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Relationship between Soil Water Content of a Surface Sandy Soil and Groundwater Level in a Study Site in Northeast Thailand

Hiromasa HAMADA* and Somsak SUKCHAN**

* Japan International Research Center for Agricultural Sciences,
Owashi 1-1, Tsukuba, Ibaraki, 305-8686, Japan
** Land Development Department, 2003/61 Phaholyothin Rd.,
Lardyao, Chatuchak, Bangkok, 10900, Thailand

Abstract

In some areas of northeast Thailand, groundwater is confined by a clay layer, and the water level in wells drilled into the aquifer is above the ground surface, suggesting that water could be supplied from the aquifer to the surface soil and making it possible to cultivate crops with minimum irrigation. We measured the groundwater level in wells and the water content of the surface sandy soil during the dry season. In recharge areas, the soil water content was usually less than the depletion of moisture content for optimum growth in the dry season, and less than the permanent wilting point in the late dry season (from January), indicating that in these areas, irrigation would be required for the cultivation of crops. In the discharge areas, where the water level in wells drilled into the confined aquifer was higher than the ground surface, the soil water content was more than the depletion of moisture content for optimum growth throughout the dry season, indicating that in these areas it would be possible to cultivate crops with minimum irrigation during the dry season using natural upward flow.

Key words : Northeast Thailand, Confined groundwater, Soil water content of sandy soil, Minimum irrigation, Natural upward flow

1. Introduction

The main industry of northeast Thailand is agriculture, which depends on rainfall. Only 10% of the area used for agriculture is irrigated (Prapertchob and Humnath, 2004). The topography is undulating hills, and farmers grow rice in the lowlands during the rainy season, and sugarcane and cassava in the uplands throughout the year. Though annual rainfall is 1,000 to 2,000 mm, little rain falls during the months of the dry season (November to April). Therefore, it is essential to develop water resources to enable cultivation during the dry season. Sandy soils cover about 80% of this region (Kohyama and Subhasaram, 1993). In some areas, a clay layer at depths of 1 to 4 m, of which permeability is on the order of 10^{-6} cm/s, is overlaid by the sandy soil. Beneath the clay layer is a weathered sandstone aquifer. In the lowlands, groundwater in the aquifer is confined by the clay layers and sometimes the water level in observation wells drilled into the aquifer is higher than the ground surface (Hamada *et al.*, 2006). In this case, water could be supplied to the surface sandy soil through the clay layer. It might be possible, therefore, to cultivate some crops with minimum irrigation using natural upward flow during the dry season. In this study, we measured water re-

Table 1 Elevation, depth, screen, period of measurement and land use

No.	Elevation (m)	Depth (m)	Screen (m)	Period of measurement	Land use
1–1	207	7	3–7	April 7, 2004 to April 4, 2005	Fallow
1–2	207	30	26–30	April 7, 2004 to April 4, 2005	Fallow
2	202	30	26–30	September 30, 2005 to May 24, 2007	Forestry
3	190	30	26–30	April 7, 2004 to April 4, 2005	Paddy (rainy season) Fallow (dry season)
4	179	30	26–30	April 7, 2004 to April 4, 2005	Paddy (rainy season) Fallow (dry season)

tention characteristics of surface sandy soil and monitored the water content in fields and the groundwater level in observation wells during the dry season to examine the influence of the groundwater level in the confined aquifer on the surface sandy soil water content and to consider the possibility of minimizing irrigation. Studies of soil water movements in Thailand have been reported, the relationship between shallow groundwater above the clay layer and moisture damage to cassava (Taniyama and Miura, 1991), the relationship between variation of soil moisture and surface runoff (Watabe *et al.,* 2005 ; Funakawa *et al.,* 2007), variation of soil water content in the sandy soil (Watanabe *et al.,* 2004, Oda and Ogura, 2008 ; Moroizumi *et al.,* 2008), and regional groundwater flow (Srisuk *et al.,* 2000). However, no reports on the influence of the groundwater level in a confined aquifer on soil moisture have been published.

2. Method

We selected Nong Saneg village, 35 km south of Khon Kaen city as the study site. The soil from the surface to 1 m depth is Loamy Sand (LS), of which permeability is on the order of 10^{-4} cm/s, and from 1 to 4 m depth is Sandy Clay (SC), of which permeability is on the order of 10^{-6} cm/s. A weathered sandstone aquifer underlies the SC layer (Hamada *et al.,* 2006). We selected two sites in the recharge area and two sites in the discharge area for the measurements of groundwater level and soil water content considering the topography (Hamada, 2005). Fig. 1 is a map of the observation sites and information about the observation wells and the measurement periods is listed in Table 1. Locations 1 and 2 are in the uplands, and locations 3 (at the foot of a hill) and 4 (a flat land) are in the lowland where farmers cultivate rice in a rainy season. We measured the groundwater level in the observation wells at intervals of one to two weeks during the period from 2004 to 2007.

In the soil investigation, we measured the water retention characteristics of the sandy soil and monitored the soil water content, to examine the possibility of the cultivation of plants with minimum irrigation. For the measurement of the water retention characteristics soil samples were collected as 100-ml cores at the point between location 2 and location 3 in September 2004 (Fig. 1). We collected nine samples, three samples at each depth, 5–10 cm, 28–33 cm and 95–100 cm. The water retention characteristics were measured by the pressure plate method. For monitoring of soil water content, we collected disturbed soil samples at every 10 cm depth by using an auger and measured the water content (by weight : w). The measured values indicate the average water content of the soil layers 10 cm thick. We conducted our first soil investigation in December 2005. After that, we measured the soil water content at locations 1–3 between October 2006 and April 2007 at intervals of one to three months. The soil water content at location 4 was measured on January 12, 2007 to confirm that the soil water content where the groundwater level in

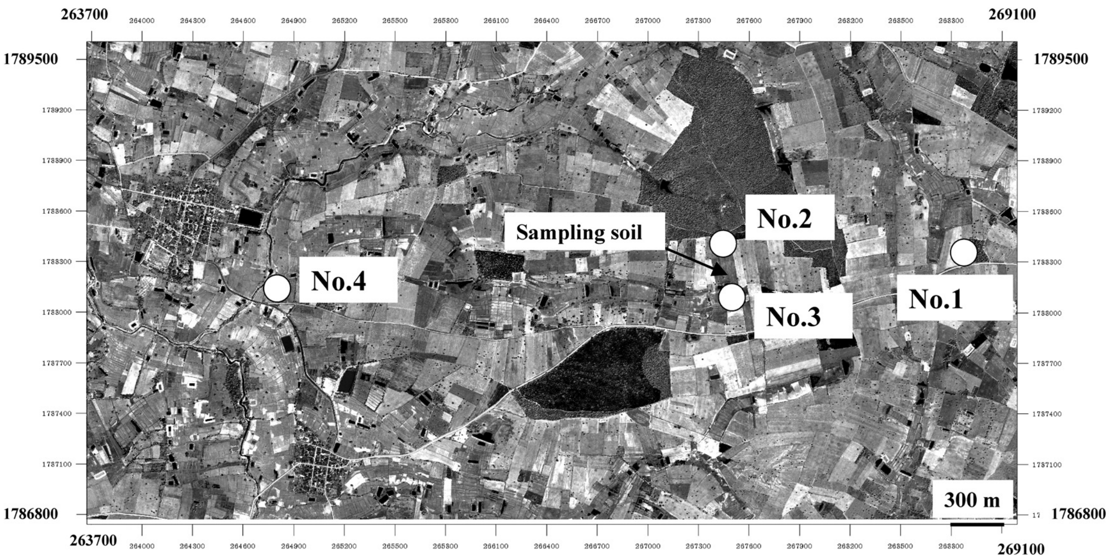

Fig. 1 Observation sites (No. 1 : Two wells)
Longitude : 263700–269100, Latitude : 1786800–1789500 (UTM coordinates).

the observation well was above the ground surface would be high. The monthly rainfalls during the investigation at location 4 were 142.4 mm in October, 2006, no data in November and December (due to equipment problems), 1.4 mm in January, 3.2 mm in February, 5.2 mm in March and 29.8 mm in April 2007(until April 27).

3. Result and discussion

3.1 Variation in groundwater level

The variation in the groundwater level is shown in Fig. 2. The water level in well 1-1 (7 m deep) was higher than that in well 1-2 (30 m deep), indicating that these wells are in the recharge area. The water level in well 2 was more than 10 m below the ground surface, indicating that the soil water content of the surface sandy soil was not affected very much by the groundwater. The water level in well 3 was higher than the ground surface and that in well 4 also rose above the ground surface after May 2004. In these areas, groundwater levels in holes which were drilled through the clay layer were higher than the surface, inferring that water from the confined aquifer could be supplied to the surface sandy soil through the clay layer and could keep the soil wet even during the dry season.

3.2 Water retention characteristics

Figure 3 shows the water retention characteristics of the sandy soil. According to the engineering manual for irrigation and drainage by Japanese Institute of Irrigation and Drainage (1990), the lower limit of available soil moisture for crops is regarded as the point at which crops begin to be damaged. The soil water content is called the depletion of moisture content for optimum growth (θ_{og}). In this study, we used the depletion of moisture content for optimum growth as the lowest point of soil moisture at which irrigation is not required, and adopted the value of 100 kPa (Suction). The bulk density of the samples (ρ_b) was 1.44±0.08 ($Mg\,m^{-3}$). Water content (w) was calculated using volumetric water content and bulk density ($w=\theta/\rho_b$). The θ_{og} of the sandy soil is 0.078 $m^3\,m^{-3}$ (w : 0.051–0.057 $kg\,kg^{-1}$), and the permanent wilting point (θ_{wp}) is 0.019 $m^3\,m^{-3}$ (w : 0.013–0.014 $kg\,kg^{-1}$). When the soil water content is more than 0.057 $kg\,kg^{-1}$, plants could grow without irrigation. When the soil water content is less than 0.013 $kg\,kg^{-1}$, the plants might

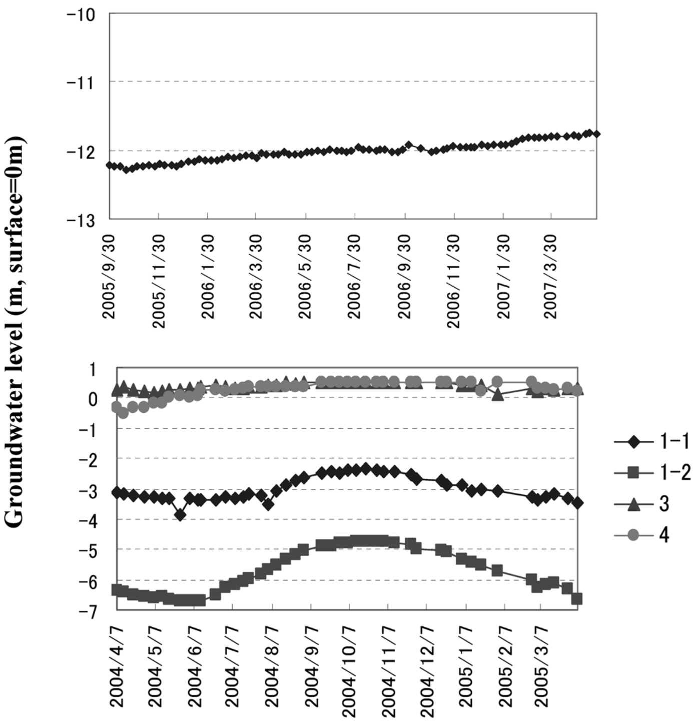

Fig. 2 Groundwater level (upper : No. 2, Lower : No. 1, No. 3 and No. 4).

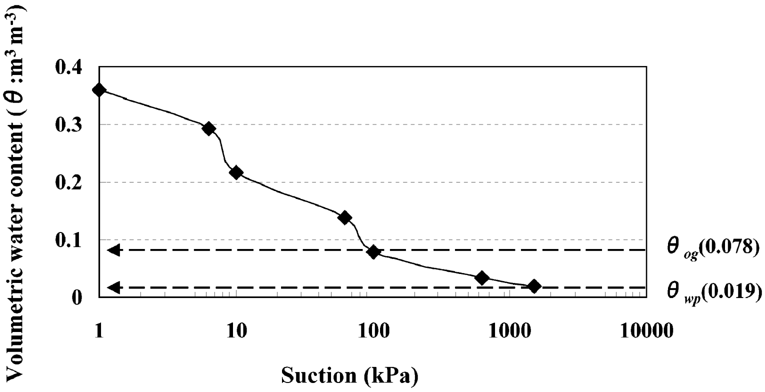

Fig. 3 Water retention characteristics.

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3.3 Variation of soil water content

Figure 4 shows the soil water content measured on December 20 and 21, 2005. The soil water content to a depth of 1 m at location 2, where the groundwater level was 12.23 m deep, was less than θ_{wp}. At location 3, where the groundwater level was 0.5 m above the ground surface, the soil water content was more than θ_{og}, indicating that plants could grow there without irrigation. The water content at location 1, where groundwater level was 4.22 m deep (well 1-1) was similar to that at location 2.

Figures 5–8 show the soil water content near

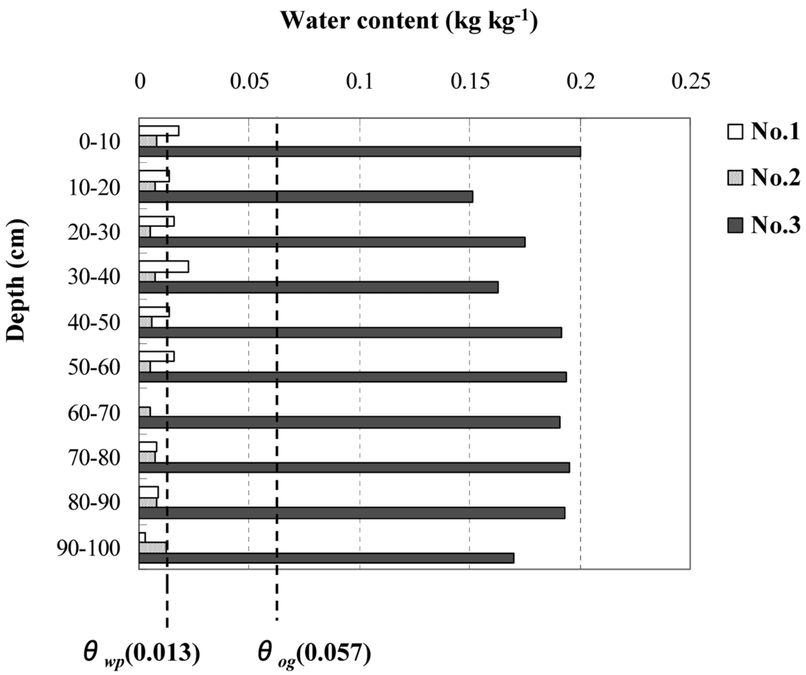

Fig. 4 Soil water content (December 20-21, 2005).

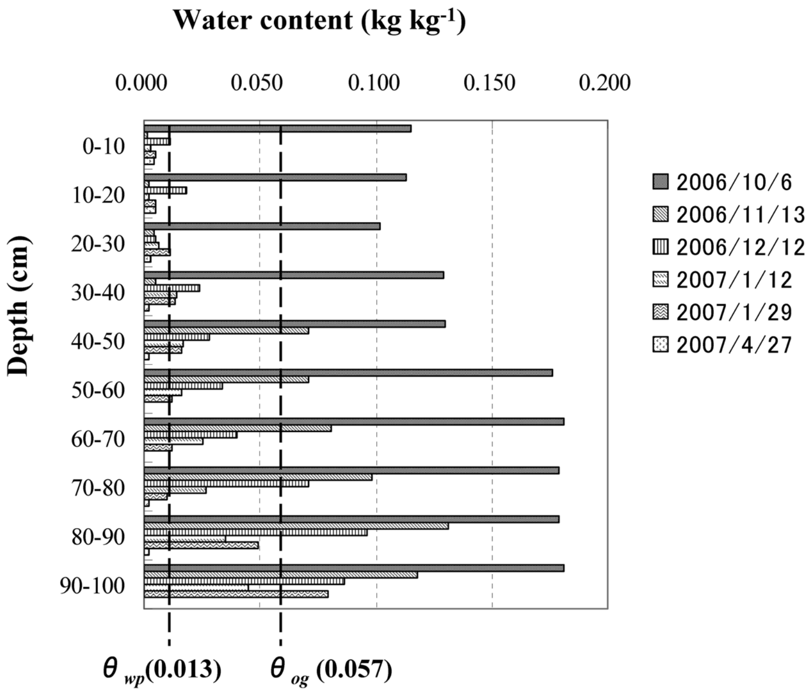

Fig. 5 Water content (No. 1).

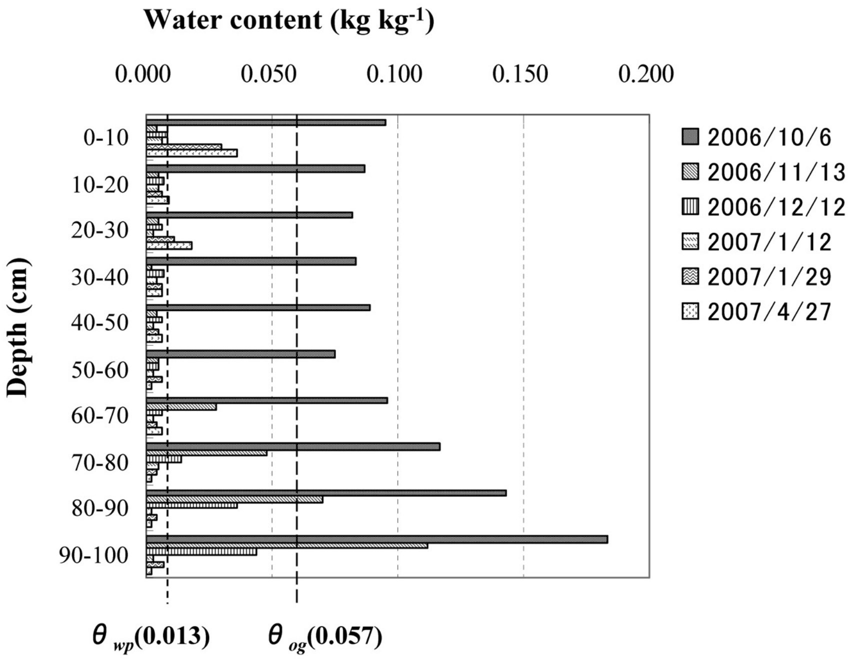

Fig. 6 Water content (No. 2).

the observation wells during the dry season (October 2006 to April 2007). At location 1, the soil water content tended to increase with depth. From December 12 2006 to April 27 2007, the values, except for some from more than 70 cm depth, were less than θ_{og}, and most values at depths above 30 cm, were less than θ_{wp} (Fig. 5). Most values of the soil water content at location 2 from November 13 were lower than θ_{og} and after December 12 2006, became less than θ_{wp} (Fig. 6). In these areas, irrigation is required for the cultivation of crops in the dry season.

The soil water content at locations 3 and 4 was more than θ_{og} throughout the period of the investigation. Moroizumi *et al.* (2008) reported that the actual evapotranspiration during the dry season in the lowland of northeast Thailand where soil is same as our study sites was 1.5 mm day^{-1}. Using this value, the decrease of soil water content in the sandy soil to a depth of 1 m during the period of between December 12, 2006 and April 27, 2007 was calculated to be about 200 mm. However, our observation showed that the decrease of soil water content in the sandy soil was about 60 mm, less than the estimated value. Moreover, the soil water content in location 4 in a flat land, where subsurface flow from the upland didn't affect the soil moisture, was more than θ_{og}, suggesting that some water was supplied to the surface sandy soil through the clay layer in locations 3 and 4. Therefore, it should be possible to cultivate crops there with minimum irrigation using natural upward flow.

4. Conclusion

In this study, we examined the influence of the groundwater level in the confined aquifer on water content of the sandy soil to a depth of 1 m in northeast Thailand. The soil water content in the area where the groundwater level in observation wells was higher than the ground surface was more than the depletion of moisture content for optimum growth, even during the dry season, indicating that it should be possible to cultivate crops there with minimum irrigation using natural upward flow.

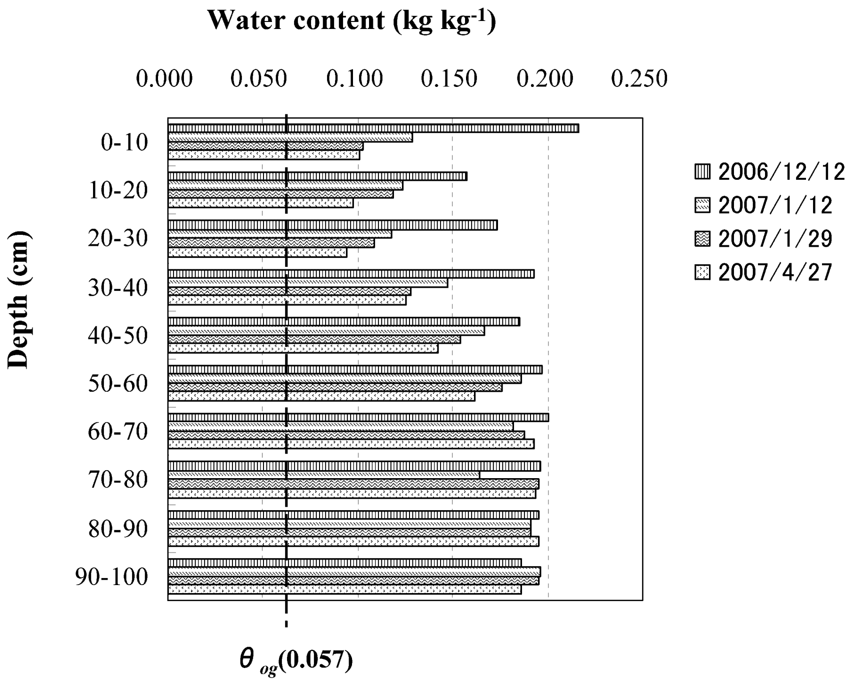

Fig. 7 Water content (No. 3).
This land was used for rice fields until the end of November.

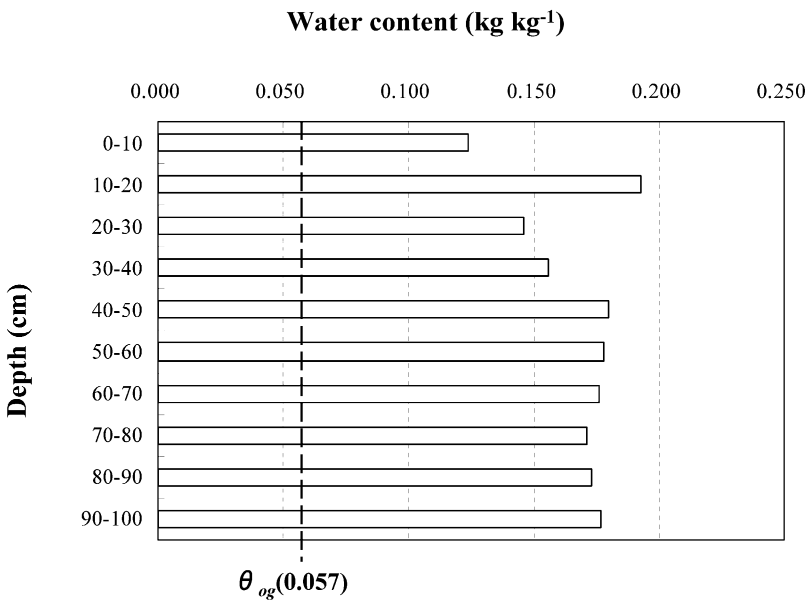

Fig. 8 Water content (No.4) : January 12, 2007.

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東北タイの試験地における表層砂質土の土壌水分と被圧地下水位との関係

濱田浩正*・ソムサック スクチャン**
* 国際農林水産業研究センター，〒305-8686 茨城県つくば市大わし 1-1
** タイ国土地開発局，2003/61 Phaholyothin Rd., Lardyao, Chatuchak, Bangkok, 10900

要 旨

東北タイでは，地下水が粘土層によって被圧され，井戸の水位が地表面よりも高くなる場所がある。そこでは，帯水層から表層に水分が供給され，かんがい水量を最小にして作物栽培を実施できる可能性がある。本研究では，乾季において地下水位と表層砂質土の水分量を測定した。地下水のかん養域では，土壌水分量は通常成長阻害水分点よりも低く，1 月以降の乾季の後半では永久しおれ点よりも低くなることが多い。これらの地域では，作物栽培にはかんがいが必要である。地下水位が地表よりも高い流出域では，土壌水分量は乾季を通じて成長阻害水分点よりも高く，乾季にかんがい水量を最小限にした作物栽培の可能性が示された。

キーワード : 東北タイ，被圧地下水，砂質土壌水分，最小かんがい，自然上昇水分

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