457	12	SL
2Cg2	128-200+	529	451	20	SL
Pedon 2 (in Ra-ngae series area)					
Apg	0-18	433	331	236	L
Bwg1	18-50/55	523	253	224	SCL
Bwg2	55-85/92	536	220	244	SCL
2Cg1	92-130	675	245	80	SL
3Cg2	130-200+	781	147	72	LS
Pedon 3 (in Thon Sai series area)					
Ap	0-25/31	532	300	168	SL
Bwg1	31-60	543	201	256	SCL
Bwg2	60-90/95	532	220	248	SCL
2Bwg3	95-133	689	143	168	SL
3Cg	133-170	785	195	20	LS

1/ Fine earths only

Table 4. Reaction and major available nutrients in some extremely acid lowland soils in southern Thailand

Horizon	Depth (cm)	pH 1 : 1 H_2O	pH 1 : 1 KCl	Organic matter (g/kg)	Avail.P (mg/kg)	Avail.K (mg/kg)
Pedon 1 (in Munoh series area)						
Apg	0-12/25	3.6	3.5	68.1	33.0	35
Bwg1	25-45/56	3.7	3.2	33.9	5.0	25
Bwg2	56-75/100	3.3	2.8	21.2	1.8	25
2Cg1	100-128	2.5	1.8	22.9	2.8	15
2Cg2	128-200+	2.5	1.9	26.9	5.3	15
Pedon 2 (in Ra-ngae series area)						
Apg	0-18	3.9	3.3	72.1	31.5	10
Bwg1	18-50/55	4.0	3.3	11.9	5.8	20
Bwg2	55-85/92	3.3	2.9	22.2	3.8	20
2Cg1	92-130	2.5	1.9	35.1	17.8	10
3Cg2	130-200+	3.0	2.5	25.5	22.0	15
Pedon 3 (in Thon Sai series area)						
Ap	0-25/31	4.5	3.7	67.5	12.5	35
Bwg1	31-60	4.3	3.4	6.2	7.0	25
Bwg2	60-90/95	4.5	3.4	12.5	9.0	20
2Bwg3	95-133	4.4	3.5	41.8	8.0	20
3Cg	133-170+	2.2	1.9	53.0	4.5	15

Table 5. Chemistry and exchange properties of some extremely acid lowland soils in southern Thailand

Horizon	Depth (cm)	Extractable Bases (EB) Ca	Mg	Na	K	Sum of EB	EA	CEC by Sum	PBS (%)
		<------------------cmol/kg						--------------------------------->	
Pedon 1 (in Munoh series area)									
Apg	0-12/25	0.15	0.13	0.15	0.09	0.52	59.5	60.02	0.87
Bwg1	25-45/56	0.24	0.19	0.15	0.06	0.64	36.0	36.64	1.75
Bwg2	56-75/100	0.25	0.32	0.11	0.06	0.74	18.5	19.24	3.85
2Cg1	100-128	0.02	1.84	0.11	0.04	2.01	122.0	124.01	1.62
2Cg2	128-200+	0.11	8.23	0.07	0.04	8.45	126.5	134.95	6.26
Pedon 2 (in Ra-agae series area)									
Apg	0-18	0.70	0.69	0.65	0.26	2.30	29.0	31.30	7.35
Bwg1	18-50/55	0.70	0.44	0.15	0.05	1.34	13.5	14.84	9.03
Bwg2	55-85/92	0.13	0.77	0.20	0.05	1.15	17.5	18.65	6.17
2Cg1	92-130	2.50	8.23	0.07	0.03	10.83	88.5	99.33	10.90
2Cg2	130-200+	10.00	2.87	0.13	0.04	13.04	16.0	29.04	44.90
Pedon 3 (in Thon Sai series area)									
Ap	0-25/31	2.30	0.53	0.26	0.09	3.18	3.50	6.68	47.60
Bwg1	31-60	0.50	0.44	0.15	0.06	1.15	5.00	6.15	18.70
Bwg2	60-90/95	0.37	0.69	0.15	0.05	1.26	16.50	17.76	7.09
2Bwg3	95-133	0.35	0.69	0.20	0.05	1.29	19.50	20.79	6.20
3Cg	133-170+	0.13	4.10	0.20	0.04	4.47	102.50	106.97	4.18

EA = extractable acidity

CEC = cation exchange capacity

PBS = percentage base saturation

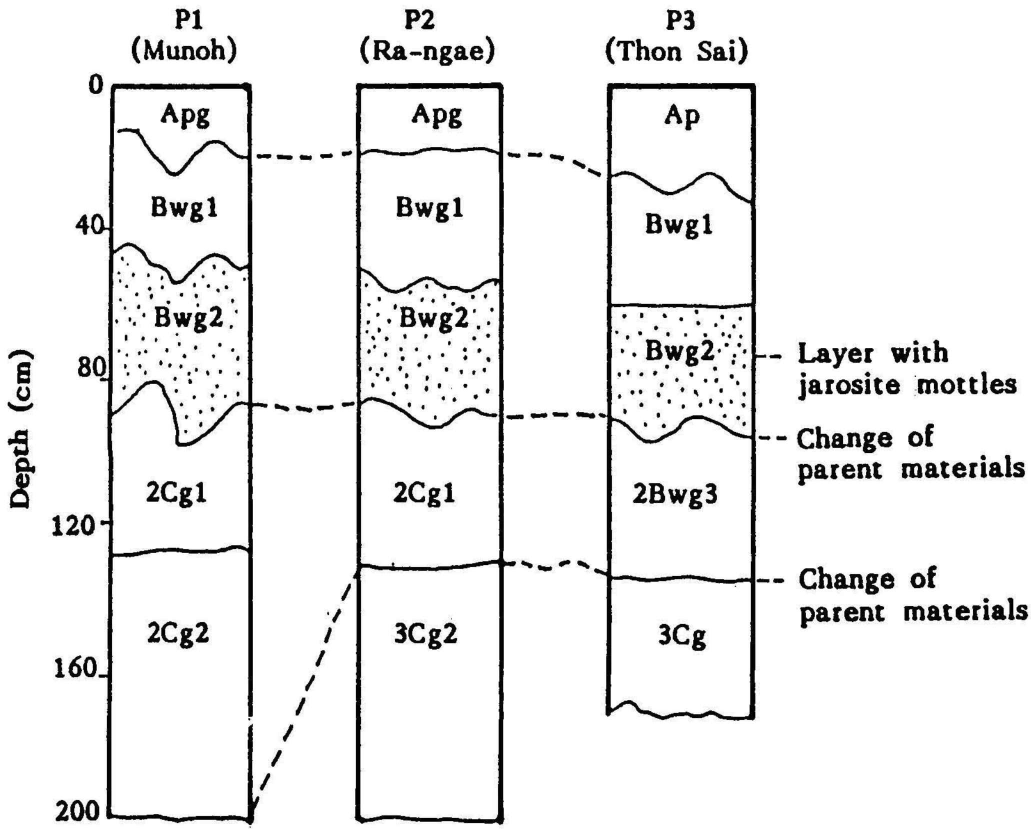

Fig. 1 Profile models of some extremely acid lowland soils in southern Thailand