ABSTRACT

An approach on soil management practices for red Oxisols under Tropical Savanna in Thailand was based on consideration derived from the soils properties. A determination of these properties was carried out for 6 representative pedons. These soils were Kandiustox in Northeast Plateau developed on limestone and basalt and had characteristics typical of highly weathered soils. They were very deep (> 2 m depth), clayey, having moderate to strong structures. The soils had low bulk densities (0.95-1.29 Mg m⁻³). Water quickly drained from these soils at high matric potentials, while at low matric potentials, water contents were relatively high. Amounts of water retained at 33 kPa (field capacity) (ranging 25-38%) and 1500 kPa (permanent wilting point) (ranging 19-29%) by these red Oxisols were both high. Water available to plants was only 3-10 percent. Their pH values were low, ranging 4.3-7.6 and CEC’s were also low ranging 5.4-20.4 cmol kg⁻¹. Organic matter contents were in a range of 2.1-41.3 g kg⁻¹. They had high amount of available P and K in the surface horizon which decreased sharply with depth. Pak Chong series (Pc) had low to medium fertility whereas Chok Chai series (Ci) had low fertility status. The approach for effective management practices includes irrigation, fertilizer and organic matter management, respectively.

Key Words: Kandiustox, physical properties, chemical properties, soil fertility assessment

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INTRODUCTION

Red Oxisols occupy about 6,080 km² distributing in small areas of all parts of Thailand. They mainly developed on basalt and limestone. Their properties are conceptually similar within the limit of this soil order (Buol et al., 2003; Soil Survey Staff, 1999). Because the chemical and physical properties of soil are mainly controlled by mineralogy, their cation exchange capacity is very low and entirely dependent on pH. As the pH of Oxisols is generally very low under native savanna, Al mainly occupies the exchange sites. Phosphorus availability in these soils is especially low as it is selectively adsorbed to oxyhydroxides (Neufeldt, 1999). However, Oxisols develop a stable microstructure called pseudosand, as a result of strong binding between positively charged oxyhydroxides and negatively charged kaolinite and organic matter (OM). The high structural stability leads to a unique water retention behavior in Oxisols which are characterized by extremely high macroporosity and a high number of intra-aggregate pores (Bui et al., 1989; Tawornpruek et al., 2005). Despite high clay contents, plants can still suffer quickly from drought during dry spells in rainy season. Under these conditions, profitable agronomic activities cannot be carried out without intensive management. In this study, soil morphological, chemical and physical properties of Kandiustox were examined in the light of management effects and possible consequences for land use.

MATERIALS AND METHODS

Two study areas of red Oxisols under tropical savanna climate were located in the Northeast Plateau between Latitude 14-16°N and Longitude 103-105°E with an annual average temperature of 26-30°C, and an annual rainfall of 1,000-1,500 mm. The sites of Pak Chong series (Pc) were on residuum derived from limestone and Chok Chai series (Ci) were on residuum derived from basalt. Three representative pedons for each soils were selected for this study. Pedon analysis in soil pits was carried out at each site including detailed profile description and sampling of soil from each genetic horizon using standard field study methods (Soil Survey Staff, 1993; Kheoruenromne, 2004). Disturbed bulk samples and soil cores were collected for laboratory analysis.

 Bulk samples were air-dried, crushed and then passed through a 2-mm sieve. The resultant <2 mm samples were used for general laboratory analysis. The soil core samples were used for physical analysis.

 Soil pH was measured in H₂O and in 1N KCl (soil:solution, 1:1) by a standardized pH meter (National Soil Survey Center, 1996). Organic carbon was determined according to the Walkley and Black wet oxidation procedure (Nelson and Sommers, 1996). Organic matter concentration of the soils was taken to be organic carbon concentration multiplied by 1.724 (Nelson and Sommers, 1996). Total nitrogen was determined by the Kjeldahl method (Jackson, 1965). Cation exchange capacity (CEC) was determined by 1N NH₄OAc at pH 7.0 (Chapman, 1965). Available potassium
was determined by ammonium acetate extraction \( (1N \text{ NH}_4\text{OAc}) \) at pH 7.0 (Thomas, 1987) and available phosphorus by the Bray II method (Bray and Kurtz, 1945).

Particle size analysis of bulk soil samples was done by the pipette method with pretreatment for removal of carbonate, organic matter and iron oxides (Gee and Bauder, 1986). Bulk density was determined by a core method (Blake and Hartge, 1986). Soil water retention measurements from selected horizons were made at field capacity (-33 kPa) and permanent wilting point (-1500 kPa) on ceramic pressure plates and plant available water was calculated as the difference between these two measurements (Klute, 1986).

RESULTS AND DISCUSSION

Classifying the soils

The soils were characterized according to Keys to Soil Taxonomy (Soil Survey Staff, 2003) as shown in Table 1. These soils were Oxisols with kandic horizons underlying a surface horizon with \( \geq 40\% \) clay that meets the weatherable mineral properties of an oxic horizon (Soil Survey Staff, 1999).

Field morphology

All red Oxisols developed on colluvium and residuum (Table 2). Their surrounding landforms were mostly undulating having 1-8 percent slope. They were well drained with rapid permeability. Land use on them was mostly field crops.

Colors of these red Oxisols range from dark reddish brown (5YR 3/4) to dark red (10R 3/6) and these colors are generally a function of the Fe content of the parent material. These soils have hues of 5YR to 10R and redder which are used as an indication of hematite in soils (Schwertmann, 1993; Kämpf, et al., 2000). The texture of these red Oxisols is clay. This is common for red Oxisols developed on limestone and basalt (Paramananthan and Eswaran, 1980). Red Oxisols under tropical savanna climate have moderate to strong angular, semi-angular and subangular blocky structure parting to moderate to strong granular structure with mostly slightly firm to very firm consistence which partially coincide with results of others’ study (Imhoff et al., 2002).

Physical properties

Particle size distribution reflected the abundance of clay size particles (Figure 1). It was closely related their parent material and the extent of their weathering (Xian-liang, 1986; Neufeldt, 1999; Beinroth et al., 2000). The soils generally had low bulk densities ranging between 0.95-1.29 Mg m\(^{-3}\) (Figure 2a) that showed no systematically decrease with increasing clay content (El-Swaify, 1980; Neves et al., 2003). The low bulk density values were due to the high porosity arising from the well structured condition of these soils (El-Swaify, 1980). The moisture characteristics curves of these soils showed two major desorption zones (Figure 2b). Water in the inter-aggregate pores drained rapidly between 0 and 10 kPa (pF 2.0). Another desorption zone occurred when the intra-aggregate pores
Table 1  Classification of the studied soils (Soil Survey Staff, 2003).

<table>
<thead>
<tr>
<th>Order</th>
<th>Suborders</th>
<th>Great Groups</th>
<th>Subgroups</th>
<th>Family</th>
<th>Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxisols</td>
<td>Ustox</td>
<td>Kandiustox</td>
<td>Rhodic</td>
<td>Very-fine, kaolinitic,</td>
<td>Pc-2,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kandiustox</td>
<td>isohyperthermic</td>
<td>Pc-3 Ci-1, Ci-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typic</td>
<td>Very-fine, kaolinitic,</td>
<td>Pc-1,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>isohyperthermic</td>
<td>Ci-2</td>
</tr>
</tbody>
</table>

Table 2  Environmental setting of the studied soils.

<table>
<thead>
<tr>
<th>Profile</th>
<th>Parent material</th>
<th>Physiographic position</th>
<th>Slope</th>
<th>Permeability/Runoff</th>
<th>Annual rainfall / Mean temperature</th>
<th>Land use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ci-1</td>
<td>Residuum derived from weathered basalt</td>
<td>Lava corrosion plain</td>
<td>1%</td>
<td>Rapid /slow</td>
<td>1097 mm / 27 °C</td>
<td>Cassava field</td>
</tr>
<tr>
<td>Ci-2</td>
<td>Colluvium and residuum derived from weathered basalt</td>
<td>Lava corrosion plain</td>
<td>1.5%</td>
<td>Rapid /slow</td>
<td>1097 mm / 27 °C</td>
<td>Cassava field</td>
</tr>
<tr>
<td>Ci-3</td>
<td>Residuum derived from weathered basalt</td>
<td>Top of lava corrosion plain</td>
<td>1%</td>
<td>Rapid /slow</td>
<td>1097 mm / 27 °C</td>
<td>Cassava field</td>
</tr>
<tr>
<td>Pc-1</td>
<td>Residuum derived from limestone</td>
<td>Karst corrosion flat footslope</td>
<td>2%</td>
<td>Moderate / Moderate</td>
<td>1035 mm / 27 °C</td>
<td>Fast growing trees, olive</td>
</tr>
<tr>
<td>Pc-2</td>
<td>Residuum derived from limestone</td>
<td>Karst corrosion plain</td>
<td>2%</td>
<td>Moderate / Moderate</td>
<td>1035 mm / 27 °C</td>
<td>Corn production experimental plot</td>
</tr>
<tr>
<td>Pc-3</td>
<td>Residuum derived from limestone</td>
<td>Karst corrosion plain on perimeter of buried lapies</td>
<td>2%</td>
<td>Moderate / Moderate</td>
<td>1035 mm / 27 °C</td>
<td>Left idle under grass and bamboo</td>
</tr>
</tbody>
</table>

![Graphs showing soil properties](image-url)
**Figure 1** Depth functions of particle size distribution of Pak Chong (Pc) and Chok Chai (Ci) soil series.

**Figure 2** (a) Depth functions of bulk density value for each profile of studied soils (b) water retention characteristic curves of Pak Chong (Pc) and Chok Chai (Ci) soil series.

began to drain at about 1500 kPa (pF 4.2). Amounts of water retained at 33 kPa (field capacity) (ranging 25-38%) and 1500 kPa (permanent wilting point) (ranging 19-29%) by these red Oxisols were both high as was a usual feature of Oxisols (Macedo and Bryant, 1987). Water available to plants which was the difference between these amounts is only 3-10% when the soil was wet to field capacity. This observation was consistent with data reported by Macedo and Bryant (1987), Larson and Padilla (1990) and Beinroth et al. (2000).

**Chemical properties**

pH values of these soils were in a range of 4.3-7.6 in top soils and 4.4-6.3 in subsoils (Figure 3a). Oxisols were dominated by variable charge minerals with a low permanent negative charge on the clay minerals (Uehara, 1986). Organic matter content decreased with depth in a range of 2.1-41.3 g kg\(^{-1}\) (Figure 3b). The cation exchange capacity of these soils ranged 5.44-20.38 cmol kg\(^{-1}\) (Figure 3c). The CEC of Oxisols was low because they contained mainly low activity clays and had low pH values and little organic matter (Uehara, 1986). Variations in CEC with depth were related to the soil organic matter content (Figure 3b,c) but there was not a systematic relationship between organic carbon and CEC in these soils. Available phosphorus had a depth function trend similar to that for organic matter content (Figure 3d). The soils had relatively high amounts of available P in the surface horizon as a result of fertilization for crop production. The subsurface horizons had very low amounts of available phosphorus as a result of much P being chemically bound to sesquioxide surfaces in these soil types (Agbenin and Tiessen, 1994; Owusu-Bennisah et al., 1997). Apart from
the surface horizon of one Kandiustox (Pc) profile values of available K were low (i.e. <30 mg kg\(^{-1}\)) throughout all profiles (Figure 3e) and might limit crop production (Land Classification Division and FAO Project Staff, 1973).

Figure 3 Depth function diagrams of some chemical properties for each soil profile.

Fertility assessment results based on a common system used in Thailand (Kheoruenromne, 2004) (Table 3) indicated that the soils developed on limestone (Pc) had medium fertility as a result of successive fertilization for a long period in the experiment plots and their parent material while the soils developed on basalt (Ci) had low fertility status.

The approach for effective management practices

The results on the soil properties indicate that in general the soils do need irrigation in some period for intensive crop production. Fertilizer application is needed to maintain suitable level of plant nutrient and organic matter management in the topsoil may be required to promote plant nutrition supply and water holding capacity. In specific cases, types of crops and their sensitivity to acidity must also be considered for the practices.

CONCLUSION

These Kandiustox developed on residuum derived from limestone and basalt. They had moderate to strong structure. Their texture was clay. The soils had low bulk density (0.95-1.29 Mg m\(^{-3}\)) indicating high soil porosity. Water quickly drained from these soils at high matric potentials, while at low matric potentials, water contents were relatively high. Their pH was low ranging 4.3-7.6 and CEC was
also low ranging 5.4-20.4 cmol kg\(^{-1}\). Soil organic matter content was in a range of 2.1-41.3 g kg\(^{-1}\) and decreased with depth. Pak Chong series (Pc) had low to medium fertility whereas Chok Chai series (Ci) had low fertility status. The approach for effective management practices includes irrigation in some periods for intensive crop production, fertilizer application to maintain suitable level of plant nutrient and organic matter management in the topsoil to promote plant nutrient supply and water holding capacity.

### Table 3  Fertility assessment for Kandiustox using some soil chemical properties.

<table>
<thead>
<tr>
<th>Profile</th>
<th>Depth (cm)</th>
<th>OM (g kg(^{-1}))</th>
<th>Available P (mg kg(^{-1}))</th>
<th>Available K (mg kg(^{-1}))</th>
<th>CEC (cmol kg(^{-1}))</th>
<th>BS (%)</th>
<th>Sum of score</th>
<th>Rating*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pc-1</td>
<td>0-30</td>
<td>31 2</td>
<td>20.9 2</td>
<td>279.9 3</td>
<td>19.9 2</td>
<td>67 2</td>
<td>11 Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-100</td>
<td>6 1</td>
<td>3.7 1</td>
<td>42.5 1</td>
<td>13.5 2</td>
<td>44 2</td>
<td>7 Low</td>
<td></td>
</tr>
<tr>
<td>Pc-2</td>
<td>0-30</td>
<td>30 2</td>
<td>4.9 1</td>
<td>130.6 3</td>
<td>15.6 2</td>
<td>75 2</td>
<td>10 Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-100</td>
<td>8 1</td>
<td>1.5 1</td>
<td>26.7 1</td>
<td>12.5 2</td>
<td>44 2</td>
<td>7 Low</td>
<td></td>
</tr>
<tr>
<td>Pc-3</td>
<td>0-30</td>
<td>24 2</td>
<td>5.6 1</td>
<td>70.0 2</td>
<td>13.3 2</td>
<td>90 3</td>
<td>10 Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-100</td>
<td>7 1</td>
<td>2.1 1</td>
<td>21.9 1</td>
<td>11.0 2</td>
<td>26 1</td>
<td>6 Low</td>
<td></td>
</tr>
<tr>
<td>Ci-1</td>
<td>0-30</td>
<td>16 2</td>
<td>8.6 1</td>
<td>10.0 1</td>
<td>7.6 1</td>
<td>7 1</td>
<td>6 Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-100</td>
<td>7 1</td>
<td>0.9 1</td>
<td>3.7 1</td>
<td>7.7 1</td>
<td>4 1</td>
<td>5 Low</td>
<td></td>
</tr>
<tr>
<td>Ci-2</td>
<td>0-30</td>
<td>10 1</td>
<td>3.3 1</td>
<td>6.2 1</td>
<td>9.1 1</td>
<td>9 1</td>
<td>5 Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-100</td>
<td>4 1</td>
<td>1.0 1</td>
<td>4.4 1</td>
<td>7.4 1</td>
<td>2 1</td>
<td>5 Low</td>
<td></td>
</tr>
<tr>
<td>Ci-3</td>
<td>0-30</td>
<td>22 2</td>
<td>9.8 1</td>
<td>16.1 1</td>
<td>7.6 1</td>
<td>7 1</td>
<td>6 Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-100</td>
<td>12 1</td>
<td>3.4 1</td>
<td>5.1 1</td>
<td>7.8 1</td>
<td>5 1</td>
<td>5 Low</td>
<td></td>
</tr>
</tbody>
</table>

OM (g kg\(^{-1}\)): <15 = 1, 15-35 = 2, >35 = 3; Available P (mg kg\(^{-1}\)): <10 = 1, 10-25 = 2, >25 = 3; Available 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, Available P, Available K, CEC and BS: ≤7, low; 8-12, medium; ≥13, high

**REFERENCES**


