JARQ 26, 165–170 (1992)

Water Dynamics in Upland Soils in Northeast Thailand

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Abstract
Characteristics of water retentivity and seasonal changes in available water were investigated in three upland soils in Northeast Thailand in order to obtain information for field crop cultivation under rainfed conditions. In general, the water retentivity at pF 1.8 to 2.7 was the highest at the soil surface within the profile, due to the contribution of soil organic matter. Based on the data on the changes of available water (pF 1.8-4.2) during a period of about two years, the amount of available water was found to be sufficient for upland farming in the rainy season. However, the content started to decrease from the beginning of the dry season. The available water content gradually decreased from the soil surface to the zone at a depth of less than 100 cm in the dry season, while it was not significantly affected in the zone at a depth of more than 100 cm. Therefore even in the dry season, a relatively large amount of available water was present in the deep layers, especially in the Quartzipsamment soil. Accordingly, cropping season, kinds of crops and soils be must judiciously selected in future farming plans.

Discipline: Soils, fertilizers and plant nutrition
Additional key words: field crop cultivation, Quartzipsamment, rainfed farming, seasonal changes, water retentivity

Introduction

It is generally considered that low soil fertility associated with the sandy nature of soils along with the presence of a long dry season and frequent dry spells due to erratic rainfall in the rainy season limit agricultural productivity in Northeast Thailand. According to the Köppen's climatic classification, Northeast Thailand belongs to the Tropical Savanna Climate, type "Aw", with an alternation of dry and rainy seasons, from November to April and May to October, respectively. Khon Kaen city which is located in the central part of Northeast Thailand is characterized by a mean annual rainfall of 1,197 mm and a mean annual temperature of 27.7°C[5]. The land surface of the region is predominantly characterized by a gently undulating landscape. In the alluvial plains and the lower part of the plateau which are annually flooded, rice is mostly cultivated. On the other hand, in the higher part of the plateau with an "ustic" moisture regime, i.e. with insufficient moisture for crop production in the dry season[4], field crops such as cassava and kenaf which can tolerate a low nutrient status and drought, are mainly cultivated without the use of fertilizer and irrigation.

Although some relevant studies on the soil moisture conditions have been carried out[2,3,7], continuous data covering a long period of time and conditions within a 2 m depth from the soil surface have not been recorded. Therefore, in the present study, the characteristics of water retentivity and seasonal

This paper is prepared on the basis of the results obtained in the cooperative study which was implemented by Department of Land Development, Thailand, and Japan International Cooperation Agency, Japan.
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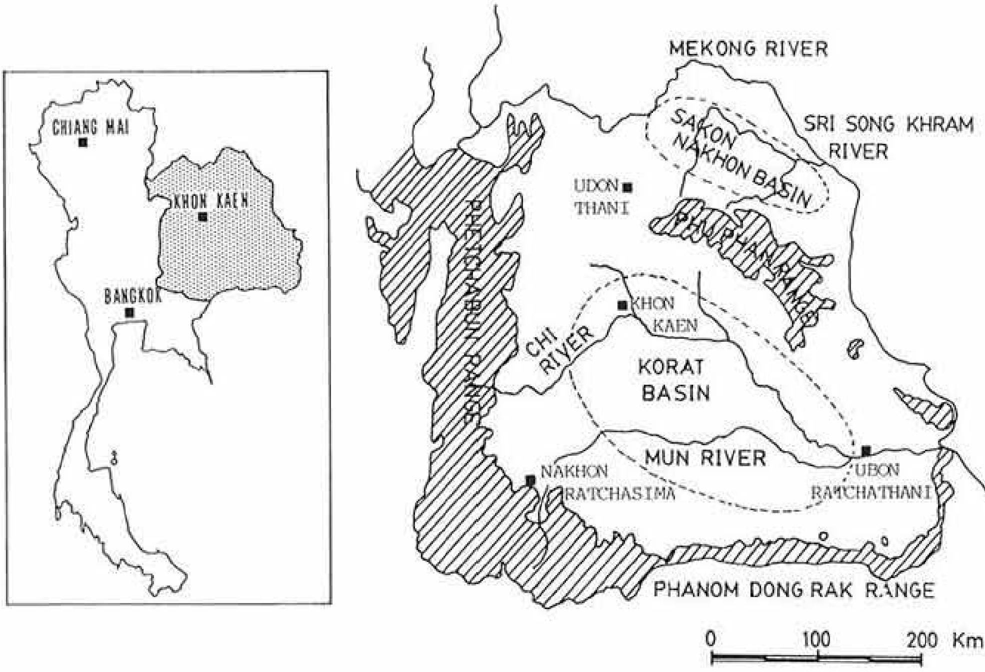

Fig. 1. Location of the study areas and physiography of Northeast Thailand

changes of available water in the upland soils, which are used for field crop cultivation, were analysed to develop future guidelines for rainfed farming.

Materials and methods

The three sites, i.e. sites 1, 2, and 3, were selected in the experimental field of Region V Office, Department of Land Development, Khon Kaen city (Fig. 1). Sites 1, 2, and 3 correspond to the order of elevation on the same transect. Site 1 is situated at the summit of the plateau (192 m above sea level), while sites 2 and 3 in the middle of the slope (180 and 176 m, respectively). These sites were kept fallow during the study period.

At each of the sites, a pit was dug and the profile was described. Disturbed soil samples from each horizon were collected for mechanical, chemical, and clay mineralogical analyses. As for the chemical properties, total carbon was determined by a dry combustion method, pH(H_2O) using a glass electrode pH meter, exchangeable Ca, Mg, K and Na were determined by NH_4OA_c (pH 7.0) extraction and exchangeable Al and H by KCl extraction. The undisturbed 100 cc core samples were taken at the respective depths of 0–10, 20, 40, 60, 80, and 100 cm from the soil surface for the analysis of physical properties, such as bulk density, three-phase distribution at pF 1.5, and pF-moisture characteristics.

In order to monitor the seasonal changes of available water content at each of the three sites, soil samples were taken at the respective depths of 0–10, 20, 40, 60, 80, 100, 150, and 200 cm from the soil surface using an auger to measure the moisture content by the oven-dry method. This investigation was carried out over a period of about 2 years, i.e. from January 1988 to February 1990.

Results and discussion

1) Soil morphological, chemical and clay mineralogical properties

The soil at each site had a sandy surface overlying the loamy substratum. The soil at site 3 was characterized by the presence of a very thick sandy layer. The subsoil of site 1 showed a red color (2.5 YR 4/6–8), while that of site 2 a reddish brown color (5YR 5–6/8).

Table 1. Some properties of the sampled soils

Horizon	Depth (cm)	Clay (%)	Total C (%)	pH (H_2O)	CECe[a)]	CECe[b)] / Clay	Clay minerals
Soil at site 1 (Paleustult)							
Ap	0–25	7.5	0.35	6.0	2.53	33.7	kaolin ≫ smectite, quartz
B1	25–37	11.5	0.17	5.7	2.52	21.9	kaolin ≫ smectite > quartz
B21 t	37–50	11.5	0.16	5.6	2.65	23.0	kaolin ≫ smectite > quartz
B22 t	50–70	11.5	0.14	5.3	3.24	28.2	kaolin ≫ smectite > quartz
B23 t	70+	9.6	0.10	5.2	3.74	39.0	kaolin ≫ smectite > quartz
Soil at site 2 (Paleustult)							
A1p	0–20	6.9	0.31	5.9	1.35	19.6	kaolin ≫ smectite, quartz
A3	20–28	9.7	0.15	5.2	1.07	11.0	kaolin ≫ smectite, quartz
B1	28–43	12.2	0.13	5.3	1.25	10.2	kaolin ≫ smectite, quartz
B21 t	43–100	11.9	0.12	5.6	1.29	10.8	kaolin ≫ smectite, quartz
B22	100–120+	9.4	0.09	5.3	1.26	13.4	kaolin ≫ smectite, quartz
Soil at site 3 (Quartzipsamment)							
A1p	0–23	5.5	0.25	5.7	1.59	28.9	kaolin, quartz ≫ smectite
A3	23–37	6.9	0.13	5.6	0.93	13.5	kaolin, quartz ≫ smectite
C	37–57	8.4	0.11	5.6	0.83	9.9	kaolin, quartz ≫ smectite
2B21	57–80	13.6	0.09	5.5	0.83	6.1	kaolin, quartz ≫ smectite
2B21 t	80–132+	14.8	0.09	4.8	1.31	8.9	kaolin, quartz ≫ smectite

a): CEC, sum of exchangeable cations (exch. Ca, Mg, K, Na, Al, and H) (me/100 g).
b): CEC of 100 g clay (me/100 g).

Table 2. Water-holding capacity within 1 m depth of the sampled soils

	Available water (mm)		Total (mm)
pF	1.8–2.7	1.8–4.2	1.8–7.0
Soil at site 1 (Paleustult)	100	143	213
Soil at site 2 (Paleustult)	74	123	172
Soil at site 3 (Quartzipsamment)	96	143	175

Table 3. Bulk density and three-phase distribution of the sampled soils

Depth (cm)	Bulk density (g/cm^3)	Three-phase distribution (%)		
		Solid	Liquid	Gas
Soil at site 1 (Paleustult)				
0–10	1.52	57.5	33.7	8.9
10–20	1.56	58.3	25.6	16.0
20–40	1.63	61.0	24.2	14.9
40–60	1.47	57.9	25.9	16.2
60–80	1.48	57.7	27.9	14.4
80–100	1.42	54.8	28.2	17.1
Soil at site 2 (Paleustult)				
0–10	1.61	60.6	26.1	13.4
10–20	1.78	66.6	23.1	10.3
20–40	1.57	58.2	24.3	17.4
40–60	1.55	57.1	24.1	18.8
60–80	1.54	56.8	24.4	18.9
80–100	1.51	55.5	25.3	19.2
Soil at site 3 (Quartzipsamment)				
0–10	1.53	58.0	30.0	12.0
10–20	1.60	59.0	29.5	11.5
20–40	1.58	60.1	27.6	12.3
40–60	1.61	62.1	23.9	14.0
60–80	1.70	64.1	22.6	13.2
80–100	1.66	62.5	23.9	13.6

The soils examined were characterized by very low amounts of organic matter and bases with a very low holding capacity of nutrients, reflecting the sandy nature and the predominance of kaolin minerals (Table 1). Based on the system of the U.S. soil taxonomy[6], both soils at sites 1 and 2 were classified into Paleustults and the soil at site 3 into Quartzipsamment at the great group level.

2) Characteristics of water retentivity

Available water-holding capacity (pF 1.8 - 4.2) within a 1 m depth was 143 mm for both soils at sites 1 and 3, and 123 mm for the soil at site 2 (Table 2). These values were close to those of upland soils in Brazil[1], but lower than those recorded in Japanese cultivated soils.

For the soils at sites 1 and 3, the water retentivity

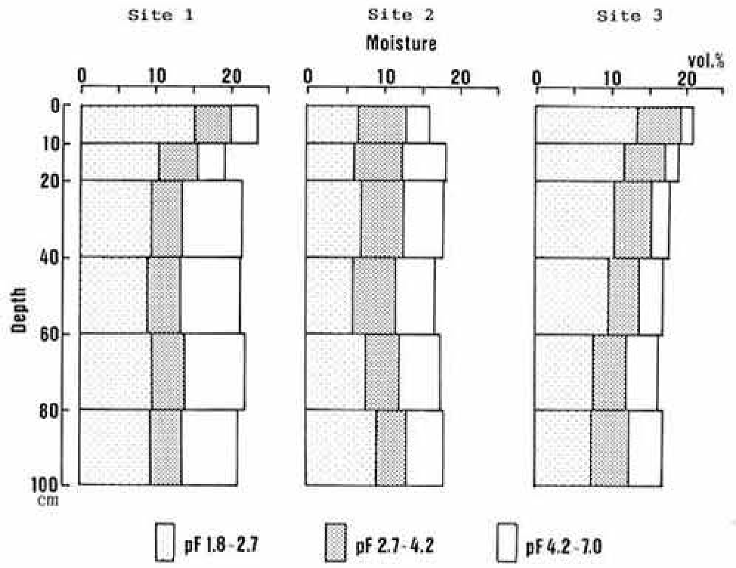

Fig. 2. Water retentivity of the sampled soils within 1 m depth

at pF 1.8 to 2.7 was the highest in the surface layers at 0-10 cm depths and the values gradually decreased with depth (Fig. 2). Based on the similar distribution pattern of the total carbon content (Table 1), the high water retention values at pF 1.8 to 2.7 may be ascribed to the contribution of organic matter. In contrast, for the soil at site 2, the water retentivity at pF 1.8 to 2.7 was relatively low in the 0-10 and 10-20 cm layers resulting in a relatively low retentivity of total available water (pF 1.8 - 4.2). Based on the relatively high solid ratio and bulk density in these parts of site 2 compared with those of sites 1 and 3 (Table 3), it is suggested that compaction may be responsible for the relatively low volume of the pores associated with water retention at pF 1.8 to 2.7.

Water retentivity at pF 2.7 to 4.2 showed nearly constant values in the zone within 1 m depth for each soil (Fig. 2). However, the high values of water retentivity recorded at pF 4.2 to 7.0 in the deeper layers, where the clay content was comparatively high (Table 1) may be ascribed to the significant role of clay particles in water retention in this pF range.

According to Kubota et al.[2], mulching with rice straw and cornstalk enables to increase the available water content and to obtain a relatively high grain yield of maize. Recently, it has been reported that living-mulch management using *Stylosanthes hamata* c.v. Verano resulted in a much higher yield of cassava root, compared with the conventional management[8]. In addition to the above-cited mulching practices, the incorporation of organic materials may be beneficial for enhancing the water retentivity at pF 1.8 to 2.7.

3) Seasonal changes in the amount of available water

During the study period, each soil contained a sufficient amount of available water at pF 1.8 to 4.2 within the 2 m depth zone for crop cultivation in the rainy season, from May to October (Fig. 3). The amount of available water decreased from the soil surface at the beginning of the dry season, starting from November. In each of the soils examined, the amount of available water in the zone at a depth of less than 100 cm from the soil surface gradually decreased in the dry season, while that in the zone at a depth of more than 100 cm was much less affected. Among the three soils examined, the soil at site 3 contained the largest amount of available water in the zone at a depth of more than 100 cm during the study period.

Based on these results, it is considered that an appreciable amount of available water was still

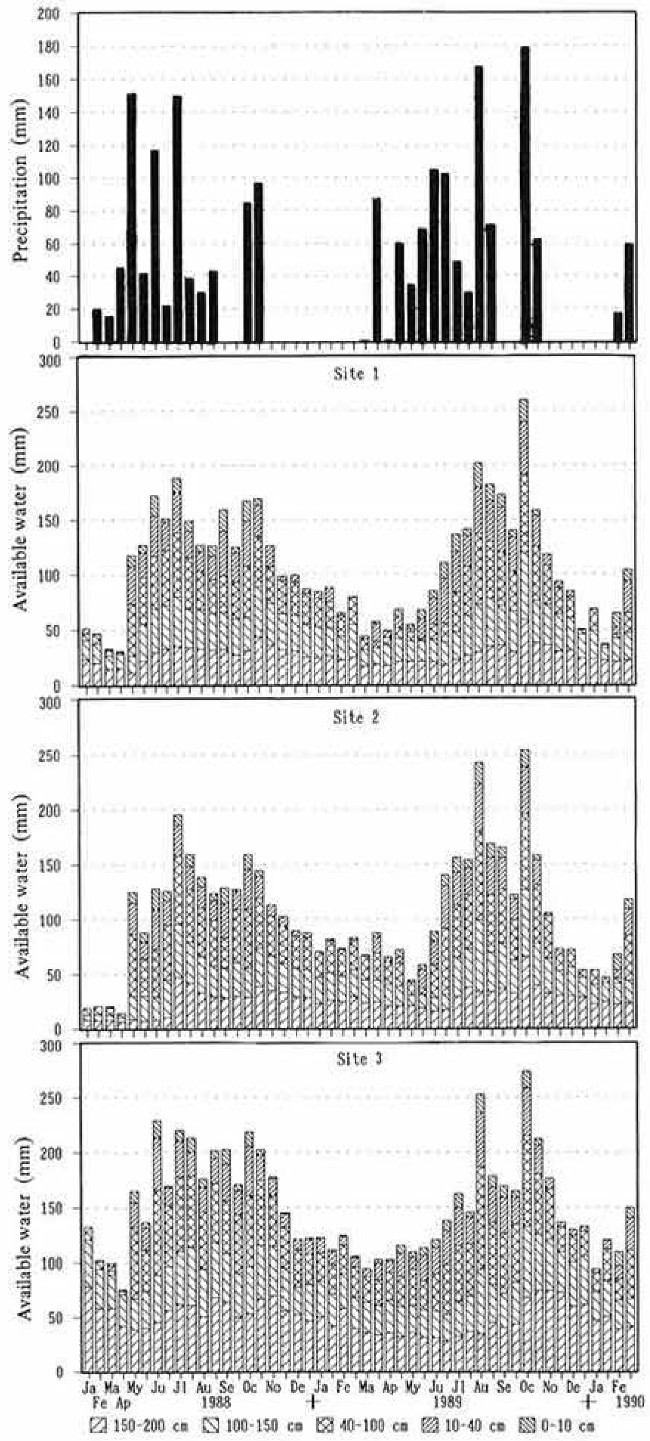

Fig. 3. Precipitation and seasonal changes in available water (pF1.8–4.2) of the soils examined during the period January 1988 to February 1990

retained in the shallower part at the beginning of the dry season and in the deeper part in the middle to the end of the dry season. Thus, judging from the moisture conditions, it is suggested that the cropping season and kinds of crops should be judiciously selected. In particular, efficient utilization of the soil which tends to retain a relatively large amount of available water in the deep layers such as the soil at site 3, i.e. Quartzipsamment, should be taken into account for rainfed farming in future.

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(Received for publication, Oct. 18, 1991)