

**CHARACTERIZATION OF CLAY MINERALOGICAL COMPOSITION  
AND CONSISTENCY OF HANOI AGRICULTURAL SOILS –  
COMPARISON WITH JAPANESE AGRICULTURAL SOILS**

**Nguyen Thi Lan Huong<sup>1</sup>**

**Abstract:** *Five agricultural soil samples from Hanoi, Vietnam were subject to clay mineralogical analysis and determination of the soil plasticity in addition to measurement of pH, organic matter content, cation exchange capacity (CEC) and exchangeable cations and particle size distribution. The pH, CEC and exchangeable cation of soil samples were similarly. In contrast, organic matter content and clay particle were comparable between the soils samples. The predominant clay minerals in soil samples were mica and kaolinite. In addition, to compare the plastic number, six Japanese agricultural soil samples were picked up. Resulting from lower of clay fraction content, organic matter content, CEC, Exchangeable cations, all of Hanoi agricultural soils samples have smaller liquid limit, plastic limit, plastic index and activity than those of Japanese agricultural soils.*

**Keywords:** Clay mineralogical, plastic number, agricultural soil.

### **1. INTRODUCTION**

It has been well-known that clay mineral plays an important role in determining soil fundamental physical and chemical properties and soil potential fertility, even though, it represents the smallest mineral substance in the soils. Especially, it takes an active part in the adsorptive process and nutrient exchange (cations and anions) with soil solutions. Therefore, clay content and mineralogical composition of soils to increase their fertility or productivities should be paid attention.

Hanoi is the capital of Vietnam which is located in the deltaic plain of Red river in Northern Vietnam. Naturally, as a sedimentary process, the soil deposits in the City have been influenced by the Red River. The geological status of Hanoi City is described as being composed of Neogene system and Quaternary system (Yamadera and Suzuki, 2004). The Quaternary system covering the base rock consists of, from the top to bottom, formations of Thai Binh and Hai Hung as alluvial deposits, over formations of Vinh Phuc, Hanoi and Le

She as diluvial deposits (Yamadera and Suzuki, 2004). Thanh Tri district is situated in the southern part which is lowest areas in Hanoi city. Due to human activities, Thanh Tri is the most polluted areas in Hanoi city, especially for agricultural soils.

Until now, only few studies have been done on the clay mineralogy of soils in Vietnam including alluvial soils. Recently, Ho et al. (1998) and Nguyen et al. (2006) clarified the clay mineralogical composition of the Red River delta alluvial soils, but their works were conducted only clay mineralogical composition, not about the effects of clay mineralogical composition on other physical properties such as soil plastic.

Based on the above review, the purposes of the present study: (1) to examine the clay mineralogical composition of agricultural soils in Thanh Tri - Hanoi; (2) to determine the soil plasticity such as: liquid limit, plastic limit, plastic index and activities of soils and the relationship between them and clay mineralogical; (3) to compare the plasticity of these soils with that of some Japanese soils.

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## 2. MATERIAL AND METHODS

### Material

Five soil samples were taken at two different locations: agricultural field (SS 3, SS 5 and SS 7) and paddy field (SS 15 and SS 18) at Tam Hiep, Thanh Tri Hanoi, Vietnam. The soil is neutral alluvial soils by Vietnam soil classification and Eutric Fluvisols by FAO/UNESCO (VSSS, 2000). All samples were taken in December 3 to 6, 2016, brought to Japan after air-drying, and then ground, passed through a 2-mm sieve, and preserved in plastic bottles.

The data of chemical and physical properties of six Japanese agricultural soils (Ni 4-1; Sa 17-4; Sa 24-2; Ni 5-3; Mi 52-3 and Ot 634-1) was pick up. Those Japanese agricultural soils are classified in Intrazonal soil types. These types are found in the area, most of which is of alluvial formation adapted for paddy field with high content of aluminum, and the poor base status.

### Methods

#### *Procedures for determination chemical properties*

The pH was measured using soil suspension with soil/water ratio of 1/25. Organic carbon content was determined by the Tyurin method and multiplied by the coefficient of 1.724 to give the organic matter content (Committee of Soil standard methods for Analyses and Measurement, 1986). Cation exchange capacity (CEC) was measured by the method proposed by Muramoto et al. (1992).

#### *Particle-size analysis*

In the particle-size analysis, 10g of air-dry sample was treated with hot 7% H<sub>2</sub>O<sub>2</sub> to remove organic matter, dispersed by ultrasonic vibration (tank-type; 38 kHz, 250W), and deflocculated by adjusting the pH to 10 by addition of 1M NaOH. After sedimentation for a fixed period of time, the clay fraction (<2μm) was siphoned out. With repetition of sonification - sedimentation - siphoning with intermittent pH adjustment, the whole clay fraction was separated. The silt fraction (2-20μm) was separated by repeated sedimentation and siphoning. The fine sand (20-200μm) and coarse sand (200-1000μm) fractions

were separated by wet sieving. After oven-drying at 105°C, each fraction was weighed to calculate the particle size distribution of a soil.

#### *Clay mineral analysis*

Mineralogical composition for the <2μm clay fraction of soils, 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 50mg of clay were taken in 10mL centrifuge tubes. Washing by centrifugation and decantation was carried out twice with 8mL of an equal mixture of 1M NaCl and 1M NaCH<sub>3</sub>COO (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<sub>2</sub> and 1M KCl, respectively. The excess salt was removed by a washing 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 x 48mm) covering 2/3 of its area, air dried, and X rayed (parallel powder mount).

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 2h) specimens for the K-saturated clay. The XRD analysis was conducted using a Rigaku diffractometer with Ni-filtered Cuα radiation at 40kV and 20 mA and at a scanning speed of 2° 2θ min<sup>-1</sup> with a scanning step of 0.02° and a continuous scanning mode over a range of 3 to 30° 2θ.

#### *Semi-quantitative estimates of mineralogical composition*

Relative mineral contents in the clay fraction were semi quantitative estimated in the basis of the XRD peak intensities. In the present estimation, the peak height was used as the peak intensity by assuming the relative proportions of the minerals of a sample normalized to 100% and the same proportionality between the peak intensity and the content of each mineral (Nguyen and Egashira, 2005).

Reflection of the Mg-saturated and glycerol-solvated specimen were usually used to calculate

peak intensities of minerals. The content of mica and was calculated from the intensities of 1.00. To calculated content of chlorite the 1.42-.44 nm peak intensity of the K-saturated and 550°C -heated specimen was used after normalization by multiplying by the intensity ratio of 0.425 nm peaks of the Mg-saturated and glycerol-solvated specimen and of the K-saturated and 550°C-heated specimen.

This normalized intensity was then subtracted from the intensity of the 0.715 nm peak of the Mg-saturated and glycerol solvated specimen to calculate the kaolinite content. The intensity used to calculate the vermiculite content was obtained by subtracting the normalized intensity of the 1.42-1.44 nm peak of the K-saturated and air dried specimen from the 1.42-1.44 nm peak intensity of the Mg-saturated and glycerol-solvated specimen. The 0.425 peak intensity was used to calculate the quart content after multiplication by the coefficient 3, and sum of the intensities around 0.32 nm peak was used to estimate the feldspars content.

#### *Liquid limit (W<sub>l</sub>)*

Casagrande subsequently standardized the apparatus and the procedures to make the measurement more repeatable. 120 g of soil is placed into the metal cup portion of the device and a groove is made down its center with a standardized tool. The cup is repeatedly dropped 10mm onto a hard rubber base until the groove is closed for 13 mm (½ inch). The moisture content at which it takes 25 drops of the cup to cause the groove to close is defined as the liquid limit.

#### *Plastic limit (W<sub>p</sub>)*

Take a sample of about 20g from the prepared soil paste and place it on a glass mixing plate. Allow the soil to dry partially by spreading it out until it becomes plastic enough to be shaped into a ball. Mould the ball of soil between the fingers and roll it between the palms of the hands until the heat of the hands has dried the soil sufficiently for slight cracks to appear in the surface. Divide this sample into two sub-samples of about 10g each and carry out a separate determination on each portion,

divide each sub-sample into four more or less equal parts. Mould the soil in the fingers to equalize the distribution of moisture, and then form a thread of about 6mm diameter between the first finger and thumb of each hand. Roll the thread between the fingers, from the finger-tip to the second joint, of one hand and the surface of the glass rolling plate. Use enough pressure to reduce the diameter of the thread to about 3mm in five to ten complete forward and back, movements of the hand. Some heavy clay will require 10 to 15 movements when the soil is near the plastic limit because the soil hardens at this stage. It is important to maintain a uniform rolling pressure; do not reduce the pressure as the thread diameter approaches 3mm.

Pick the soil up, mould it between the fingers to dry it further, form it into a thread and roll it out again. Repeat until the thread shears both longitudinally and transversely when it has been rolled to about 3mm diameter, as gauged by a rod. Gather together the portions of crumbled soil thread, transfer then to a suitable container and replace the lid instantly. Repeat on the other three portions of soil, placing them all in the same container. Repeat on the duplicate sample. Calculate the moisture content of both samples tested. Calculate the average of the two moisture content values and express the value to the nearest whole number. This is the plastic limit.

### **3. RESULTS AND DISCUSSION**

#### **Properties of Agricultural Soil**

The chemical properties of agricultural soil in Hanoi were shown on Table 1. The pH ranged between 6.81 - 7.70, suggesting the natural condition and slightly alkali of soils. Organic matter content of soil samples was in the larger ranged between 0.12- 3.87%. The cation exchange capacity of agricultural soil was in a range of 8.6 to 11.7 cmol<sub>c</sub>/kg. Exchangeable cations were 5.7 to 8.2 cmol<sub>c</sub>/kg for Ca; 2.4 to 3.6 cmol<sub>c</sub>/kg for Mg; 0.3 to 0.5 cmol<sub>c</sub>/kg for K and 0.1 to 0.6cmol<sub>c</sub>/kg for Na. Table 1 shown that the total of exchangeable cation is much higher than the cation exchange capacity. It can be explained that the digestion process could not

fixed the dissolve Ca and dissolve Mg thus the exchangeable Ca and exchangeable Mg were highly increased, Comparing to Japanese agricultural

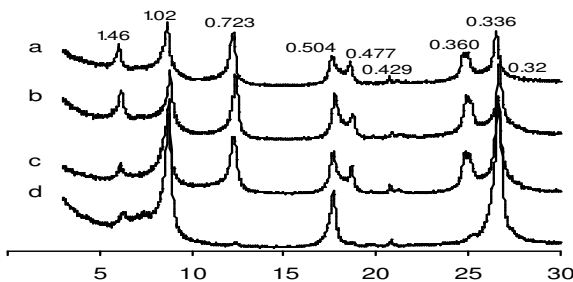
soil, organic matter, CEC and exchangeable cation of agricultural soil in Hanoi were much lower, only pH was higher.

**Table 1. Chemical properties of soil samples**

No	Depth (cm)	pH (H <sub>2</sub> O)	OM (%)	CEC ( meq/100g)	Exchangeable cation ( cmol <sub>c</sub> /kg)			
					Ca	Mg	K	Na
SS 3	40-60	8.2	1.1	10.3	8.2	3.4	0.4	0.1
SS 5	20-40	7.6	1.8	11.7	6.8	3.6	0.4	0.3
SS 7	0-20	7.7	2.7	9.9	6.0	2.4	0.3	0.1
SS 15	20-40	8.3	1.1	8.6	5.7	3.1	0.4	0.2
SS 18	0-20	8.2	3.9	8.7	7.4	3.6	0.5	0.6
Ni 4-1	0-17	5.9	3.0	28.8	17.6	6.6	0.6	0.4
Sa 17-4	50-100	6.7	0.9	35.3	28.1	7.3	0.5	0.7
Sa 24-2	13-50	6.6	4.1	22.9	13.9	3.8	0.5	0.4
Ni 5-3	35-48	5.0	2.7	17.9	8.7	3.4	0.2	0.6
Mi 52-3	35-55	6.5	1.2	21.1	12.1	6.8	0.2	0.7
Ot 634-1	0-11	6.0	3.0	22.0	14.8	4.2	0.2	0.6

**Table 2. Physical properties of soil samples**

No.	Particle size distribution (%)				Texture	Liquid limit	Plastic limit	Plastic index	Activity of clay
	Clay (<2 μm)	Silt (2-20 μm)	Fine sand (20-200μm)	Coarse sand (200-1000μm)					
SS 3	16.8	60.52	14.67	8.04	SiL	34.19	24.67	9.52	0.57
SS 5	29.7	63.27	4.23	2.89	SiCL	42.33	26.93	15.4	0.53
SS 7	14.7	36.16	46	3.17	L	33.38	22.92	10.46	0.71
SS 15	18	41	3.15	37.85	L	34.77	22.70	12.07	0.67
SS 18	25.7	51.23	3.44	19.67	SiL	43.81	26.70	17.11	0.67
Ni 4-1	38.4	33.9	23.9	3.9	LiC	69.0	31.0	38.0	0.99
Sa 17-4	52.8	42.5	4.3	-	HC	78.4	33.2	45.2	0.86
Sa 24-2	43.2	43.0	13.7	0.2	LiC	72.2	30.5	41.7	0.97
Ni 5-3	23.3	39.2		37.5	CL	52.3	31.3	21.0	0.90
Mi 52-3	32.1	25.8		42.1	LiC	58.0	26.6	31.4	0.98
Ot 634-1	22.0	51.0	21.3	5.8	SiCL	58.7	37.4	21.3	0.97



*Fig.1. The XRD patterns of the <2μm clay fraction of SS 18, representing agricultural soil in Hanoi. Spacing is in nm. Treatments: a, Mg-saturation and glycerol - solvation; b, Mg-saturation and air-drying; c, K-saturation and air-drying; d, K-saturation and heating at 500<sup>o</sup>C*

The clay, silt and fine and coarse sand of agricultural soil in Hanoi were in ranged between 14.7 to 29.7%; 36.16 to 63.27%; 2.15 to 46.0% and 2.89 to 37.85%, respectively, giving Loam and Silty Loam and Silty Clay Loam texture according to the IUSS standard (Table 2). These value were positioned at the middle of the ranges of the clay and silt content reported by Nguyen and Egashira (2005) for alluvial soils in the Red River delta region. Comparing to Japanese agricultural soil, clay fraction content was much smaller.

**Mineral identification**

The XRD patterns of the <2μm clay fraction

of a representative of Agricultural soils in Hanoi are illustrated in Fig.1. The presence of mica was indicated by the 1.02 nm peak along its higher-order reflections at 0.504 and 0.336 nm. Similarly, the presence of kaolinite was ascertained by the peaks at 0.723 and 0.360 nm which disappeared by heating at 550°C of the K-saturated specimen. Chlorite was identified by the peak at 1.46, 0.723, 0.477, and 0.360 nm. Vermiculite was identified by the decrease in the intensity of the 1.46 nm peak with the corresponding increase in the intensity of the 1.02 nm peak by K-saturation and air-drying. Quarts were detected by the peaks at 0.429 and 0.336 while feldspars were detected by the peaks around 0.322 nm.

#### Clay mineralogical characterization

The approximate relative mineral contents

in the <2 μm clay fraction were semi-quantitatively estimated based on the XRD peak intensities and are given in Table 3. Five samples of agricultural soil in Hanoi showed the relatively identical composition among them and were characterized by the predominance of mica (38 to 42% with average of 41%) and kaolinite (20 to 30 % with average of 26%). Other minerals detected were chlorite (12-14%), Vermiculite (6-7%). Minerals other than layer silicate minerals included quartz (6-10%) and Feldspars (4-6%). The mineral composition obtained was qualitatively similar to the composition reported by Ho et al (1998) for agricultural soil in Hanoi, Vietnam. Contrasting with Vietnamese soil, clay mineral component of Japanese soil was mainly dominant by Montmorillonite (Table 4).

**Table 3. Approximate relative mineral contents (%) in the <2μm clay fraction of agricultural soils**

No.	Mc	Ch	Vr	Kt	Qr	Fd
SS3	42	14	6	26	8	4
SS5	40	12	6	29	8	5
SS7	45	14	7	20	9	5
SS15	40	13	6	30	6	5
SS18	38	14	7	25	10	6

\*. Abbreviation: Mc: Mica; Ch: Chlorite; Vr: vermiculite; Kt: Kaolinite; Qr: Quartz; Fd: feldspars;

#### Soil plasticity

##### *Liquid limit, plastic limit and plastic index*

The plasticity index (Ip) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The Ip is difference between the liquid limit and the plastic limit (Ip = WI-Wp). Soils with a high Ip tend to be clay, those with a lower Ip tend to be silt, and those with an Ip of 0 tend to have little or no silt or clay.

Table 2 showed the plastic number of both agricultural soil in Hanoi and Japanese agricultural soil. The liquid limits, plastic limit and plastic index for Agricultural soil in Hanoi,

with the range of 33.38 to 43.81%; 22.70 to 26.93%; and 52-17.12%, were much lower than that for Japanese Agricultural soils (with range of 52.3-78.4%; 26.6 -37.4%; and 21-45.2%). It can be explained that first of all due to clay content of these soils samples (14.7-29.7%) was lower than clay contents of Japanese agricultural soils (22.0-52.8%). Baver et al (1972) showed that an increase in the percentage of clay causes plastic limits to be higher on the moisture scale and increase the plastic number. In addition, the exchangeable cations have considerable influence upon soil plasticity (Baver et al, 1972). Higher in CEC and exchangeable cation (such as Ca, Mg, K and Na) of Japanese agricultural soil

compare to agricultural soil in Hanoi was another reason for higher in plastic number of Japanese agricultural soil. Furthermore, due to the organic matter content of Japanese agricultural soil was higher than that for agricultural soil in Hanoi. Baver et al (1972) also instated that the organic matter have strong affected on soil plastic because of high absorptive capacity for

water. Finally, because of depending strongly on the nature of clay minerals of plastic number, all agricultural soil in Hanoi with predominant of kaolinite and mica; and Japanese agricultural soil with mainly predominant by Montmorillonite; can be explained for lower in plastic number of agricultural soil in Hanoi compare to Japanese agricultural soil (Table 4).

**Table 4. Clay mineral composition of paddy soils**

Group soils	Dominant	Clay minerals		
		Subdominant	Accessory	
Vietnamese agricultural soils	SS3,SS5, SS7, SS15, SS18	Mc	Kt	Ch. Vt. Qr. Gt. Fd
Japanese Paddy soils	Ni 4-1	Mt	Kt. Ilt	
	Sa 17-4	Mt	Kt. Ilt	
	Sa 24-2	Mt	Kt. Ilt. Vr	
	Ni 5-3		Mt. Kt. Ilt. Ch	
	Mi 52-3		Mt. Kt. Vr.	
	Ot 634-1		Mt. Ch. Vt. Kt. Mc	

\*. Abbreviation: Mt: Montmorillonite, Mc: Mica; Ch: Chlorite; Vr: vermiculite; Kt: Kaolinite; Gt: Goethite; Qr: Quartz; Fd: feldspars; Ilt: Illite

**Activities**

Both the type and amount of clay in a soil influence the liquid and plastic limits of the soils. Different types of clays have different specific surface areas which controls how much wetting is required to move a soil from one phase to another such as across the liquid limit or the plastic limit.

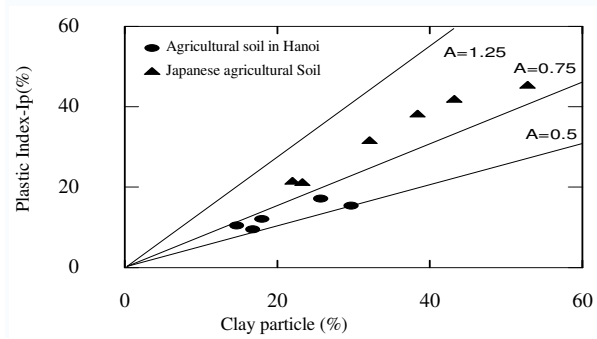
To separate them, the ratio of the plasticity index to the clay fraction percentage, termed the activity (A), can be used (Skempton, 1953). From the activity one can predict the dominant clay type present in a soil sample.

High activity signifies large volume change when wetted and large shrinkage when dried. Soil with high activity is very reactive chemically. Normally, activity of clay is between 0.75 and 1.25. It is assumed that the plasticity index is approximately equal to the clay fraction ( $A = 1$ ). When A is less than 0.75, it is considered inactive. When it is greater than 1.25, it is considered active, from 0.75 to 1.25 is normal.

The activities values of agricultural soil in

Hanoi ranging from 0.53-0.71 was also smaller than that for Japanese Agricultural soil (ranging from 0.86-0.99) (Table 2).

Figure 2 also shows the plastic index of soil samples plotted against the clay fraction percentage. Agricultural soil in Hanoi, with mainly dominated by mica and kaolinite, the activity was less than 0.75, are classified as inactive. In contract, Japanese agricultural soil, with mainly predominant by montmorillonite, the activity ranged from 0.75 to 1, is classified as normal.



*Fig.2. Relationship between Plastic index, clay particles and Activity (A)*

Baver et al, 1972 has been shown that the type of clay mineral has a tremendous influence upon the adsorption of water by the colloidal system. The adsorption of water in the vapor form increases according to the clay mineral series montmorillonite > mica > kaolinite. The activity is related to the mineralogy of clay (Skempton, 1953). Table 5 shows the activity values for some clay minerals, montmorillonite has highest activity values (Ca-montmorillonite 1.5; and for Na-montmorillonite 7.2), followed by illite (0.90); kaolinite (ranged from 0.33 to 0.46); and Mica (0.23).

**Table 5. Values of Activity for some clay minerals**

<i>Mineral</i>	<i>Activity</i>
Quartz	0
Calcite	0.18
Mica	0.23
Kaolinite	0.33
	0.46
Illite	0.9
Ca-montmorillonite	1.5
Na-montmorillonite	7.2

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## 4. CONCLUSION

Five agricultural soil samples in Hanoi, Vietnam were subject to clay mineralogical analysis and determine the soil plasticity in addition to measure of pH, organic matter content, cation exchange capacity (CEC) and exchangeable cations and particle size distribution.

The pH, CEC and exchangeable cation of soil samples were similarly. In contract, organic matter and clay particle was comparable between the soils samples. The predominant clay minerals in soil samples were mica and kaolinite.

In addition, to compare the plastic number, six Japanese agricultural soil samples were picked up. Resulting from lower of clay fraction content, organic mater content, CEC, Exchangeable cation, all of Hanoi agricultural soils have smaller liquid limit, plastic limit, plastic index and activity than those of Japanese agricultural soils.

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**Tóm tắt:**

**ĐẶC TRƯNG THÀNH PHẦN KHOÁNG SÉT VÀ ĐỘ CHẶT  
CỦA ĐẤT NÔNG NGHIỆP TẠI HÀ NỘI -  
SO SÁNH VỚI ĐẤT NÔNG NGHIỆP TẠI NHẬT BẢN**

*Để xác định thành phần khoáng sét và độ chặt của đất nông nghiệp tại Hà Nội, Việt Nam, tác giả đã tiến hành lấy 5 mẫu đất nông nghiệp (12/2016) và phân tích thành phần khoáng sét, xác định độ dẻo bên cạnh việc phân tích pH, chất hữu cơ, hàm lượng cation trao đổi và thành phần cơ giới. Kết quả nghiên cứu cho thấy giá trị pH, CEC và các catio trao đổi tương đương trong các mẫu đất. Ngược lại, hàm lượng chất hữu cơ, thành phần sét khá khác biệt. Kết quả nghiên cứu cho thấy thành phần khoáng sét chính trong các mẫu đất nông nghiệp tại Hà Nội là Mica và Kaolinite. Khi so sánh các kết quả thu được này với các kết quả tương tự của các mẫu đất nông nghiệp tại Nhật Bản (6 mẫu đất), nghiên cứu chỉ ra rằng đất nông nghiệp tại Hà Nội có hàm lượng sét, chất hữu cơ, CEC, cation trao đổi, chỉ số dẻo, giới hạn dẻo trên và giới hạn dẻo dưới nhỏ hơn của đất nông nghiệp tại Nhật Bản.*

**Từ khóa:** Khoáng sét, chỉ số dẻo, đất nông nghiệp.

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