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The study of the soil texture parameter in the upland of Khon Kaen province; Thailand

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Abstract

This study investigated the soil texture parameter in the upland of Khon Kaen Province; Thailand. The testing of primary tillage was conducted using general farming equipment consisting of three types of machinery as a 3-disk plow, 7-disk harrow, and a trash eliminated disk plow. The field test size was 20x150 m, and testing was replicated three times with each piece of equipment. Soil properties and primary tillage data were measured using the draft force of the equipment, the width and depth of the plow, average speed, and work efficiency. The soil texture parameters were evaluated using an empirical model developed by the American Society of Agricultural and Biological Engineers [1]. The results showed that the soil texture was loamy sand. It was in dual classification of coarse texture and medium texture soil. The soil texture parameter (Fi) were calculated and founded between 1.4-1.5. It was greater than the soil texture parameter guidelines of the American Society of Agricultural and Biological Engineers which guided 0.45-0.70. It seemed to be a specific case of soil texture parameter (Fi). Thus, the study would be carried on in the future to clarify this phenomenon.

Keywords: Draft force, Loamy sand, Soil texture parameter

1. Introduction

Sugarcane is an important economic crop in Thailand which has extensive areas of sugarcane farming. The farmers use traditional methods for soil preparation employing both human and animal labor, however, this is time consuming and unproductive [2]. Therefore, the farmers choose the appropriate size of tractor for soil preparation to increase work efficiency.

Soil preparation is an important step in the cultivation of field crops, especially for sugarcane as it affects plant growth and also controls and eliminates weeds. The weeds are plowed back into the soil to increase the quantity of organic matter [3]. Primary tillage of soil for sugarcane uses maximum draft force to plow in the sugarcane stubble left over from the previous crop. The draft force of primary tillage was tested in this study, and draft force sensors were designed and calibrated [4]. A test field was selected to study the physical properties of the soil, the type of soil, soil hardness, and soil moisture to calculate the soil texture parameters.

2. Materials and methods

2.1 Materials

The test area selected was a sugarcane field after harvesting. Typically, soil preparation was done after harvesting, which was dry season (Jan-April), to keep the early planting season. The test was conducted during this time by using a Ford tractor, brand model 7840 (Figure 1). The farming equipments [5-6] tested were a 3-disk plow, a 7-disk harrow, and a trash eliminated disk plow (Figure 2). The field test size was 20 x 150 m, and each test was performed with three replications.

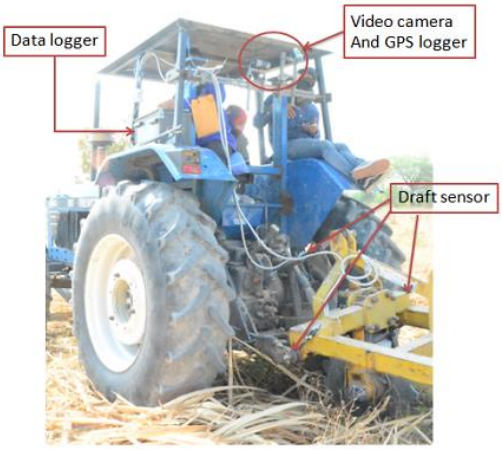

Figure 1 The test was conducted using a Ford tractor, brand model 7840

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Figure 2 Testing implements: 3 Disks Plow (a), 7 Disk Harrow (b) and Trash Eliminate Disks Plow (c)

2.2 Methods

2.2.1 Soil property measurements

Soil properties were measured before and after the test. The research area was divided into head space field, middle space field, and bottom space field. Soil samples were taken at three random positions in each area. Each sample was used to measure soil hardness [7-8]. This was repeated for undisturbed soil samples by core sampling and analysis of soil properties. The details were as follows:

- Soil hardness : Soil hardness tester brand Yamagata
- Soil texture : United States Department of Agriculture standard (USDA)
- Field capacity (FC), Permanent wilting point (PWP) : Wide range pF meter & Pressure plate method
- Bulk density (BD) : Core method
- Permeability (Ksat) : Permeameter (Falling head permeameter model DIK-4050)

2.2.2 Primary tillage measurement

Draft force measurement methods

The draft force data were measured with a draft sensor using single way strain gauges type UFLA-2-350-11-1L, gauge factor 2.13±1%, and gauge resistance 350.4±1.5Ω installed on lower link pins, and a draft sensor using two way strain gauges type FCA-2-11-1L, gauge factor 2.10±1%, and gauge resistance 120.4±1.5Ω installed on the top link by a full bridge circuit (Figure 3). The measured signals were translated to the force data and recorded in the data logger installed on the tractor. (KEYENCE brand NR-ST04).
Before use, the draft sensors were calibrated [9] by a universal testing machine and equations were created to indicate the relation between the measured signals with the force (Eq. 1-5) [10-11]. All three equations were calculated as the vertical force (F_V), and horizontal force (F_H) position and direction (Figure 4).

Lower link pin: Horizontal force	F1 = 16.781*X1 - 285.13	(1)
Lower link pin: Vertical force	F2 = 12.129*X2 + 12.9	(2)
Top link pin: Top link force	F3 = 33.085*X3 + 120.65	(3)
Total Horizontal force	FH = F1 +F3 cosθ	(4)
Total Vertical force	FV = F2 +F3 sinθ	(5)

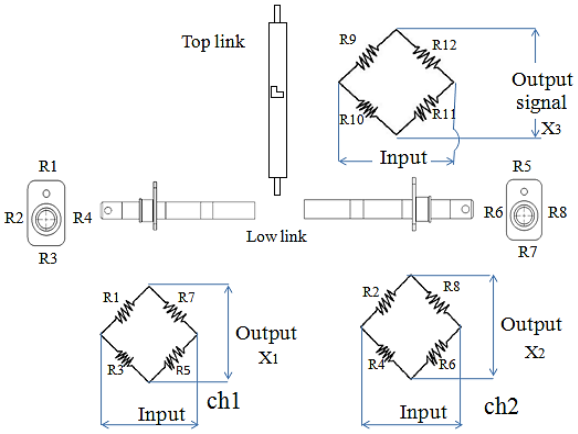

Figure 3 Sensors wiring circuit (Wheat stone bridge, Full bridge)

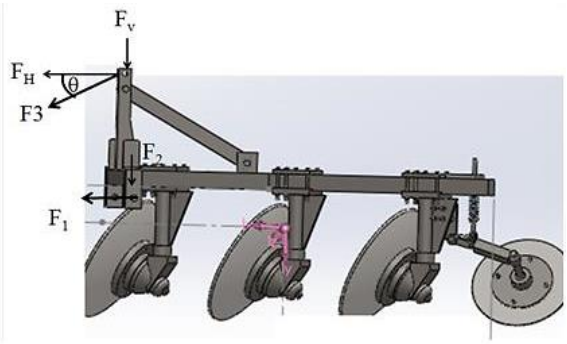

Figure 4 the vertical force (F_V), and horizontal force (F_H) position and direction

Forward speed measuring methods for the tractor

The forward speed was measured with the tractor working at a steady pace [12] Travelling time was measured over a 50 m length in the middle section of each row. The forward speed was calculated by Eq. (6) as follows:

$$V = \frac{L}{t} \quad (6)$$

V = Forward speed
L = Travelling disk plow
t = Traveling time

Table 1 Soil properties

Soil properties	3 Disks plow	7 Disk harrow	Trash eliminate disks plow
Soil hardness (kgf/sq.cm)	3.70	1.83	6.37
Soil texture	Loamy Sand	Loamy Sand	Loamy Sand
Sand (%)	75.54	87.27	78.40
Silt (%)	20.08	8.46	17.10
Clay (%)	4.38	4.27	4.50
FC (%vol.)	14.85	13.89	12.49
PWP (%vol.)	5.76	4.21	4.52
BD before plowing (g/cu.cm)	1.57	1.64	1.62
BD after plowing) g/cu.cm)	1.44	1.32	1.47
Ksat. (cm/sec)	0.00045	0.00049	0.00038

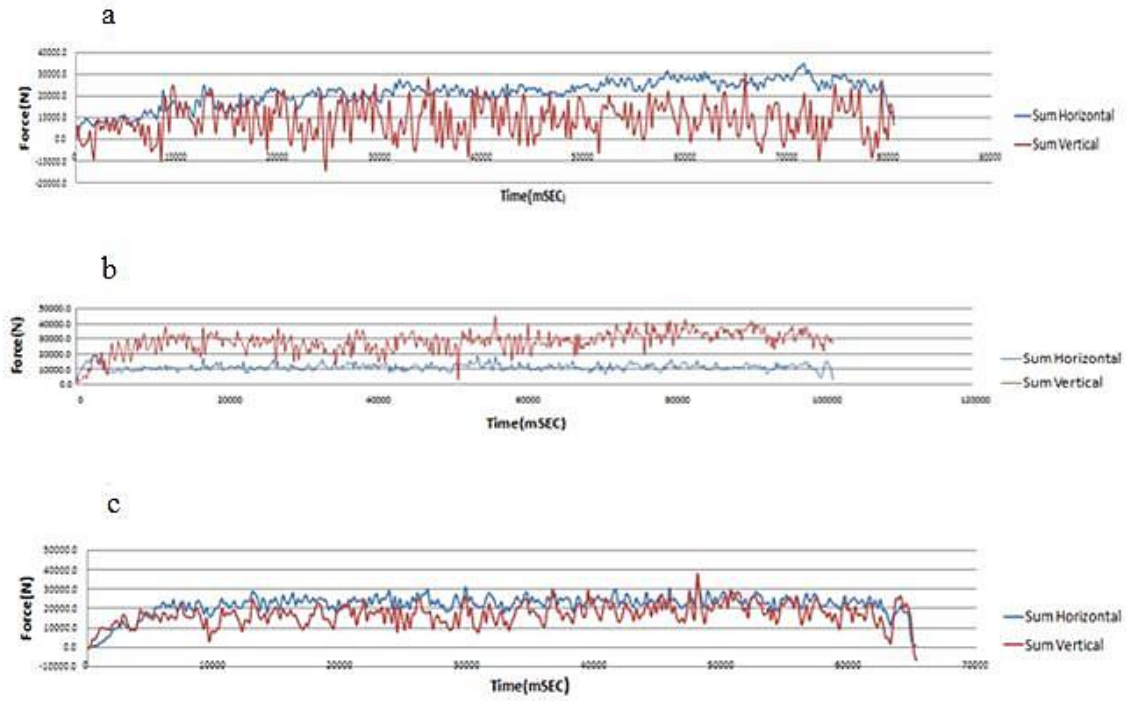

Figure 5 Vertical and horizontal forces recorded during the field tests. 3 Disks Plow (a), 7 Disk Harrow (b) and Trash Eliminate Disks Plow (c)

Measuring the width and depth of the plow furrow

After plowing, each row was randomly measured for the width of the plow groove. The depth of the plow groove was measured from the soil surface to the bottom of the plow groove using a clinometers and measuring tape.

2.2.3 Parameters of soil texture

The parameters of soil texture (F_i) were calculated using the empirical model developed by the American Society of Agricultural and Biological Engineer) [13] (Eq.7).

$$F_i = \frac{D_f}{[C_1 + (C_2 \times v) + (C_3 \times v^2)] \times w \times T_d} \quad (7)$$

Fi = Soil parameter
Df = Draft force (N)
C1, C2, C3 = Machine parameter
V = Velocity, (km/hr)
W = Width of the plow furrow, (m)
Td = Depth of the plow furrow, (cm)

3. Results

3.1 Soil properties

The soil properties in the test area are summarized in Table 1 as sandy loam with an average strength of 3.97 kg/sq.cm.

3.2 Primary tillage data

The action force was calculated at a three points hitch as vertical force (F_V) and horizontal force (F_H) [14] (Figure 5). The draft force range was 16,271-24,038 N. (Table 2).

$$R(\%) = \frac{Draft\ force\ (N)}{soil\ resistance\ (N)}\ x\ 100 \quad (8)$$

The traveling speed range was 1.52-2.23 m/s, and the working width and depth range were 0.96-1.88 m/strip and 17.0-26.7 cm, respectively [15].The soil resistance was determined by calculating the effective plowing width x the depth of plowing x soil hardness. The effective section area percentage (R, %) was then determined by calculating the ratio of draft force to soil resistance as (Eq.8).

Table 2 Performance

Item	3 Disks plow	7 Disk harrow	Trash eliminate disks plow
Draft force (N)	23,073	16,271	24,038
Soil resistance (N)	59,216	57,356	163,605
R (%)	38.96	28.37	14.69
Traveling speed (m/sec)			
Length of plantation < 100 m	2.05	2.09	1.52
Length of plantation 100-300 m	2.15	2.19	1.60
Length of plantation > 300 m	2.19	2.23	1.62
Working width (m/strip)	0.96	1.88	0.97
Working depth (cm)	17.5	17.0	26.7

Table 3 The soil texture parameter (F_i) calculation results

Implements	W (m)	Td (cm)	V (km/hr)	C1	C2	C3	Df (N)	Fi
3 Disks plow	0.96	17.5	7.88	652	0	5.1	23,073	1.4
7 Disk harrow	1.81	17.0	8.03	364	18.8	0	16,271	1.5
Trash eliminate disks plow	0.78	26.7	5.83	652	0	5.1	24,038	1.4
Average	1.18	20.4	7.25	556	6.3	3.4	21,127	1.43

Note: refer to ASABE 497.4 standard, Fi = 0.58 when operating in medium-coarse textured soil.

3.3 The soil texture parameter (Fi)

From the test results of primary tillage, the soil texture parameter (F_i) was calculated from an empirical model developed by the American Society of Agricultural and Biological Engineers) ASABE Standard D497.5, 2006 (Eq. 5) (Table 3).

4. Discussion

Base on USDA standard, the soil texture (Table 1) was considered of loamy sand. It was in dual classification of coarse texture and medium texture soil. Thus, the soil texture parameter (Fi) should be between 0.45-0.70, or the average value (0.58) could be assumed.

This test was conducted in dry season (Jan-April), when soil moisture content was low. Thus, the soil hardness (Table 1: 1.83-6.37 kgf/sq.cm) and the draft force (Table 2: 16,271-24,038 N) appeared to be high value. A study of 'effect of soil moisture content on the bearing capacity' for this soil type was report by [16] It shown that, when the moisture content decreased from 15% to 9%wb, bearing capacity was increased 1.73 times. It was concluded that the strength of soil greatly varied by moisture content and classified as a collapsible soil. Consequently, this test results found the high draft, and affected a soil texture parameter (Fi) ranged from 1.4 to 1.5 (Table 3). It seemed to be a specific case of soil texture parameter (Fi). Thus, the study would be carried on in the future to clarify this phenomenon.

5. Conclusions

The soil texture of a sugarcane field in the upland of Khon Kaen Province, was considered of loamy sand. It was in dual classification of coarse texture and medium texture soil. Three types of equipment were conducted during the typically season, dry season. The soil texture parameter (Fi) were calculated and founded between 1.4-1.5. It was greater than the soil texture parameter guidelines of the American Society of Agricultural and Biological Engineers which guided 0.45-0.70. It seemed to be a specific case of soil texture parameter (Fi). Thus, the study would be carried on in the future to clarify this phenomenon.

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