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Properties and Agricultural Potential of Skeletal Soils in Southern Thailand

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ABSTRACT

A study on properties and agricultural potential of skeletal soils in Southern Thailand placed a major emphasis on representative skeletal soils that can be found in large extent, moderate extent and limited extent in the region. Study method included field investigation and pedon analysis of the representative soils and collecting soil samples from their genetic horizons, and laboratory analysis on their physical and chemical properties to evaluate their vital properties and their agricultural potential. Eight representative soil series included Chumphon series, Khao Khat series, Nong Khla series, Phato series, Ranong series, Phayom Ngam series, Sawi series and Yi-ngo series.

Results of the study revealed that most of them are upland soils mainly occupying undulating and rolling terrains with a major slope range of 3-8 percent. Most of them are deep to very deep, highly leached, well developed Ultisols. The skeletal materials in these soils vary but the ones that can be found frequently are ironstone nodules. Their basic fertility status is generally poor and problem on available phosphorus in most soils exists. Their high extractable acidity is also a vital adversary property that can affect their exchange properties markedly whereas the presence of skeletal materials in the soils does not appear to pose any serious problem on their uses and management. These soils are not suited for paddy rice but they are moderately suited for upland field crops and livestock pasture, and well suited for tree crops including fruit trees with different degrees of problem on topography and the presence of skeletal materials. Since these soils have been used mainly for rubber and fruit tree production, land use problem on them can be coped with quite well by the use of existing agricultural technologies. Therefore, sustainability in their use, at present, is somewhat achieved.

Key words : skeletal soils, ironstone nodules, Ultisols, agricultural potential, Southern Thailand

INTRODUCTION

Skeletal soils are those having substantial amount of coarse materials present within 50 centimeters from the soil surface (Soil Survey Staff, 1975). They were considered problem soils in Thailand (Panichapong, 1982). It was reported that skeletal soils can be found extensively in upper Northeast and substantial area of these soils are in Southern Thailand (Vijarnsorn, 1984). Basic properties of these skeletal soils vary in many aspects, i.e., nature of skeletal materials, depth of soils and their specific ecology (Dee-saeng, 1993). Their agricultural uses and potential, in general, are poor to very poor (Chintaskul, 1989). The uses of these soils for crop practices in Thailand become

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more common nowadays due to the need of land for cropping practices. In Southern Thailand, these soils have been used generally for tree crop production such as for para rubber, tropical fruit trees and oil palm and problems on their uses, so far, have been least reported. It appears that the soils can support the uses in this aspect sufficiently.

This study was conducted on skeletal soils in Southern Thailand with three objectives including 1) to determine the vital properties of the skeletal soils, 2) to evaluate their agricultural potential, and 3) to analyze problems on their uses.

MATERIALS AND METHODS

Method of the study consisted of two parts: field investigation and laboratory analysis. The field study included identification, pedon analysis and sampling of skeletal soils distributed in Southern Thailand by standard field study method (Kheoruenromne, 1987; Soil Survey Division Staff, 1993) using several soil maps published by the Land Development Department, Ministry of Agriculture and Cooperatives as guides to locations of the soils. The Laboratory analysis was on the physical and chemical properties of the soil samples collected from the field using standard methods of soil analysis (Soil Survey Laboratory Staff, 1992). Parameters involved in the laboratory analysis of the soil samples include particle size distribution, chemical properties related to major plant nutrients present in the soils and chemical parameters indicating their exchange properties.

RESULTS AND DISCUSSION

Ecology and profile models of skeletal soils

Results of field investigation indicated that many skeletal soils can be found in Southern Thailand. However, some of them are quite similar or can be grouped together. From the groups of these skeletal soils, seven soil series representing most of them were chosen to be studied in details. These are Chumphon series which can be found extensively in Southern Thailand, Khao Khat series, Nong Khla series and Phato series which can be found in a moderate extent, Phayom Nyam series, Sawi series and Yi-ngo series which can be found in a limited extent in Southern Thailand (Vijarnsorn, 1985).

Some data on ecology of skeletal soils in Southern Thailand are summarized in Table 1. It is clear that most of skeletal soils have been formed on old alluvial deposits and residuum and colluvium derived from clastic sedimentary and metasedimentary rocks such as shale, phyllite and quartzitic sandstone on undulating to rolling and hilly terrains. Most of them are well drained soils and their uses are mainly for tree crop production such as para rubber and tropical fruit trees. The ecology of these skeletal soils appears to be different from what can be seen for skeletal soils in the North and Northeast of Thailand (Kheoruenromne, 1991).

Profile models of these skeletal soils are shown in Figures 1, 2 and 3. Chumphon series, a skeletal soil that can be found rather extensively in Southern Thailand (Figure 1) is a very deep soil and the coarse fragments are ironstone nodules. This is a highly developed soil and have a distinct profile feature. The profile models of Khao Khat series, Nong Khla series, Phato series and Ranong series (Figure 2) illustrate well of skeletal soils having different nature of the coarse fragment and profile arrangement relating to the presence of coarse materials. Khao Khat and Nong Khla series are both deep and well developed soils and plinthite layer in the Khao Khat profile does not limit root penetration seriously. Both profiles indicate a well developed soils. For Phato and Ranong series, their profile features indicate a similar nature of the coarse materials as being rock fragments. However, the arrangement of soil horizons in their profile is

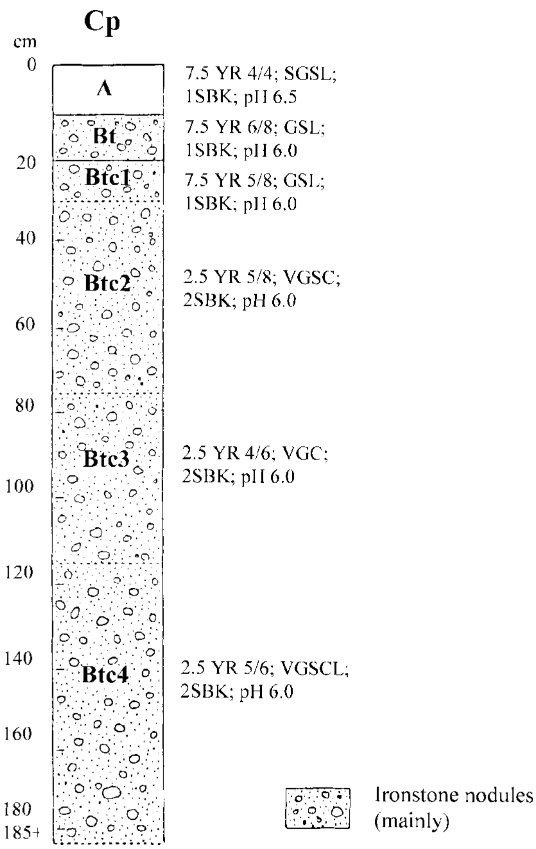
Table 1 Ecology of skeletal soils in Southern Thailand.

Soil series	General setting			Soil condition[1/]		Climate[2/]		Land use
	Landform	Slope (%)	Parent materials	Drainage	Runoff	R (mm)	T (°C)	
Chumphon (Cp)	Alluvial fan	3-8	Old alluvium	WD	Rapid	2500	26-28	Rubber
Khao Khat (Kkt)	Eroded hill & terrace	3-8	Colluvium & residuum of clastic rocks	WD	Moderate	2000+	26-28	Rubber
Nong Khla (Nok)	Eroded hill & erosion surface	2-8	Colluvium & residuum of clastic rocks	WD	Rapid	3000	26-28	Rubber & fruit tree
Phato (Pto)	Hill & footslope	8-30	Residuum & colluvium of clastic rocks	WD	Rapid	2500	26-28	Rubber
Ranong (Rg)	Footslope & hill	5-30	Residuum & colluvium of clastic rocks	WD	Rapid	2000	26-28	Rubber
Phayom Ngam (Pym)	Lower foothill slope & terrace	1-3	Residuum of clastic rocks	SPD	Slow	2000	26-28	Forest & rubber
Sawi (Sw)	Middle alluvial terrace	3-6	Old alluvium	WD	Moderate	2200	26-28	Fruit trees mainly
Yi-ngo (Yg)	Hill and footslope	8-20	Residuum & colluvium of clastic rocks	WD	Rapid	2500	26-28	Rubber & fruit trees

[1/] Drainage : WD = well drained, SPD = somewhat poorly drained

[2/] R = annual rainfall, T = range of mean annual temperature different. Based on their profile models, Phato series can be considered a deep soil whereas Ranong series is generally a shallow soil and its quartzitic sandstone parent material can limit penetration of plant roots. Within this group of skeletal soils found in a moderate extent in southern Thailand, Ranong series portrays the soil of poorest profile feature to support the use of land for cropping practices.

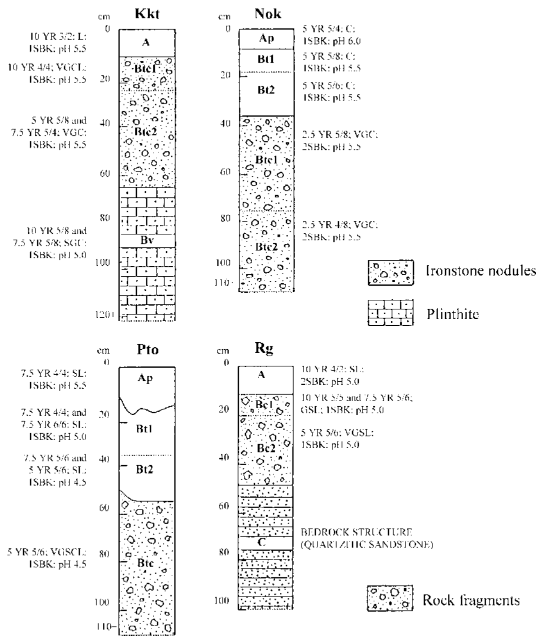
Phayom Ngam series, Sawi series and Yi-ngo series are skeletal soils found in a limited extent in Southern Thailand. Skeletal materials in Phayom Ngam and Sawi series are ironstone nodules, and somewhat broken plinthite layer exists in Phayom Ngam series. This layer does not appear to restrict penetration of plant roots either. Both of



Texture: GSL = Gravelly sandy loam,
SGSL = Slightly gravelly sandy loam,
VGC =Very gravelly clay,
VGSC = Very gravelly sandy clay

Structure: SBK = Subangular blocky, 1 = Weak, 2 = Moderate

Figure 1 Profile model of a skeletal soil found rather extensively in Southern Thailand.



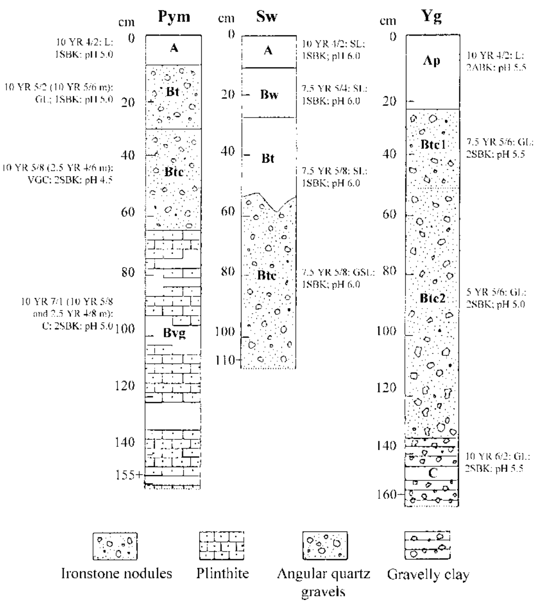
Texture: C = Clay, GC = Gravelly clay; GSL = Gravelly sandy loam, L = Loam,
SL = Sandy loam, SGC = Slightly gravelly clay, VGC = Very gravelly clay
VGCL = Very gravelly clay loam;
VGSCL = Very gravelly sandy clay loam

Structure: SBK = Subangular blocky, 1 = Weak, 2 = Moderate

Figure 2 Profile models of some skeletal soils found in a moderate extent in Southern Thailand.

these soils illustrate a generally deep and highly developed soils. Yi-ngo series is a very deep, well drained and highly developed soils having quartz gravels as skeletal materials. This differs from the other soils within this group substantially. Another characteristic deviating from other soils is the thick surface layer in this soil making it more supportive for crops with a shallow rooting zone.

Both data on the ecology of these soils and their profile models suggested quite clearly that these soils are readily manageable for crop practices.



Texture: GC = Gravelly clay, GCL = Gravelly clay loam, GSCL = Gravelly sandy clay loam,
GSL = Gravelly sandy loam, SL = Sandy loam SiC = Silty clay,
VGCL = Very gravelly clay loam

Structure: ABK = Angular blocky, SBK = Subangular blocky,
1 = Weak, 2 = Moderate

Figure 3 Profile models of some skeletal soils found in a limited extent in Southern Thailand.

However, the condition would also depend on their specific physico-chemical properties.

Physical properties and status of basic fertility of skeletal soils

Table 2 summarizes data on particle size distribution, organic matter and available phosphorus and potassium of a skeletal soil found rather extensively in Southern Thailand (Chumphon series). A vital parameter found in this soil as indicated in Table 2 is the relatively sandy nature in the upper part of its profile and the sharp break in the amount of clay from the depth of 30 centimeters downwards. This condition when added with the low organic matter content, very low available phosphorus and low available potassium making its basic fertility status rather poor.

Four skeletal soils found in a moderately extent in Southern Thailand have been studied. They are Khao Khat series, Nong Khla series, Phato series and Ranong series. Table 3 summarizes data on particle size distribution, organic matter content and available phosphorus and potassium of these soils. Khao Khat and Nong Khla series have relatively finer texture comparing to that of Phato and Ranong series. Considering data on organic matter available phosphorus and potassium of these soils it appears that all the more clayey soils tend to have a better basic fertility status than the sandy ones. It should be noted here, that organic matter content values in the surface layer of these soils show no problem for crop practices. Available phosphorus data is too low for general crop production in these soils. Available potassium values however, are varied but most of them except those in Ranong series appear to be within a readily manageable range. Therefore, another vital property of these skeletal soils is the available phosphorus in their fine earths.

Data on particle size distribution, organic matter and available nutrients of Phayom Ngam

Table 2 Particle size distribution in fine earths (USDA grading), organic matter (O.M.) and available nutrients of a skeletal soil found rather extensively in Southern Thailand.

Depth (cm)	Horizon	Particle size distribution ($g\ kg^{-1}$) Sand	Silt	Clay	Textural [1/] class	O.M. ($g\ kg^{-1}$)	Avail.P ← ($mg\ kg^{-1}$)	Avail.K →
Chumphon series								
0-10	A	710	210	80	SL	9.1	1.2	54
10-20	Bw	700	190	110	SL	3.3	0.8	24
20-30	Btc1	690	190	120	SL	3.6	1.0	18
30-75	Btc2	460	150	390	SC	3.6	0.7	45
75-115	Btc3	420	130	450	C	2.1	1.0	39
115-185+	Btc4	470	190	340	C	4.6	1.2	36

1/ C = Clay, SC = Sandy clay, SL = Sandy loam.

Table 3 Particle size distribution in fine earths (USDA grading), organic matter (O.M.) and available nutrients of some skeletal soils found in a moderate extent in Southern Thailand.

Depth (cm)	Horizon	Particle size distribution ($g\ kg^{-1}$) Sand	Silt	Clay	Textural [1/] class	O.M. ($g\ kg^{-1}$)	Avail.P ← ($mg\ kg^{-1}$)	Avail.K →
Khao Khat series								
0-10	A	270	470	260	SiL	39.0	4.1	143
10-22	Bc	235	385	380	CL	23.4	1.7	62
22-65	Btc	140	335	525	C	7.1	1.3	41
65-122+	Bv	185	395	620	C	8.1	1.9	35
Nong Khla series								
0-8	Ap	330	250	420	C	23.4	2.0	67
8-18	Bt1	205	190	605	C	24.1	3.7	47
18-35	Bt2	170	170	660	C	20.8	1.9	32
35-75	Btc1	155	110	735	C	21.1	1.4	29
75-110+	Btc2	150	110	740	C	21.1	1.4	29
Phato series								
0-12/17	Ap	735	165	100	SL	16.2	2.5	50
17-35	Bt1	690	200	110	SL	8.4	1.7	38
35-50/55	Bt2	670	180	150	SL	4.8	1.2	41
55-110+	Bc	595	175	230	SL	3.6	0.9	59
Ranong series								
0-10	A	680	260	60	SL	17.2	4.3	39
10-20	Bc1	680	270	50	SL	6.9	2.9	30
20-47	Bc2	690	250	60	SL	1.9	1.6	21
47-100+	C	--------------------- Saprolite of quartzitic sandstone ---------------------						

1/ C = Clay, CL = Clay loam, SiL = Silt loam, SL = Sandy loam.

series, Sawi series and Yi-ngo series, skeletal soils that occupy a limited extent in Southern Thailand are summarized in Table 4. Phayom Ngam series is only soil having clayey texture where clay content determines the activities and chemical properties of the soil. Also, this soil differs from other two soil series in this group in its more poorly drained environment. The trend for their basic fertility relating to the amount of clay present in the fine earths follows what can be found in other groups of skeletal soils. The soils do not have any problem on organic matter content and their available potassium values are also within a readily manageable range. Available phosphorus in general is the problem for Phayom Ngam and Sawi series but very high values of available phosphorus were found in the analysis of soil samples collected from the profile of Yi-ngo series. This makes basic fertility status of Yi-ngo series relatively better than the other two soils for a general cropping practices (Sanchez, 1976).

Data on physical properties and basic fertility of these skeletal soils found in Southern Thailand indicate mildly that most of them have a generally light texture in their fine earths. Most of them have manageable level of organic matter content and available potassium. Available phosphorus in these soils can vary markedly and most of them have too low available phosphorus. This aspect should be looked into in using them for crop practices.

Exchange properties of skeletal soils in Southern Thailand

Table 5 summarizes laboratory analytical data related to exchange properties in the fine earths of Chumphon series, a skeletal soil found

Table 4 Particle size distribution in fine earths (USDA grading), organic matter (O.M.) and available nutrients of some skeletal soils found in a limited extent in Southern Thailand.

Depth (cm)	Horizon	Particle size distribution ($g\ kg^{-1}$) Sand	Silt	Clay	Textural [1/] class	O.M. ($g\ kg^{-1}$)	Avail.P	Avail.K
							← ($mg\ kg^{-1}$)	→
Phayom Ngam series								
0-15	A	445	315	240	SCL	35.4	3.1	64
15-29	Bw	390	270	340	SCL	30.7	3.9	38
29-65	Btc	330	215	450	C	18.1	3.3	29
65-155+	Bvg	323	205	470	C	7.5	1.1	29
Sawi series								
0-9	Ap	710	235	55	SL	13.8	1.9	39
9-25	Bw	705	230	65	SL	7.6	1.8	21
25-52/58	Bt	700	235	65	SL	2.4	1.4	26
58-110+	Btc	580	270	150	SL	1.5	1.9	36
Yi-ngo series								
0-22	Ap	521	354	125	SL	17.2	64.2	62
22-50	Btc1	472	312	216	SL	8.8	60.8	48
50-135	Btc2	421	338	241	SL	3.8	58.2	36
135-160+	C	434	366	200	SL	1.7	59.1	33

1/ C = Clay, SCL = Sandy clay loam, SL = Sandy loam.

Table 5 Laboratory analytical data related to exchange properties in the fine earths of a skeletal soil found rather extensively in Southern Thailand.

Depth	Horizon	pH (1:1)		Extractable bases				Sum	E.A.[1/]	C.E.C.[2/]	B.S.[3/]
(cm)		H_2O	KCl	Ca	Mg	Na	K	bases		(sum)	%
				←cmol kg^{-1}						→	
Chumphon series											
0-10	A	6.0	4.8	1.9	0.3	0.1	0.1	2.4	3.7	6.1	56
10-20	Bw	5.5	3.8	0.8	0.2	0.1	0.1	1.2	3.7	4.9	22
20-30	Btc1	5.3	3.9	0.9	0.2	0.1	0.1	1.3	4.4	5.7	23
30-75	Btc2	5.7	4.1	4.0	0.9	0.2	0.1	5.2	7.6	12.8	38
75-115	Btc3	5.7	4.2	4.0	1.1	0.2	0.1	5.4	7.3	12.7	37
115-185+	Btc4	5.6	4.1	3.4	1.3	0.2	0.1	5.0	5.6	10.6	34

1/ E.A. = Extractable acidity
2/ C.E.C. (sum) = Cation exchange capacity by the sum of E.A. and sum of bases
3/ B.S. = Base saturation

rather extensively category being highly leached, well developed soil poor exchange properties of this soil can be expected. Though this poor soil still favour cation exchange in the soil system since its delta pH (Δ pH) is negative, other chemical parameters such as the low extractable bases, relatively high extractable acidity, relatively low cation exchange capacity and low base saturation make them have poor exchange properties in their fine earths. With at least 35 percent by volume of coarse fragments in the soils the overall exchange properties of soil mass can be quite poor.

Table 6 summarizes laboratory data related to exchange properties in the fine earths of four soil series found in a moderate extent in Southern Thailand. Normally, the pH level of these soils do not pose any serious condition and they also favour cation exchange judging from their negative delta pH values. The problem of their exchange properties generally lies in their low extractable basic cations and their markedly high extractable acidity. This implies the excessive acidic cations (H^+, Al^{3+}) in the soil system affecting balance of plant nutrient status. The cation exchange capacity values of these soils range widely but depending on their extractable acidity mainly since their base saturation can be considered quite low. This condition in the soils can be quite serious for crop practices and their soil-fertilizer management. The condition in Khao Khat and Nong Khla series is more serious than the one in Phato and Ranong series.

Laboratory analytical data related to exchange properties in the fine earths of three skeletal soils found in a limited extent in Southern Thailand are summarized in Table 7. Pattern of the data on their exchange properties appear to strictly follow those of the ones shown in Table 6. Though it is obvious that their soil system still favour cation exchange, acidic cations in the soils adversely affect their cation exchange capacity and base saturation. The excessive extractable acidic cations in Phayom Ngam series makes its cation exchange poorest. A moderate condition on cation exchange properties of these soils can be found in Sawi series. Among these three soils the exchange properties of Yi-ngo series are the best one.

Table 6 Laboratory analytical data related to exchange properties in the fine earths of some skeletal soils found in a moderate extent in Southern Thailand.

Depth (cm)	Horizon	pH (1:1) H_2O	pH (1:1) KCl	Extractable bases Ca	Mg	Na	K	Sum bases	E.A.[1/]	C.E.C.[2/] (sum)	B.S.[3/] %
				←cmol kg^{-1}						→	
Khao Khat series											
0-10	A	5.1	4.2	0.7	1.0	0.1	0.1	1.9	19.8	21.7	9
10-22	Bc	5.0	4.0	0.1	1.1	0.1	0.1	1.4	15.8	17.2	8
22-65	Btc	5.5	4.2	0.1	0.2	0.1	0.1	0.5	13.4	13.9	4
65-122+	Bv	5.7	4.1	0.1	0.1	0.2	0.1	0.5	13.0	13.5	4
Nong Khla series											
0-8	Ap	4.6	3.7	0.3	0.3	0.2	0.1	0.9	12.5	13.4	7
8-18	Bt1	4.9	3.8	0.3	0.2	0.3	0.1	0.9	12.7	13.6	7
18-35	Bt2	5.0	3.7	0.2	0.1	0.2	0.1	0.6	12.8	13.4	4
35-75	Btc1	5.4	3.8	0.2	0.1	0.2	0.1	0.6	12.5	13.1	5
75-110+	Btc2	5.5	3.8	0.2	0.1	0.2	0.1	0.6	12.5	13.1	5
Phato series											
0-12/17	Ap	4.8	4.0	0.5	0.2	0.1	0.1	0.9	4.9	5.8	15
17-35	Bt1	4.8	3.9	0.2	0.1	0.1	0.1	0.5	3.9	4.4	11
35-50/55	Bt2	4.8	3.7	0.2	0.1	0.1	0.1	0.5	3.9	4.4	11
55-110+	Bc	4.9	3.7	0.2	0.1	0.1	0.1	0.5	5.2	5.7	9
Ranong series											
0-10	A	4.6	4.0	0.9	0.1	0.2	0.1	1.3	3.4	4.7	28
10-20	Bc1	4.5	4.0	0.5	0.1	0.2	0.1	0.9	3.3	4.2	21
20-47	Bc2	5.0	4.0	0.2	0.1	0.1	0.1	0.4	1.4	1.8	22
47-100+	C	--------------------------Saprolite of quartzitic sandstone--------------------------									

1/ E.A. = Extractable acidity

2/ C.E.C. (sum) = Cation exchange capacity by the sum of E.A. and sum of bases

3/ B.S. = Base saturation

Data related to exchange properties of these skeletal soils indicate few of their common vital properties. Firstly, these skeletal soils possess a system favouring cation exchange. Secondly, due to their highly leached and well developed nature their exchange complex is generally affected strongly by the acidic cations since the extractable acidity values are generally higher than their total extractable basic cations. Thirdly, the high amount of clay in the fine earths of these soils does not really give positive effect on their exchange properties. Some of the soils with high clay content in the fine earths appear to show more adverse effect of the acidic cations. These conditions of their exchange properties seem to suggest that soil-fertilizer management in crop practices for these soils should not emphasize the cation form of fertilizer elements too strongly. Anionic forms of nutrients should

Table 7 Laboratory analytical data related to exchange properties in the fine earths of some skeletal soils found in a limited extent in Southern Thailand.

Depth (cm)	Horizon	pH (1:1) H_2O	pH (1:1) KCl	Extractable bases Ca	Extractable bases Mg	Extractable bases Na	Extractable bases K	Sum bases	E.A.1/	C.E.C.2/ (sum)	B.S.3/ %
				←cmol kg^{-1}						→	
Phayom Ngam series											
0-15	A	4.8	3.8	0.3	0.2	0.3	0.1	0.9	15.0	15.9	6
15-29	Bw	4.8	3.7	0.2	0.1	0.4	0.1	0.8	10.6	11.4	8
29-65	Btc	5.1	3.8	0.2	0.1	0.4	0.1	0.8	10.1	10.9	7
65-155+	Bvg	5.1	3.7	0.1	0.1	0.3	0.1	0.6	12.0	12.6	5
Sawi series											
0-9	Ap	5.3	4.4	0.9	0.2	0.1	0.1	1.3	2.6	3.9	33
9-25	Bw	5.5	4.3	0.9	0.2	0.1	0.1	1.3	2.3	3.6	36
25-52/58	Bt	6.3	4.6	0.1	0.2	0.1	0.1	0.5	1.7	2.2	23
58-110+	Btc	6.1	3.8	0.1	0.3	0.1	0.1	0.5	2.5	3.0	17
Yi-ngo series											
0-22	Ap	4.7	3.7	0.3	0.1	7.8	0.6	8.8	5.3	14.1	62
22-50	Btc1	4.5	3.7	0.3	0.2	7.7	1.3	9.5	5.1	14.6	65
50-135	Btc2	4.7	3.9	0.4	0.2	7.2	0.8	8.6	7.5	16.1	53
135-160+	C	5.1	3.9	0.2	0.2	0.6	0.6	1.6	4.5	6.1	26

1/ E.A. = Extractable acidity
2/ C.E.C. (sum) = Cation exchange capacity by the sum of E.A. and sum of bases
3/ B.S. = Base saturation

also be considered more seriously for a more efficient fertilizer management. The presence of skeletal materials in these soils would not have strong negative effect in soil-crop practices.

Based on their morphology and data on their properties these soils can be classed mainly as Ultisols. Chumphon series and Yi-ngo series are Hapludults; Khao Khat series is Plinthudult; Nong khla series, Phato series and Sawi series are Paleudults, Phayom Ngam series is a Plinthaquult. However, Ranong series is a Udorthent (Soil Survey Staff, 1998).

Agricultural potential of skeletal soils in Southern Thailand

Data on ecology, profile models and physical and chemical properties of these skeletal soils illustrate that these soils are generally deep soils having skeletal materials of different nature but the most common one is the ironstone nodule. Generally, the soils are well developed, highly leached Ultisols and their fine earths have poor exchange properties. Though their surface layers would appear to possess a better quality for crop practices, the condition within the whole soils in most of them are poor. This is a typical condition of Ultisols in the humid tropics. Based on their properties and morphology most of these soils can be classed into U-IVct according to the land capability classification system and P-Vt, N-IIIct, F-IIct (T-IIct), L-IItc according to land suitability classification (FAO, 1976; Land Classification Division and FAO Project Staff, 1973) where U indicates upland cropping, P = paddy rice, N = non-flooded annual crops (upland field crops), F = fruit trees, T = tree crops, L = livestock pasture, IV = marginally suited (land capability classification) V = not suited, III = moderately suited, II = well suited (for suitability classess of paddy rice, upland field crops and fruit trees or tree crops) and II = moderately suited (for suitability class of livestock pasture). Two limiting parameters can be envisioned for these soils include topography (t) and gravels or coarse materials (c) in the soils.

In a strict sense these skeletal soils do not have potential for lowland crop production in agriculture. They are moderately suitable for upland field crop and livestock pasture, well suited for fruit trees and tree crop production with two inherent problems, slope and coarse materials in the soils. From these analyses it should be noted that these skeletal soils in Southern Thailand can be used readily in crop practices but attention on types of crops is needed.

Sustainable uses of skeletal soils in Southern Thailand

Development of crop production and practices in Southern Thailand has been quite adaptive to climatic and soil conditions. For the upland region including areas occupied by skeletal soils, para rubber and fruit tree have been emphasized. The general condition on agricultural technology is also directed to perennial tree crop production. These include both soil-fertilizer management and integrated pest management. As indicated in Table 1 on the ecology of the skeletal soils, most of them are now supporting para rubber planting with some limited part under fruit trees. Stands of these crops are quite acceptable and their yields have been quite satisfactory with common plantation and orchard management basing on existing technologies. Therefore, the overall agricultural use of upland soils including the skeletal ones in most parts of Southern Thailand can be considered stable and productive.

A factor that can affect the stability of land use on these soils is strictly economic. Marketing of the products, at time, becomes problem, but with the relatively fast development in agro-industry in the country the situation can be sustained for a good period of time. Though it appears to be somewhat accidental the use of skeletal soils in Southern Thailand at present is well adapted and generally sustainable.

CONCLUSION

Results of the study on vital properties and agricultural potential of skeletal soils in Southern Thailand revealed that most of them are upland soils mainly occupying undulating and rolling terrains with a major slope range of 3-8 percent. Most of them are deep to very deep, highly leached and well developed Ultisols. The skeletal materials in these soils vary but ones that can be found frequently are ironstone nodules. Their basic fertility status is generally poor and available phosphorus problem in most soils exists. Their high extractable acidity can affect their exchange properties markedly whereas the presence of skeletal materials does not appear to pose serious problem on their uses and management.

Evaluation of their suitability for cropping reveals that they are not suited for paddy rice, but they are moderately suited for upland field crops and livestock pasture, and well suited for tree crops including fruit trees with different degrees of problem on topography and the presence of skeletal materials. Since they have been used mainly for rubber and fruit tree production, land use problem on them can be coped with quite well by the use of existing agricultural technologies. Therefore, sustainability in their use, at present, is somewhat achieved.

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LITERATURE CITED

Chintaskul, P. 1989. An Analysis on Types and Properties of Laterite in Sakon Nakhon Basin, Northeast Thailand. Ph.D. Thesis, Kasetsart University, Bangkok. (in Thai with English Abstract).

Dee-saeng, B. 1993. Characteristics of Skeletal Soils on a Toposequence in Sakon Nakhon Basin. M.S. Thesis, Kasetsart University, Bangkok. (in Thai with English Abstract).

FAO. 1976. A Framework for Land Evaluation. FAO Soils Bulletin No. 32. Rome. 87 p.

Kheoruenromne, I. 1987. Soil Survey Laboratory Manual. Department of Soil Science, Faculty of Agriculture, Kasetsart University, Bangkok. 187 p. (in Thai).

Kheoruenromne, I. 1991. Soils of Thailand-Characteristics, Distribution and Uses. Department of Soil Science, Faculty of Agriculture, Kasetsart University, Bangkok. 651 p. (in Thai).

Land Classification Division and FAO Project Staff. 1973. Soil Interpretation Handbook for Thailand. Department of Land Development, Ministry of Agriculture and Cooperatives, Bangkok. 135 p.

Panichapong, S. 1982. Problem Soils of Thailand; Their Characteristics, Distribution and Utilizsation. Ph.D. Thesis, The University of Tokyo, Tokyo.

Sanchez, P.A. 1976. Properties and Management of Soils in the Tropics. John Wiley and Sons Inc., New York. 617 p.

Soil Survey Division Staff. 1993. Soil Survey Manual. United States Department of Agriculture, Washington D.C. 437 p.

Soil Survey Laboratory Staff. 1992. Soil Survey Laboratory Methods Manual. Soil Survey Investigation Report No. 42, United States Department of Agriculture, Washington D.C. 400 p.

Soil Survey Staff. 1975. Soil Taxonomy-A basic system of soil classification for making and interpreting soil survey. United States Department of Agriculture. U.S. Government Printing Office, Washington D.C. 754 p.

Soil Survey Staff. 1998. Keys to Soil Taxonomy. 8th ed., United States Department of Agriculture. U.S. Government Printing Office, Washington D.C. 326 p.

Vijarnsorn, P. 1984. Skeletal soils of Thailand, pp. F2.1-F2.14. *In* Proceedings of the Fifth ASEAN Soil Conference, Vol. 1. Department of Land Development, Ministry of Agriculture and Cooperatives. Bangkok, Thailand.

Vijarnsorn, P. 1985. General Soil Map of the Southern Region, Thailand (scale 1:500,000). Department of Land Development, Ministry of Agriculture and Cooperatives. Bangkok (2 map sheets).

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