# Chemical, Physical and Mineralogical Properties of Soils in Tuliem and Thanhtri Districts of Hanoi City, Vietnam

Tra, Ho Thi Lam
Laboratory of Soils, Faculty of Agriculture, Kyushu University

Phuong, Hoang Xuan
National Institute for Agricultural Planning and Projection

Egashira, Kazuhiko
Laboratory of Soils, Faculty of Agriculture, Kyushu University

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# Chemical, Physical and Mineralogical Properties of Soils in Tuliem and Thanhtri Districts of Hanoi City, Vietnam

**Ho Thi Lam Tra, Hoang Xuan Phuong***
**and Kazuhiko Egashira**

Laboratory of Soils, Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan

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Fundamental soil properties relating to soil productivity or fertility were assessed to soils in Tuliem and Thanhtri districts of Hanoi city, which have been subjected to rapid urbanization and industrialization. The pH was slightly acid to neutral. Organic matter and total N contents of soils were in a range between 16 and 31 g/kg and between 1.3 and 3.2 g/kg, respectively, with the C/N ratio of 6.7 in average. Available $P_2O_5$ content measured by the Truog method was below 26 mg/kg except for one soil from the vegetable field which had 99 mg/kg. Cation exchange capacity ranged from 18 to 27 cmol(+)/kg and exchangeable cations were dominated by Ca followed by Mg. In the particle-size distribution, clay content was 18 to 63% but mostly in a range of 20 to 45% with the texture of clay loam and light clay. Mineralogical composition in the clay fraction was similar to one another: mica was a predominant clay mineral accompanied by chlorite and kaolinite with negligible smectite and with considerable quartz. Soil fertility of these soils was anticipated to be poor because of recent intensive farming, but was in the improved status probably due to increased application of organic manure and residues by farmers.

## INTRODUCTION

Hanoi is the capital of Vietnam and located in the deltaic plain of the Red River in the Northern Vietnam. Climate of the Red River delta area is dominated by subtropical monsoon with two distinct seasons: the hot–wet season (from April to October) and the cool–dry season (from November to March). Mean annual rainfall is 1,600–1,900 mm (Nguyen *et al.*, 1997).

Tuliem and Thanhtri districts are situated in the western to southern part of Hanoi city. The two districts have population of nearly one million. The area is 20,282 ha in which approximately 40% is the agricultural land (Ho *et al.*, 1998). Tuliem and Thanhtri districts have been one of the most productive area in Hanoi and rice and vegetables are main agricultural products. They are supplied to markets of the city throughout the year. Double–cropping system with a rotation of rice–rice is the major cropping system in the area. Side by side with this, there is a triple–cropping system with rice–rice–vegetables or rice–vegetables–vegetables rotation. River mud had been used for long time as organic fertilizer or amendment to sustain soil productivity. Now farmers use organic manure and apply a lot of chemical fertilizer to raise crop yield.

Nine soil samples were collected from agricultural soils in Tuliem and Thanhtri

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*National Institute for Agricultural Planning and Projection, 61 Hangchuoi Str., Hanoi, Vietnam.

districts and one river-sediment sample was from the Kimnguu River flowing through Thanhtri district in July, 1997. In the present study, selected chemical properties, particle–size distribution and clay mineralogical composition of the samples were analyzed to clarify the fundamental soil properties relating to soil productivity or fertility of agricultural soils in Tuliem and Thanhtri districts of Hanoi city.

## MATERIALS AND METHODS

### 1. Location and soil samples

The river system and sampling sites of soils and river–sediment in Tuliem and Thanhtri districts are shown in Fig. 1. Samples are briefly described in Table 1. Samples of No. 1 through No. 4 were taken from Tuliem district and those of No. 5 through No. 10 were from Thanhtri district. Sample No. 10 is the river–sediment sample. Nine soil samples were taken at different land height and land use to cover the whole agricultural area of Tuliem and Thanhtri districts. Soils on the high, middle, low and lowest positions in the relative land height of the region are classified as Orthi–Umbri–Eutric Fluvisols, Orthi–Plinthi–Eutric Fluvisols, Endo–Orthi–Eutric Fluvisols and Epi–Stagni–Eutric Gleysols, respectively, according to FAO/UNESCO soil classification system. Samples were taken at the surface 15–cm layer. They were air–dried, ground with a ceramic pestle, passed through a 1–mm sieve and preserved in plastic bottles for subsequent analyses.

**Table 1.** Brief description of soil and river–sediment samples used in the present study.

| Sample No. | Location | | Relative land height in the region | Land use (crop) | Soil classification of FAO/UNESCO |
|---|---|---|---|---|---|
| | District | Commune | | | |
| 1 | Tuliem | Taytuu | High | Upland (vegetables) | Orthi–Umbri–Eutric Fluvisols |
| 2 | | Phudien | Low | Paddy (rice–rice) | Endo–Orthi–Eutric Fluvisols |
| 3 | | Xuanphuong | Middle | Paddy (rice–rice –vegetables) | Orthi–Plinthi–Eutric Fluvisols |
| 4 | | Yenhoa | Lowest (marshy) | Paddy (rice–rice) | Epi–Stagni–Eutric Gleysols |
| 5 | Thanhtri | Mydinh | Low | Paddy (rice–rice) | Endo–Orthi–Eutric Fluvisols |
| 6 | | Thanhliet | Middle | Paddy (rice–rice) | Orthi–Plinthi–Eutric Fluvisols |
| 7 | | Tuhiep | Low | Paddy (spinach) | Endo–Orthi–Eutric Fluvisols |
| 8 | | Lienninh | Middle | Paddy (rice–rice –vegetables) | Orthi Plinthi Eutric Fluvisols |
| 9 | | Daiang | Lowest (marshy) | Paddy (rice–rice) | Epi–Stagni–Eutric Gleysols |
| 10 | | Tranphu | River bed | – | – |

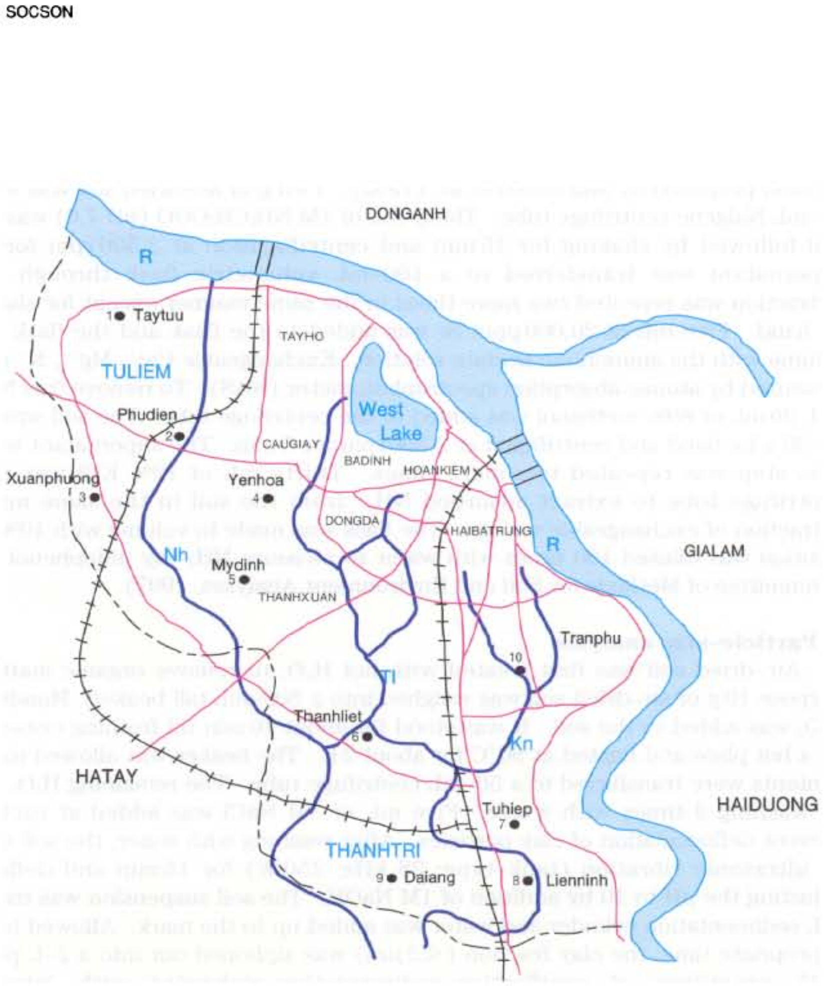


**Fig. 1.** The river system and sampling sites in Tuliem and Thanhtri districts of Hanoi city.

● : Sampling site
R : Red River
Nh : Nhue River
Tl : Tolich River
Kn : Kimnguu River

## 2. Determination of soil chemical properties

The pH was measured in the suspension having the soil/water(solution) ratio of 1/2.5; organic C was determined by the Tyurin method and multiplied by the coefficient of 1.724 to give the organic matter content; total N was determined by the Kjeldahl method; and available $P_2O_5$ was determined by the Truog method (Committee of Soil Standard Methods for Analyses and Measurements, 1986).

Exchangeable cations and cation exchange capacity (CEC) were determined by the method proposed by Muramoto *et al.* (1992). Two g of air–dried soil was weighed into a 50–mL Nalgene centrifuge tube. Thirty mL of 1M $NH_4CH_3COO$ (pH 7.0) was added to the soil followed by shaking for 15 min and centrifugation at 2,500 rpm for 5 min. The supernatant was transferred to a 100–mL volumetric flask through filter paper. Extraction was repeated two more times in the same manner except for shaking for 30 s by hand. Five mL of 20,000 ppm Sr was added to the flask and the flask was made to volume with the ammonium acetate solution. Exchangeable $Ca^{2+}$, $Mg^{2+}$, $K^+$ and $Na^+$ were measured by atomic absorption spectrophotometer (AAS). To remove free $NH_4^+$ from the soil, 20 mL of 80% methanol was added to the centrifuge tube. The soil was then shaken for 30 s by hand and centrifuged at 2,500 rpm for 5 min. The supernatant was discarded. This step was repeated two more times. Thirty mL of 10% KCl was added to the centrifuge tube to extract adsorbed $NH_4^+$ from the soil in the same manner as the extraction of exchangeable cations. The flask was made to volume with 10% KCl and the solution was diluted 100 times with water to measure $NH_4^+$ by indophenol blue method (Committee of Methods for Soil and Environment Analyses, 1997).

## 3. Particle–size analysis

Air–dried soil was first treated with hot $H_2O_2$ to remove organic matter. For this purpose 10 g of air–dried soil was weighed into a 500–mL tall beaker. Hundred mL of 7% $H_2O_2$ was added to the soil. It was stood for about 10 min till frothing ceased and placed on a hot plate and heated at 90 °C for about 2 h. The beaker was allowed to cool and the contents were transferred to a 50–mL centrifuge tube. The remaining $H_2O_2$ was removed by washing 3 times with water. Five mL of 3M NaCl was added at each washing to prevent deflocculation of clay particles. After washing with water, the soil was dispersed by ultrasonic vibration (tank–type; 38 kHz, 250 W) for 15 min and deflocculated by adjusting the pH to 10 by addition of 1M NaOH. The soil suspension was transferred to a 1–L sedimentation cylinder and water was added up to the mark. Allowed to stand for an appropriate time, the clay fraction ($<2\mu m$) was siphoned out into a 2–L plastic beaker. With repetition of sonification–sedimentation–siphoning with intermittent pH adjustments, the clay fraction was completely separated and flocculated by addition of small amounts of 3M NaCl. The 2–20 $\mu m$ silt fraction was separated by repeated sedimentation and siphoning. The fine sand (20–200 $\mu m$) and coarse sand (200–1,000 $\mu m$) fractions were separated by wet–sieving. The weight of each fraction was determined to calculate the particle–size distribution.

## 4. Clay mineralogical analysis

Mineralogical composition of the $<2\mu m$ clay fraction, which had been separated in the particle–size analysis, was analyzed by the X–ray diffraction (XRD). The clay fraction preserved as a flocculated sol was used. Duplicate sols containing 50 mg of clay were taken in 10–mL centrifuge tubes. Washing by centrifugation and decantation was carried out twice with 8 mL of an equal mixture of 1M NaCl and 1M $NaCH_3COO$ (pH 5.0) in order to decrease the pH of the preserved clay sols. The clay was saturated with Mg and K by washing 3 times with 8 mL of 0.5 M $MgCl_2$ and 1M KCl, respectively. The excess salt was removed by washing once with 8 mL of water. The clay in the tube was thoroughly suspended with 1 mL of water. An aliquot of 0.4 mL of the sol was dropped onto a glass slide (28 × 48 mm) covering two–thirds of its area, air–dried, and X–rayed (parallel powder mount). XRD patterns were obtained using a Rigaku diffractometer with Ni–filtered CuK$\alpha$ radiation at 40 kV and 20 mA and at a scanning speed of °2$\theta$/min over a range of 3 to 30 °2$\theta$. XRD analysis was made with air–dried and glycerol–solvated specimens for the Mg–saturated clay and with air–dried and heated (at 300 °C and at 550 °C for 2 h) specimens for the K–saturated clay.

## RESULTS AND DISCUSSION

### Chemical properties

Some chemical properties of the soil samples in Tuliem and Thanhtri districts are shown in Table 2. The pH ($H_2O$) of the soils in this study ranged between 5.7 and 7.3,

**Table 2.** Some chemical properties of the soil and river–sediment samples.

| Sample No. | pH ($H_2O$) | pH (KCl) | Organic matter (g/kg) | Total N (g/kg) | Available $P_2O_5$ (mg/kg) |
|---|---|---|---|---|---|
| 1 | 7.21 | 6.91 | 15.9 | 1.3 | 99.3 |
| 2 | 7.26 | 6.86 | 28.3 | 2.0 | 24.6 |
| 3 | 5.93 | 4.68 | 30.3 | 2.7 | 10.6 |
| 4 | 6.27 | 5.35 | 21.9 | 3.2 | 25.8 |
| 5 | 5.72 | 4.85 | 24.7 | 2.1 | 20.9 |
| 6 | 6.75 | 5.66 | 30.9 | 2.3 | 12.5 |
| 7 | 5.93 | 4.62 | 26.0 | 2.2 | 9.5 |
| 8 | 6.47 | 5.33 | 18.8 | 1.8 | 8.4 |
| 9 | 5.91 | 4.75 | 22.2 | 2.0 | 10.0 |
| 10 | 6.85 | 6.58 | 105.0 | 6.9 | 51.1 |

| Sample No. | CEC | Exchangeable cations (cmol(+)/kg) | | | | | Base-saturation |
|---|---|---|---|---|---|---|---|
| | (cmol(+)/kg) | $Ca^{2+}$ | $Mg^{2+}$ | $K^+$ | $Na^+$ | Total | (%) |
| 1 | 18.0 | 8.4 | 2.27 | 0.18 | 0.23 | 11.1 | 62 |
| 2 | 24.3 | 11.8 | 1.26 | 0.15 | 0.22 | 13.4 | 55 |
| 3 | 20.9 | 6.8 | 1.24 | 0.21 | 0.19 | 8.4 | 40 |
| 4 | 24.4 | 7.6 | 2.02 | 0.14 | 0.26 | 10.0 | 41 |
| 5 | 23.7 | 6.2 | 1.40 | 0.12 | 0.17 | 7.9 | 33 |
| 6 | 27.1 | 8.1 | 3.69 | 0.33 | 0.63 | 12.8 | 47 |
| 7 | 22.6 | 6.8 | 1.85 | 0.12 | 0.29 | 9.1 | 40 |
| 8 | 20.6 | 6.1 | 2.14 | 0.14 | 0.28 | 8.7 | 42 |
| 9 | 24.5 | 7.0 | 2.13 | 0.11 | 0.18 | 9.4 | 38 |
| 10 | 30.7 | 39.8 | 4.59 | 0.61 | 0.75 | 45.8 | 149 |

suggesting the slightly acid to neutral condition of soil. Sample No.1 (vegetable field in Taytuu commune of Tuliem district) showed a high pH ($H_2O$) of 7.21 and the highest percent base–saturation of 62%.

Organic matter content of the nine soil samples was in the range between 15.9 and 30.9 g/kg with an average of 24.3 g/kg, and total N content ranged from 1.3 to 3.2 g/kg with an average of 2.2 g/kg. The values obtained in the present study were a little higher than the values of organic matter of 19.4 g/kg and total N of 1.3 g/kg, which are averages of data reported to agricultural soils of the Red River delta between 1973 and 1982 (Nguyen *et al.*, 1997). This tendency can be ascribed to the increased application of organic manure and residues by farmers after Vietnam Government executed the new land policy in 1993, by which farmers were permitted to use agricultural soils for 20 years in case of cultivation of annual crops. Available $P_2O_5$ content was lower than 26 mg/kg, except for sample No. 1 which showed a quite high value (99.3 mg/kg). The high available $P_2O_5$ content of sample No.1 can be ascribed to the fertilizer application, since farmers have applied a lot of P fertilizer to vegetable fields in Taytuu area. According to the Truog method, the critical level of available $P_2O_5$ is 100 mg/kg (Committee of Soil Standard Methods for Analyses and Measurements, 1986). All soils were equal to or lower than this value, suggesting the requirement of P–fertilizer application except for Taytuu vegetable field.

CEC of the soil samples was in a range between 18 and 27 cmol(+)/kg. Sample No. 6 (rice field near General paint factory in Thanhliet commune of Thanhtri district) showed the highest CEC, probably controlled by the highest clay percentage (Table 3). Exchangeable cations were 6.1 to 11.8 cmol(+)/kg for Ca, 1.2 to 3.7 cmol(+)/kg for Mg, 0.1 to 0.3 cmol(+)/kg for K and 0.2 to 0.6 cmol(+)/kg for Na.

River–sediment sample of No.10 (the Kimnguu River in Tranphu commune of Thanhtri district) showed quite high organic matter, total N and exchangeable cations compared to the soil samples, while its available $P_2O_5$ was in the same range as them. Contents of organic matter and total N of sample No. 10 were 4.3 and 3.1 times higher, respectively, than the averages of organic matter and total N contents for the nine soil samples. It is easy to understand why farmers had continued to apply river mud as organic fertilizer or amendment.

**Table 3.** Particle–size distribution of the soil and river–sediment samples.

| Sample No. | Particle–size distribution (%) | | | | Soil texture (IUSS)* |
|---|---|---|---|---|---|
| | Clay <2μm | Silt 2–20μm | Fine sand 20–200μm | Coarse sand 200–1,000μm | |
| 1 | 17.8 | 40.6 | 40.9 | 0.7 | CL |
| 2 | 21.2 | 30.3 | 48.0 | 0.5 | CL |
| 3 | 46.4 | 42.8 | 9.0 | 1.8 | HC |
| 4 | 41.1 | 41.1 | 17.7 | 0.1 | LiC |
| 5 | 29.1 | 40.2 | 14.5 | 16.2 | LiC |
| 6 | 63.4 | 32.1 | 4.2 | 0.3 | HC |
| 7 | 34.9 | 41.0 | 23.9 | 0.2 | LiC |
| 8 | 29.5 | 49.6 | 20.6 | 0.3 | SiC |
| 9 | 32.2 | 39.0 | 28.1 | 0.7 | LiC |
| 10 | 30.8 | 39.5 | 29.4 | 0.3 | LiC |

* CL: clay loam; HC: heavy clay; LiC: light clay; SiC: silty clay.

### Particle–size distribution

Particle–size distribution of the soil and river–sediment samples are given in Table 3. In the present particle–size analysis, particles not less than 2.0 mm but less than 1.0 mm were used. However, this did not seem to have a serious influence on the results of the particle–size analysis, because of very low contents of particles over 0.2 mm in size, except for sample No. 5.

Samples No. 1 and No. 2 (vegetable field in Taytuu commune and rice field in Phudien commune of Tuliem district) are located near the Red River. They were dominated by fine sand (20–200 $\mu$m) and silt (2–20 $\mu$m), giving the clay loam texture according to the IUSS standard.

Samples No. 3 and No. 6 (rice fields in Xuanphuong commune of Tuliem district and Thanhliet commune of Thanhtri district) on the middle position were dominated by clay ($<2\,\mu$m) with low fine (20–200 $\mu$m) and coarse(200–1,000 $\mu$m) sands contents, giving the heavy clay texture. In contrast to them sample No. 8 (rice field in Lienninh commune of Thanhtri district) on the middle position was dominated by silt (2–20 $\mu$m) with medium clay ($<2\,\mu$m) and fine sand (20–200 $\mu$m) contents, giving the silty clay texture.

Samples No. 5 and No. 7 (rice fields in Mydinh and Tuhiep communes of Thanhtri district) on the low position and samples No. 4 and No. 9 (rice fields in Yenhoa commune of Tuliem district and Daiang commune of Thanhtri district) on the lowest position showed the medium content of clay ($<2\,\mu$m), ranging from 29.1 to 41.1%, and were all light clay in texture. The particle–size distribution of sample No. 10 (the Kimnguu River in Tranphu commune of Thanhtri district) was similar to that of samples No. 4, No. 5, No. 7 and No. 9 of the low and lowest positions, with the light clay texture.

### Clay mineralogical composition

XRD patterns of samples No. 2, No. 4, No. 6 and No. 10 are reproduced in Fig. 2. Due to the similarity among the samples, those of the selected ones are shown. Mica was identified by the peaks at 10.0, 5.0 and 3.3 Å. The second–order peak of mica at 5.0 Å is indicative of the dioctahedral subgroup (muscovite). Trace of smectite was noticed by the small shoulder around 18.0 Å. Vermiculite was detected by the decrease in the intensity of the 14.2 Å peak and the simultaneous increase in the intensity of the 10.0 Å peak in the K–saturated and air–dried specimen. Chlorite was detected by the remaining of the 14.2 Å peak after heating at 550 °C of the K–saturated specimen. The peaks at 7.1, 4.73 and 3.54 Å also belong to chlorite. Kaolinite was identified by the 7.1 and 3.57 Å peaks which disappeared by heating at 550 °C. Presence of vermiculite–chlorite intergrade was not indicated, because the 14.2 Å peak of the K–saturated specimen hardly changed by heating. Geothite was noticed by the peak at 4.18 Å which disappeared by heating at 300 °C, and quartz and feldspars by the peaks at 4.25 Å and at 3.2 Å, respectively. The most strong peak due to quartz appears at 3.34 Å but it overlaps with the 3.32 Å peak of mica.

Approximate mineral contents in the clay fraction of the soil and river-sediment samples were estimated based on the relative peak intensities of the XRD patterns of parallel powder mount. The intensity–weight coefficient (*Kp,q*) defined as follows, was applied to the estimation of a mineral content (weight proportion) from the peak intensity:

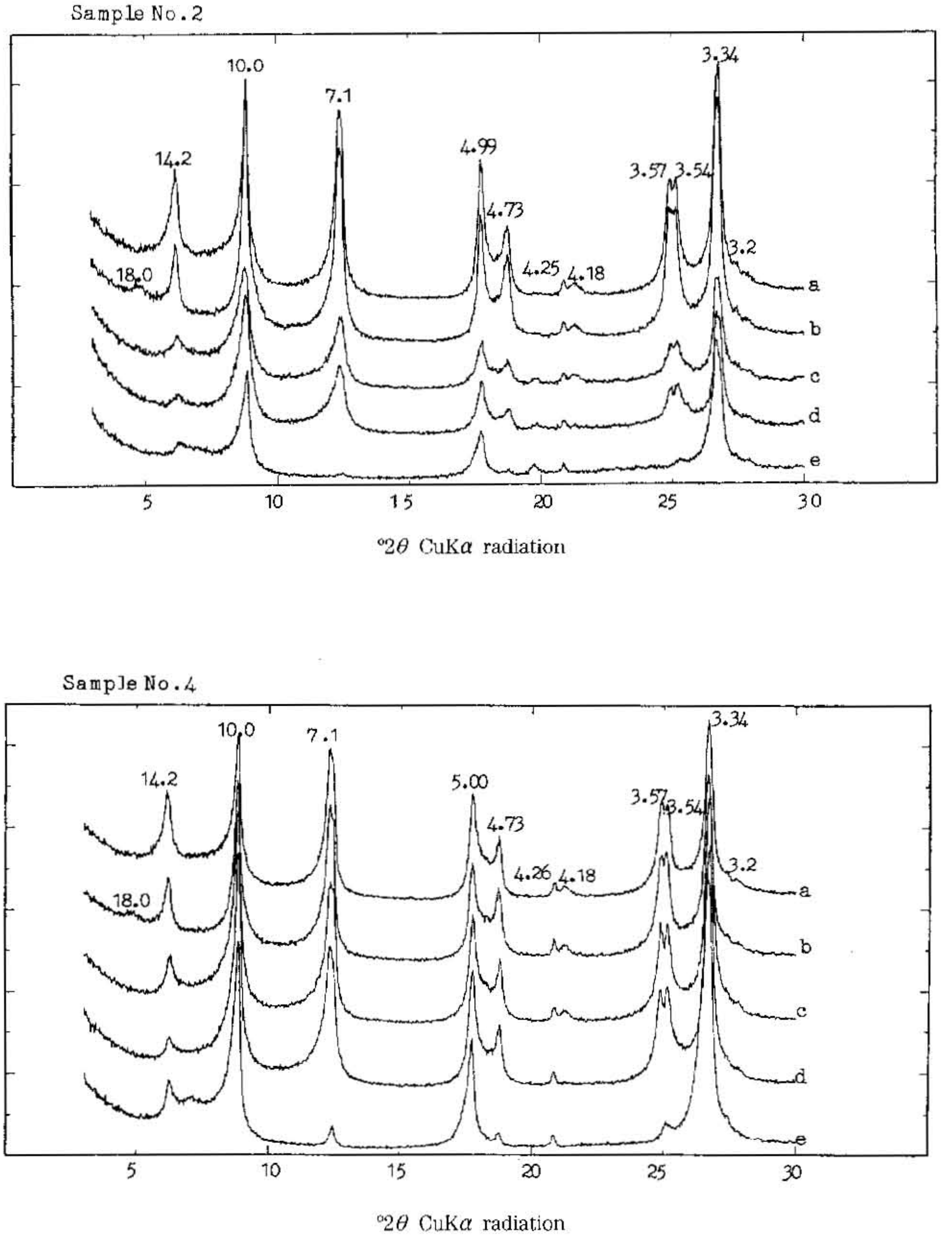
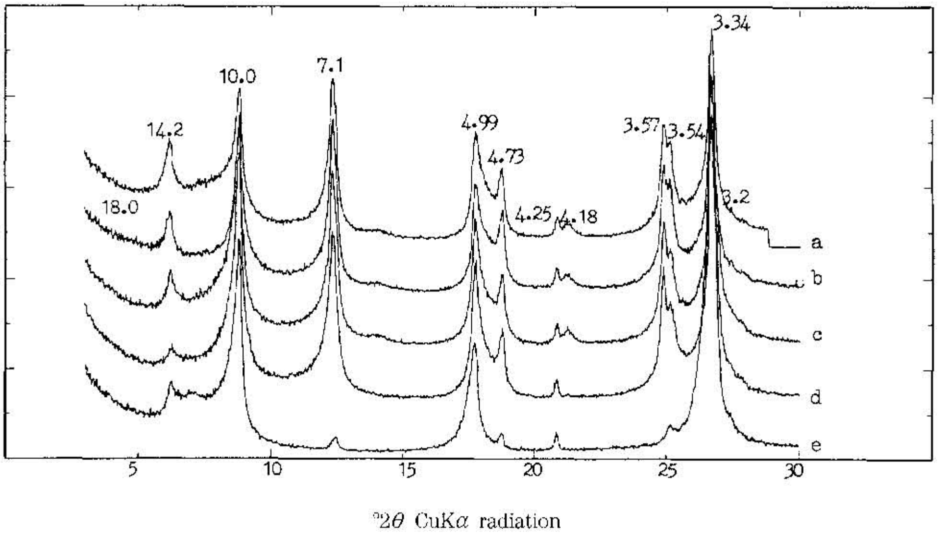
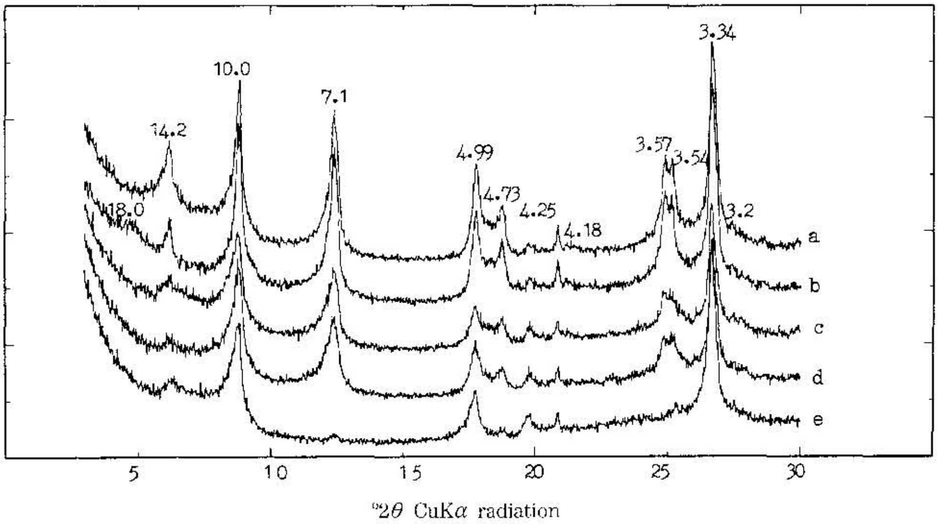


**Fig. 2.** XRD patterns of the selected soil and river–sediment samples. Treatments: a, Mg–saturation and air–drying; b, Mg–saturation and glycerol–solvation; c, K–saturation and air–drying; d, K–saturation and heating at 300 °C; e, K–saturation and heating at 550 °C. Spacings are in Å.

Sample No.6



Sample No.10



$$Ip/Iq=Kp,q\ (wp/wq)$$

where $Ip$ and $Iq$ are the XRD peak intensities of the $p$ and $q$ components, respectively, and $wp$ and $wq$ are the weight proportions of the $p$ and $q$ components, respectively. Values for the coefficients $Kp,q$ employed in the present study are given in Table 4. Since mica was identified in all the samples, all the other minerals were paired with this mineral and the intensity ratios were calculated. Assuming that the sum of weight proportions of all minerals in a mixture is 1.0, a mineral content (%) was calculated.

Reflections of the Mg–saturated and glycerol–solvated specimen were used for the calculation of peak intensities. The 10.0 Å peak was used for calculating the intensity of mica. The intensity of the 7.1 Å peak was allocated between chlorite and kaolinite according to the intensity ratio of the 3.54 Å (chlorite) and 3.57 Å (kaolinite) peaks. Since vermiculite was identified by the decrease in the intensity of the 14.2Å peak and the corresponding increase of the 10.0 Å peak by K–saturation and air–drying, vermiculite was calculated by subtracting the intensity of the 14.2Å peak of the K–saturated and air–dried specimen from that of the Mg–saturated and glycerol–solvated specimen with normalization using the intensity of the 7.1 Å peak. For geothite, quartz and feldspars the peaks at 4.18, 4.25 and 3.2 Å, respectively, in the Mg–saturated and glycerol–solvated specimen were used for the calculation of the peak intensities.

**Table 4.** Values for the coefficients $Kp,q$ employed for the estimation of mineral contents in the clay fraction (<2 μm)(parallel powder mount).

| $p,q$ | $Kp,q$ | $p,q$ | $Kp,q$ |
|---|---|---|---|
| Vt, Mc | 1.5 | Gt, Mc | 2 |
| Ch, Mc | 2 | Qr, Mc | 1/3 |
| Kt, Mc | 2 | Fd, Mc | 4 |

Abbreviations: Mc, mica; Vt, vermiculite; Ch, chlorite; Kt, kaolinite; Gt, goethite; Qr, quartz; Fd, feldspars.

**Table 5.** Approximate mineral contents (%) in the clay fraction (<2 μm) of the soil and river–sediment samples.

| Sample No. | Minerals[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mc | St | Vt | Ch | Kt | Gt | Qr | Fd |
| 2 | 53 | +[2] | 6 | 15 | 14 | 2 | 8 | 2 |
| 3 | 40 | + | 5 | 16 | 17 | 2 | 17 | 3 |
| 4 | 46 | + | 4 | 17 | 17 | 3 | 11 | 2 |
| 6 | 44 | + | 3 | 13 | 18 | 3 | 16 | 3 |
| 8 | 47 | + | 7 | 19 | 13 | 2 | 10 | 2 |
| 10 | 41 | + | 6 | 12 | 13 | 3 | 23 | 2 |

[1] Abbreviations: Mc, mica; St, smectite; Vt, vermiculite; Ch, chlorite; Kt, kaolinite; Gt, goethite; Qr, quartz; Fd, feldspars.

[2] Detected but not calculated due to insignificant quantities.

Approximate mineral contents thus calculated are given in Table 5 for samples No. 2 through No. 4, No. 6, No. 8 and No. 10. Mica was the most abundant and predominant mineral, with a range of 40 to 53%. Smectite was noticed in the XRD charts but could not be calculated due to its insignificant quantities. The vermiculite content was low (3–7%). Chlorite and kaolinite were included in considerable amounts with a range of 12 to 19% and 13 to 18%, respectively. Quartz (8–23%) was also present in considerable amounts, but feldspars (2–3%) and geothite (2–3%) were in small amounts. The mineralogical composition of the present study was qualitatively similar to the composition reported by Dao (1986) to a soil of the Red River delta.

## CONCLUSIONS

Chemical properties of agricultural soils in Tuliem and Thanhtri districts are in a narrow range, irrespective of the relatively large variation in the particle–size distribution. It is partly controlled by the dominance of mica accompanied by chlorite and kaolinite with being devoid of smectite in the clay mineralogical composition. Based on the soil properties, soil productivity or fertility of agricultural soils in Tuliem and Thanhtri districts was evaluated to be sufficient in general. Impact of intensive farming might be alleviated by increased application of organic residues and of chemical fertilizers to improve fertility status of soils.

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