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# Estimating Percolation and Lateral Water Flow on Sloping Land in Rainfed Lowland Rice Ecosystem

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**Abstract** : Quantifying water losses in paddy fields assists estimation of water availability in rainfed lowland rice ecosystem. Little information is available on water balance in different toposequence positions of sloped rainfed lowland. Therefore, the aim of this work was to quantify percolation and the lateral water flow with special reference to the toposequential variation. Data used for the analysis was collected in Laos and northeast Thailand. Percolation and water tables were measured on a daily basis using a steel cylindrical tube with a lid and perforated PVC tubes, respectively. Percolation rate was determined using linear regression analysis of cumulative percolation. Assuming that the total amount of evaporation and transpiration was equivalent to potential evapotranspiration, the lateral water flow was estimated using the water balance equation. Separate perched water and groundwater tables were observed in paddy fields on coarse-textured soils. The percolation rate varied between 0 and 3 mm/day across locations, and the maximum water loss by lateral movement was more than 20 mm/day. Our results are in agreement with the previously reported findings, and the methodology of estimating water balance components appears reasonably acceptable. With regard to the toposequential variation, the higher the position in the topoesquence, the greater potential for water loss because of higher percolation and lateral flow rates.

**Key words** : Percolation, Rice, Toposequence, Water table.

Quantifying the water budget in lowland rice fields is helpful for understanding and modelling plant water availability. The water balance equation represents the relationships among rainfall, runoff, percolation, seepage, evaporation and transpiration. Rainfall is measured at fields or nearby weather stations, while runoff may be estimated from bund height, rainfall and runoff from the neighbouring fields. Evaporation and/or transpiration can be measured and determined using micro-lysimeters, and evapotranspiration may be estimated from potential evapotranspiration or pan evaporation (Bouman et al., 1994; Fukai et al., 2000). Therefore, if the change in free water level is known, the total amount of percolation and seepage can be determined. If percolation is independently determined, seepage can be then computed by difference. This would then allow for the estimation of the water available for plant growth on all parts of the toposequence. Fukai et al. (1998) have reported that the low availability of water and nutrients limits lowland rice production. The availability of water differs from position to position in the toposequence of the lowland environments (Homma et al., 2001). The objective of this paper was, therefore, to quantify percolation rate and the lateral water flow (seepage) using the water balance equation with reference to the toposequential variation of sloped lowlands.

## Materials and Methods

### 1. Field experiments

Field experiments were carried out under rainfed conditions in Laos and Thailand during the main crop-growing season (June – December). In Laos, the experiments were conducted in Savannakhet province (16°N, 105°E) during the 2001 and 2002 seasons. In Thailand, the experiments were conducted during the 2000 season at Chum Phae (16°32'N, 102°7'E), Khon Kaen (16°25'N, 102°48'E)/Ta Pra (16°19'N, 102°49'E), Phimai (15°14'N, 102°28'E), Surin (14°54'N, 103°30'E) and Ubon Ratchathani (15°19'N, 104°40'E), which are located in the northeast. The experimental treatments were three (top, middle and bottom) positions of the toposequence for Laos and four cultural practices, including cultivar, direct seeding/transplanting, and fertilizer application, for Thailand. In addition, Ta Pra had two (high and low) toposequential position treatments.

### 2. Measurements

Percolation was measured using a “percolator” which was constructed using a steel cylindrical tube 400 mm in length and 200 mm in diameter with a lid to prevent

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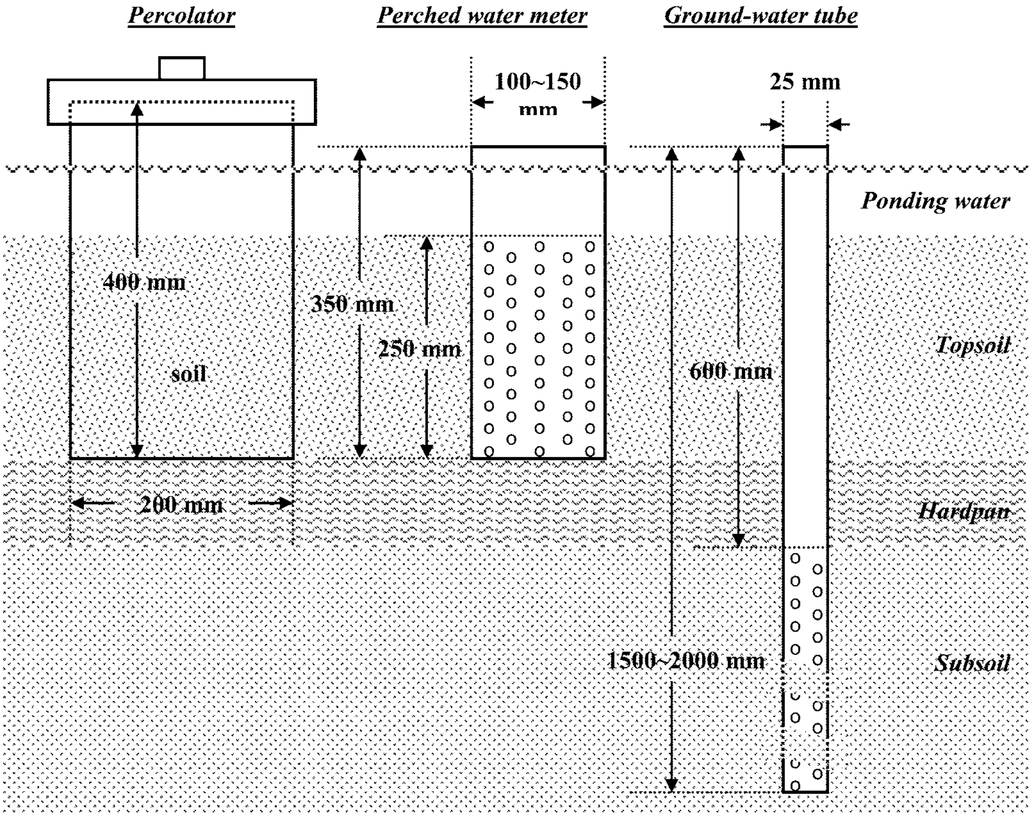

Fig. 1. Schematic diagrams of the percolator, the perched water table meter, and the groundwater table meter.

evaporation and rainfall. The percolator was installed in the topsoil slightly penetrating into the hardpan, so the meter could measure the vertical water movement through the hardpan. The perched water table was measured using a PVC tube with a cylinder diameter of 100 to 150 mm and a depth of 350 mm. Similarly, the groundwater table was measured using a 1500 to 2000 mm long PVC tube with a cylinder diameter of 25 mm. The side below 100 mm and 500 mm from the top of the perched water and groundwater tubes, respectively, has systematically designed holes with 5 mm in diameter. The design of the holes is a lozenge shape-systematic pattern, and the diagonal holes are vertically 20 mm and horizontally 40 mm apart. The perched water table meter was set at the hardpan surface, while the perforated part of the groundwater table meter was installed in the subsoil. The schematic diagrams of the tubes are shown in Fig. 1. All measurements were taken on a daily basis.

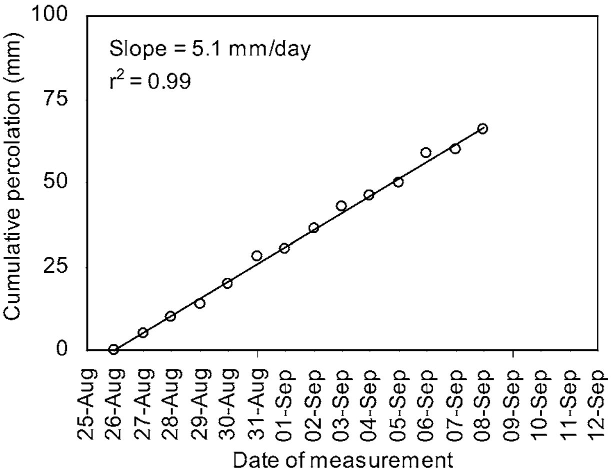

Fig. 2. An example of the linear regression analysis for estimating cumulative percolation loss measured over three months during the main rainy season (Ubon Ratchathani, Thailand).

## 3. Calculations

Assuming that all transpiration water comes from soil above the hardpan because most of the root system is present in the topsoil layer, the lateral water flow (seepage), L, on the i-th day is given by:

$$L_i=(S_{i-1}-S_i)+R_i-E_i-T_i-P_i-O_i$$

where S is free water level, R is rainfall, E is evaporation, T is transpiration, P is percolation rate through the hardpan, and O is surface drainage/runoff. L is defined as the flow under and through the bunds. For each experiment, L was computed daily during three months of August, September and October, and the computation was carried out during

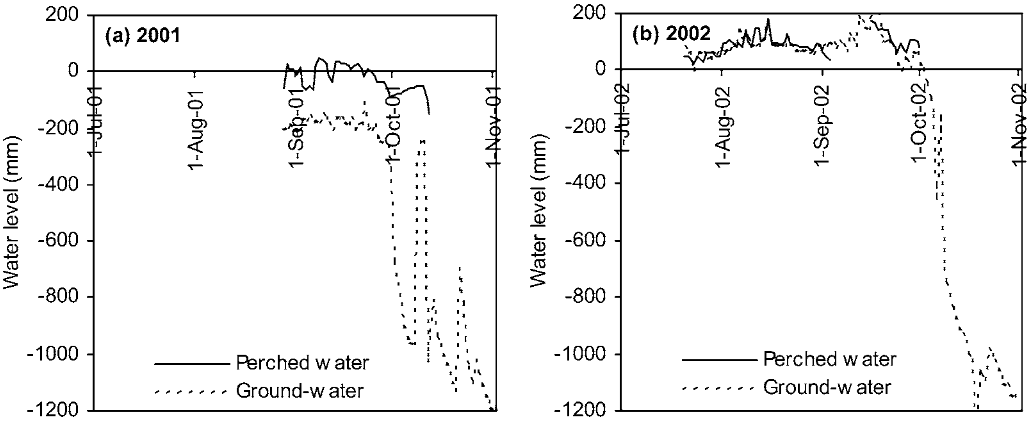

Fig. 3. Examples of perched water and groundwater levels in Savannakhet province, Laos

Table 1. Percolation and lateral water flow (mm/day) for the Thailand experiments.

| | Texture (%) | | (a) Percolation | | | | (b) Lateral water flow | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Location | Sand | Clay | Min | Max | Mean | SD | Min | Max | Mean | SD |
| Chum Phae | 20 | 59 | 0.5 | 0.8 | 0.6 | 0.2 | -38.4 | 52.8 | 0.8 | 9.8 |
| Khon Kaen/Ta Pra | 13/21 | 62/56 | 0.5 | 3.3 | 1.7 | 1.4 | -73.1 | 46.8 | -0.1 | 16.2 |
| Phimai | 29 | 52 | 1.2 | 2.7 | 1.9 | 0.8 | -71.3 | 20.8 | -3.5 | 11.9 |
| Surin | 8 | 78 | 1.2 | 2.0 | 1.6 | 0.3 | -151.7 | 113.0 | 1.9 | 28.2 |
| Ubon Ratchathani | 5 | 82 | 1.4 | 5.1 | 3.0 | 1.6 | -50.3 | 69.6 | 2.2 | 19.1 |

the time when there was standing water in the field. The period of estimation did not include any days when the fields were flooded, so O was assumed to be nil. The total amount of E and T is assumed to be equal to potential evapotranspiration (PET). PET was calculated using weather data for the 2000 season at Khon Kaen, Thailand, and this was used for the study area in northeast Thailand. P was determined during a period before standing water disappeared, using linear regression analysis of cumulative percolation. Fig. 2 shows an example of the linear regression. Then, P was assumed to be constant during the three months for each experiment.

## Results and Discussion

### 1. Water tables

Paddy fields can be classified into two types with respect to water availability. Some paddy fields have only one water table, while others have separate perched water and a groundwater table or both as shown for Savannakhet province, Laos, during the 2001 season (Fig. 3). By contrast, readings of the perched water table meter mostly overlapped those of the groundwater table meter during the 2002 season, suggesting that there was continuous free water through the soil profile. In Thailand, both perched water and groundwater tables were observed at most of the Ubon Ratchathani fields during the season, while the other four locations (Chum Phae, Khon Kaen/Ta Pra, Phimai and Surin) had mostly no perched water.

### 2. Percolation rate

The fields in Thailand, Ubon Rachathani and Chum Phae had the highest and lowest mean values of percolation rate, respectively, as shown in Table 1a. Those in Khon Kaen/Ta Pra had high variation in percolation rate although the mean value was very similar to those for the other two locations (Phimai and Surin). The mean values at Chum Phae, Khon Kaen/Ta Pra, Phimai and Surin ranged between 0.6 and 1.9 mm/day and these are in agreement with the values of 1.5, 1.0, 1.5 and 0.0 mm/day for Chum Phae, Khon Kaen/Ta Pra, Phimai and Surin, respectively as reported by Fukai et al., (1995) for the same areas. The mean value for Ubon Ratchathani was a half the value (6.0 mm/day) for the same area reported by Fukai et al., (1995); however, this high value was similar to the maximum value determined in this study (5.1 mm/day). Percolation rates at three (top, middle and bottom) positions of the toposequence for Savannakhet province, Laos were 3.3, 2.6 and 1.9 mm/day, respectively. At Ta Pra, percolation rate was also greater at the high position than at the low position. Thus, the higher position in the topoesquence, the greater percolation loss, which may be related to its lighter soil texture.

### 3. Lateral water flow

The lateral water flow for five locations of Thailand is presented in Table 1b. Mean values indicate that Chum Phae, Surin and Ubon Ratchathani had net water loss/outflow (positive values); in contrast, Khon Kaen/Ta Pra and Phimai had net water gain/inflow (negative values). The means and standard deviations ranged between – 3.5 and 2.2 mm/day and between 9.8 and 28.2 mm/day, respectively. The high standard deviation indicates high variation in the lateral water movement during the season, as lateral flow rate varied greatly with rainfall events. The average maximum value for the five locations was very high (60 mm/day). Tuong et al., (1994) also reported a high value of the lateral water outflow. They indicated that this high flow was due to the under-bund percolation. There was also a difference in the lateral flow at the different positions in the toposequence. The means and the standard deviations for the high and low positions of the toposequence at Ta Pra were − 0.9 ± 9.8 mm/day and − 4.0 ± 17.6 mm/day, respectively, indicating that fields in low landscape position have potentially high lateral water inflow. A similar result was found in the lateral water flow in Savannakhet province, Laos.

## Conclusions

A method of quantifying components of the water balance for paddy fields in sloping landscapes in rainfed rice systems was described. It allows for the modelling of water availability in the toposequence of rainfed systems by, in addition to measuring rainfall and evapotranspiration, also measuring percolation which is an important component of the water budget. The percolation rate determined in this study for a number of rainfed lowland sites in Thailand agrees with the previously reported values. The maximum values of the lateral water flow were very high with values of more than 20 mm/day. The methodology also was able to measure different rates of percolation from different positions on the toposequence. The higher the position on the sloped land, the greater the potential of the water losses. Thus, paddies at the lower position gain more water than those at the higher position. In other words, there is high water availability to crops grown at the lower position.

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