J. Jpn. Soc. Soil Phys.
土壌の物理性
No. 109, p. 45～50 (2008)

# Analysis of Surface Runoff in a Sloping Sandy Soil in Northeast Thailand Using Soil Water Storage Capacity

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**Abstract**

In Northeast Thailand, permeable sandy soils are widely distributed. Most rainfall may infiltrate the ground and there may be little surface runoff. However, soil erosion caused by surface runoff has been reported. To investigate the mechanism by which surface runoff occurs, we selected a sloping area where the top soil consisted of a permeable sandy layer overlying a very low permeability clay layer. We defined the soil water storage capacity of the sandy layer at a particular time as the difference between the maximum observed water content and the observed water content at that time. We assumed that when the amount of rainfall exceeded the soil water storage capacity, the excess rainfall became surface runoff. As a result of monitoring of soil water content in the sandy soil layer over a period of one year, the total amount of runoff was estimated to be about 30% of the total rainfall and the periods for which our analysis showed that soil water storage capacity was exceeded were followed by rises in the water level of a pond that surface runoff flowed into.

**Key words** : Northeast Thailand, Sandy soil, Soil water storage capacity, Sloping layered soil, Surface runoff

## 1. Introduction

The Northeast Thailand region accounts for one-third of the total area of Thailand. The topography of the region is undulating hills, and sandy soils occupy about 80% of the area. Annual rainfall is 1,000-2,000 mm, and falls mainly during the rainy season, May to October (Kohyama and Subhasaram, 1993). Agriculture in the region is dependent on rainfall, but the highly variable monthly rainfall results in unstable crop yields. To use the available rainwater effectively, it is essential to identify the movement of rainwater after it reaches the ground surface. The permeability of the widely distributed sandy soils in Northeast Thailand is very high. Consequently, most rainfall may infiltrate and there may be little surface runoff. However, damaging soil erosion caused by surface runoff has been reported (Mitsuchi *et al.,* 1986 ; Sombatpanit *et al.,* 1995). It was difficult to explain the mechanism of the occurrence of surface runoff from the viewpoint of the permeability of surface soil. Watabe *et al.* (2004) hypothesized that surface runoff would occur after the sandy soil overlying a clay soil with

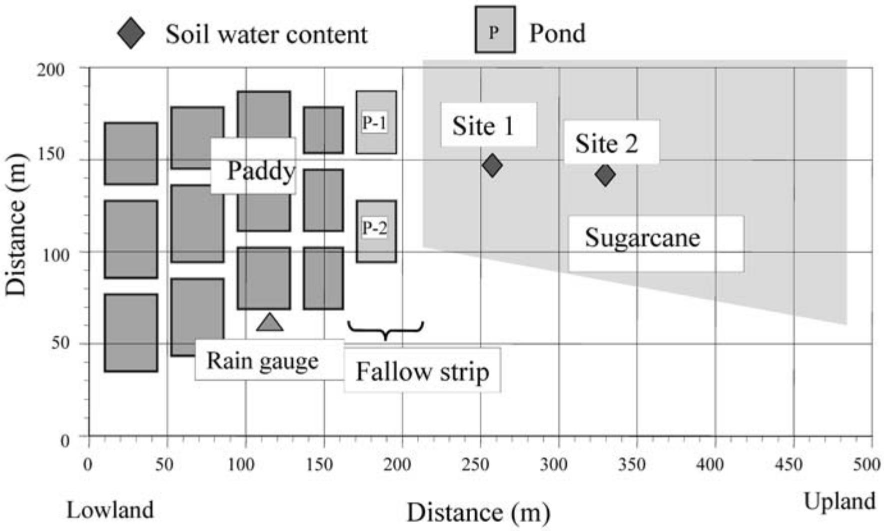



**Fig. 1** Experimental site
(N : 16°9′, E : 102°48′)

very low permeability was filled with water. However, their research has not been verified experimentally. In this study, we measured the water content of the sandy soil overlying a very low permeability clay soil on a hill slope to verify the mechanism by which surface runoff occurs.

## 2. Materials and Methods

### 2.1 Study site

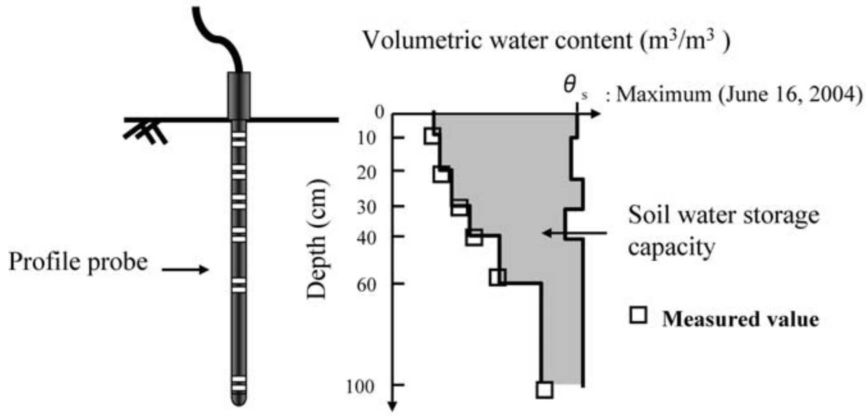
We selected a sloping field covered by sandy soil in the Nong Saeng village, about 35 km south of Khon Kaen city. In the rainy season, farmers in this area cultivate rice in the lowland, and sugarcane in the upland (Fig. 1). The surface slope of the sugarcane field in our study area was about 3°. There were two ponds in the lower part of the sugarcane field. The water level in these ponds was not affected by groundwater and subsurface flow (Hamada and Sukchan, 2008), indicating that when surface runoff occurred, the water level would increase markedly.

The soil from the surface to 1 m depth was Loamy Sand (LS), 7% clay, 2% silt and 91% sand. The soil below 1 m depth was Sandy Clay (SC), 27% clay 4% silt and 69% sand. The saturated hydraulic conductivity was on the order of $10^{-4}$ cm/s in the LS layer and on the order of $10^{-6}$ cm/s in the SC layer (Hamada *et al.,* 2006). From the permeability values, we inferred that rainwater infiltrated the ground and is retained in the LS layer above the SC layer.

### 2.2 Field investigation and analytical method

We measured soil water content (at two sites, Site 1 and Site 2), rainfall, and water level in a pond (P-1 : area 390 $m^2$) (Fig. 1).

Soil water content in the LS layer was measured using Profile Probe (Delta-T Device, PR 1/6) at depths of 10, 20, 30, 40, 60 and 100 cm at intervals of about one week between September 20, 2003 and September 20, 2004. Using these data, we estimated the soil water storage capacity of the LS layer. The soil water storage capacity on a particular day was defined as the difference between the maximum recorded volumetric water content of the LS layer (June 16, 2004) and the measured value on that day. We assumed that when the amount of rainfall was less than the soil water storage capacity, all rainfall would infiltrate, and when the amount of rainfall was greater than the soil water storage capacity, the excess would become




| Depth (cm) | Water content ($m^3/m^3$) (April 7, 2004) | Water content ($m^3/m^3$) (June 16, 2004) | Soil water storage capacity (mm) |
|---|---|---|---|
| 10 | 0.05 | 0.34 | 29 |
| 20 | 0.03 | 0.33 | 30 |
| 30 | 0.06 | 0.33 | 27 |
| 40 | 0.09 | 0.33 | 24 |
| 60 | 0.12 | 0.33 | 42 |
| 100 | 0.34 | 0.34 | 0 |
| **Total** | | | **152** |

**Fig. 2**　Estimation of soil water storage capacity (at site 1 on April 7, 2004)

surface runoff. The process for estimation of the soil water storage capacity is shown in Fig. 2.

We measured water levels in the pond P-1 by using survey instruments, GPS positioning (Sokkia, RADIAN™ IS) in order to check the occurrence of surface runoff. First, we measured the elevation of the bottom of the pond. We then calculate the depth of water in the pond as the difference in the elevation between the water surface and the bottom of the pond (error : ±0.02 m). The water-level measurements were recorded at intervals of one to two weeks from March 1, 2004 to September 17, 2004.

Rainfall data was collected at intervals of 10 minutes with a rain gauge (SEC, WeatherBucket).

## 3.　Results and Discussions

Figure 3 shows daily rainfall and calculated soil water storage capacity in the LS layer at site 1 and 2 (squares and triangles). The total rainfall was 1266 mm during the period of our investigation. The soil water storage capacity was calculated at intervals of about one week. It was therefore necessary to determine the daily soil water storage capacity in order to estimate the daily amount of the surface runoff. We calculated the daily soil water storage capacity by using the following equation :

$$W_n = W_{n-1} - P_n + E_n \quad (1)$$

where on day $n$, $W_n$ is soil water storage capacity ($W_n < 0$ indicates surface runoff), $P_n$ is daily rainfall, and $E_n$ is daily evapotranspiration (September 21, 2003 was day one). We assumed that deep percolation beyond a depth of 1 m was negligibly small. Daily values of $E$ used in Equation (1) were chosen by trial and error. We used 1 mm/day from September 21, 2003 to January 18, 2004 and as 3 mm/day from January 19, 2004 to September 20, 2004, chosen so that, $Wn$ values (Solid line in Fig. 3) would follow

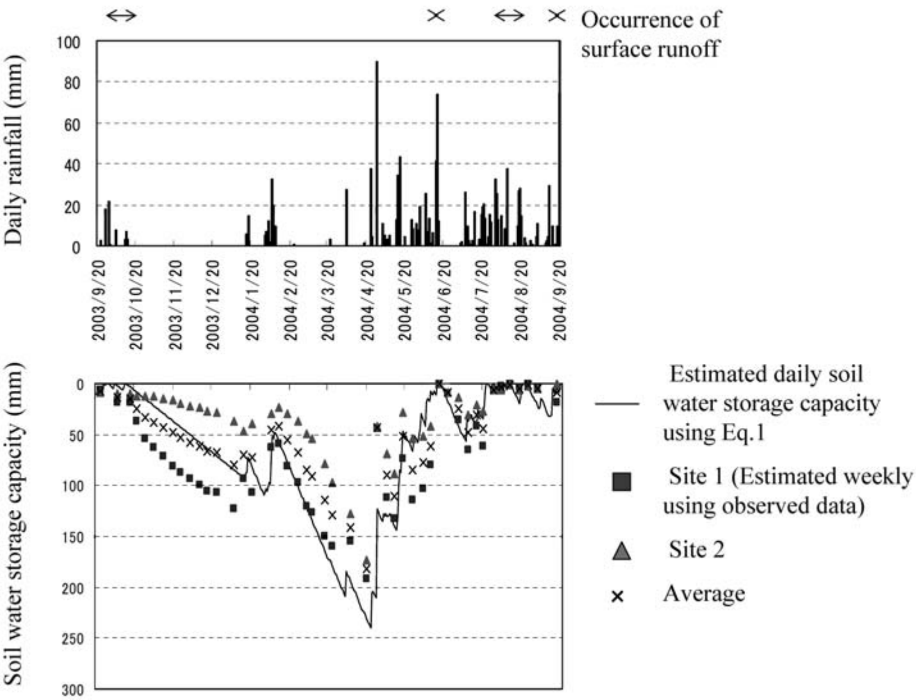



**Fig. 3** Daily rainfall and estimated weekly and daily soil water storage capacity

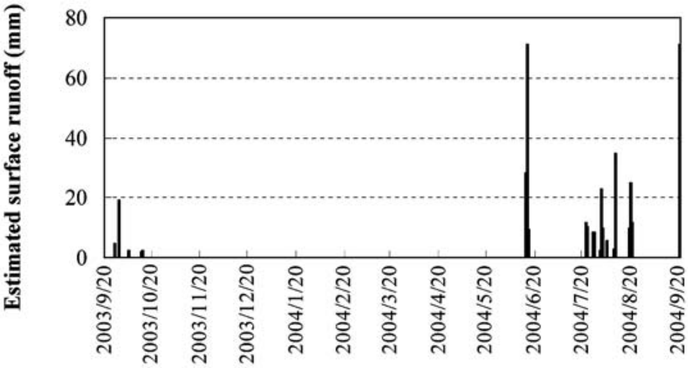



**Fig. 4** Estimated surface runoff (Total : 374 mm)

the trend of calculated capacities using weekly observed soil water content. Using $Wn$ obtained with Equation (1), we estimated the daily surface runoff as the difference between the amount of rainfall and soil water storage capacity.

Our analysis results showed that the surface runoff occurred between September 20 to October 20, 2003, in the middle of June, 2004, between July 20 and August 20, and on September 20, 2004 (Fig.4). The total amount of runoff during the period of our study was estimated to be 374 mm, which was about 30% of the total rainfall (1,266 mm). The temporal relationship between daily surface runoff and variations of water level in the pond (Fig. 5) shows that the periods when the water level rose in the pond coincided with periods of surface runoff, thus validating our hypothesis that runoff occurs

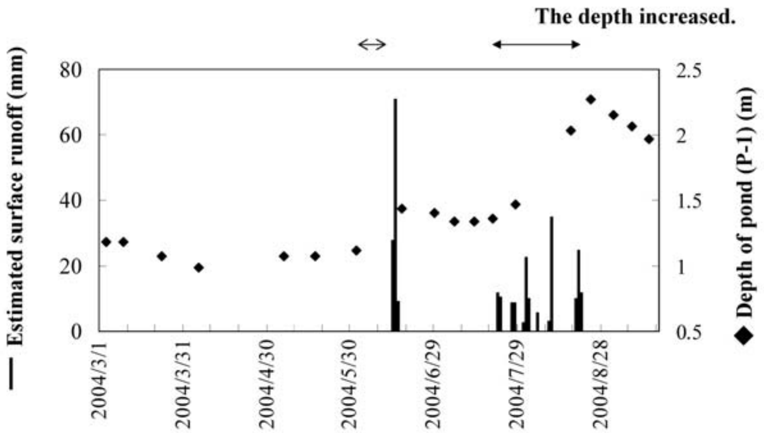



**Fig. 5** Relationship between estimated surface runoff and depth of the pond (P-1).

when the amount of rainfall exceeds soil water storage capacity.

## 4. Conclusion

This study identified the mechanism by which surface runoff occurs in a sloping area in Northeast Thailand, where the soil from the surface to 1 m depth is LS layer and overlies a very low permeability SC layer. We defined soil water storage capacity as the difference between the maximum water content we observed in the LS layer and observed values. We assumed that when the amount of rainfall exceeded soil water storage capacity, the excess water became surface runoff. The periods during which we estimated that surface runoff occurred coincided with rises in the water level of the pond that surface runoff flowed into, thus validating our hypothesis that runoff occurs when the amount of rainfall exceeds soil water storage capacity.

## Acknowledgement

We would like to acknowledge the useful suggestions for this research from Dr Shuichi Hasegawa of Hokkaido University. We would also like to thank Mr Chikara Ogura, from the National Agriculture and Food Research Organization, for his assistance in our field investigations.

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# 土壌水分貯留容量を用いた東北タイの砂質傾斜地における表面流出解析

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## 要 旨

東北タイは透水性の良い砂質土が広く分布している。そのため，地表に到達した降水は地下に浸透することが想定されるが，その一方で表面流出による土壌侵食の被害も報告されている。本研究は，東北タイの砂質土の傾斜地を試験地として表面流出の発生のメカニズムについて検討した。試験地は，1 m 厚の砂質土の下に難透水層の粘土が存在する。そのため，砂質土内に浸透した水は粘土層の上に貯留され，降水量が砂質土の土壌水分貯留容量を超えた時，超過分が表面流出となるものと仮定して解析を実施した。土壌水分貯留容量は，プロファイルプローブで測定した砂質土の最大水分量と測定した水分量の差と定義した。解析の結果，表面流出量は全降水量の約 30% と算出され，表面流出が発生すると推定された時期とその表面流出が流入するため池の水位上昇の時期が一致した。

**キーワード** : 東北タイ，砂質土，土壌水分貯留容量，成層斜面，表面流出

受稿年月日 : 2008 年 1 月 9 日
受理年月日 : 2008 年 4 月 3 日