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“Litter marks” indicating infiltration area of stemflow-induced water

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Abstract

We found out “litter marks” around the tree bases, which have the shape like circle. These litter marks seem to be caused by the infiltration excess overland flow due to higher intensity of stemflow than the infiltration capacity of surface soil. It is suggested that the litter marks can be a useful indicator to estimate the infiltration area of stemflow-induced water.

Key words: groundwater recharge, infiltration excess, litter mark and stemflow

1. Introduction

Forest canopy intercepts rainfall and the intercepted rainfall is partitioned into throughfall and stemflow. These two components have different infiltration patterns significantly. Throughfall, which drips from the canopy wetted by rainfall or reaches the forest floor directly without contact with the canopy, is highly spatial diffused inputs on the forest floor. Stemflow is yielded by the intercepted rainfall and funnels down along the stem, meaning concentrated point inputs around the tree base.

This concentrated inputs of stemflow has been considered as an important source for the groundwater recharge (*e.g.* Durocher, 1990; Tanaka *et al.*, 1991). However, there are few studies clarifying the contribution of stemflow-induced water on the groundwater recharge except for Tanaka *et al.* (1996) and Taniguchi *et al.* (1996). The main reason is the difficulty to evaluate the infiltration area of the stemflow-induced water (A_i), which is needed to calculate the groundwater recharge amount as a unit of water column, R_s (*i.e.* R_s = amount of stemflow/A_i). Although Tanaka *et al.* (1991) evaluated A_i based on the data of “infiltration area mark”, this phenomenon is rarely observed because the infiltration area mark of stemflow-induced water is often difficult to distinguish from the infiltration area of throughfall. Therefore, it is necessary to find the simple and facile methods for the evaluation of A_i to evaluate the recharge amount by the stemflow-induced water.

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We looked around the tree bases and found out “litter marks” which have the shape like circle. It seems that litter marks result from the movement of the litter due to higher intensity of stemflow than the infiltration capacity of surface soil, that is the infiltration excess overland flow. Assuming that the stemflow-induced water percolates in the vertical direction, the infiltration area of stemflow (A_i) can be estimated by the area of the infiltration excess overland flow (A_o) (*i.e.* $A_i = A_o$). Herwitz (1986) also evaluated A_i from the observed data of stemflow intensity and infiltration capacity of surface soil in a tropical rain forest ($A_i = A_o$ = intensity of stemflow / infiltration capacity). The purpose of this paper is to describe the phenomenon of litter marks and to compare the extent of litter marks with the infiltration area marks by Tanaka *et al.* (1991) for evaluating the availability of litter marks to estimate A_i.

2. Method

In March 2005, we observed the litter marks of Formosa sweet gum (*Liquidambar formosana* Hance) and two species of evergreen oak (*Quercus myrsinaefolia* Blume and *Quercus phillyraeoides* A. Gray) within the campus of Univ. Tsukuba. Figures 1–3 show the litter mark found around the tree base of Formosa sweet gum and evergreen oaks, respectively. It is obvious from these figures that the shape of the litter marks shows an almost circle. The radius of litter mark and the diameters at breast height (*DBH*) and at the tree base (*DTB*) were determined by tape measures. Hourly amounts of gross rainfall were obtained from the routine observation data of the Terrestrial Environment Research Center (TERC), Univ. Tsukuba.

3. Results and discussion

3.1 Possible formation process of litter marks

The observed shape of the litter marks was an almost circle (Figs. 1–3), and corresponded with the shape of infiltration area marks of stemflow reported by Tanaka *et al.* (1991). During the rainfall event on 23 March 2005, the infiltration excess overland flow was observed around the tree base of Formosa sweet gum as shown in Fig. 4. From onset of the rainfall (22 March 2005) to the time when Fig. 4 was taken, 18 mm of gross rainfall was recorded, and the rainfall intensity was 1.5 mm/h

Fig. 1 Litter mark around the tree base of Formosa sweet gum (*Liquidambar formosana* Hance). Photo was taken on 10 March 2005.

Fig. 2 Litter mark around the tree base of evergreen oak (*Quercus myrsinaefolia* Blume). Photo was taken on 9 March 2005.

Fig. 3 Litter mark around the tree base of evergreen oak (*Quercus phillyraeoides* A. Gray). Photo was taken on 10 March 2005.

at this time. The total amount of rainfall of this event was 38 mm, and the maximum and mean rainfall intensities were 6.5 and 1.1 mm/h, respectively (Table 1). Iida *et al*. (2005) reported that the annual mean rainfall intensity ranged from 1.2 to 1.4 mm/h for the two common years at TERC. There is little difference between the annual mean rainfall intensities and the rainfall intensity of 1.5 mm/h on 23 March 2005. This fact implies that the infiltration excess overland flow could occur so often in this study site. Another possible important factor affecting the area of infiltration excess overland flow is the impact of raindrop energy on the forest floor. Nanko *et al.* (2004) pointed out that total energy of raindrop impact of throughfall was over twice that of gross rainfall, and suggested that such large energy of raindrop impact of throughfall could increase the occurrence of surface erosion on a bare ground surface. In the case of this study, however, ground surface was covered entirely by litter fall before appearing the litter marks. Therefore, it is considered that the impact of raindrop energy on the extension of the litter marks may not be so large in this site.

The observed litter marks could correspond to the largest rainfall event after the end of fall in 2004, when Formosa sweet gum had defoliated and the material of litter has been provided on the forest floor. The largest rainfall event was recorded from 15 to 16 January 2005, and the total amount of gross rainfall and the mean rainfall intensity were 88.5 mm and 2.3 mm/h, respectively (Table 1). This mean rainfall intensity was 1.5 times larger than 1.5 mm/h, when the infiltration excess overland flow was observed on 23 March, 2005 (Fig. 4). It is appropriate to consider that the observed litter marks occurred during the maximum rainfall event after the defoliation.

Table 1 Characteristics of rainfall for the events in January and March, 2005. The former is the largest event after the defoliation of Formosa sweet gum, and the latter is the event when Fig. 4 was taken.

Event name (start and end date)	20050115−0116	20050322−0323
Rainfall amount (mm/event)	88.5	38.0
Rainfall duration time (hour)	38	36
Maximum rainfall intensity (mm/h)	9.5	6.5
Mean rainfall intensity (mm/h)	2.3	1.1

3.2 Relationship between diameter at tree base and radius of litter mark

Tanaka *et al.* (1991) clarified that there was a logarithmic relationship between *DTB* and the infiltration area mark of stemflow inputs. The observed litter marks also have similar relationship with *DTB* as shown in Fig. 5.

Fig. 4 Occurrence of the infiltration excess overland flow by stemflow-induced water for Formosa sweet gum. Photo was taken on 23 March 2005 when the rainfall intensity was 1.5 mm/h.

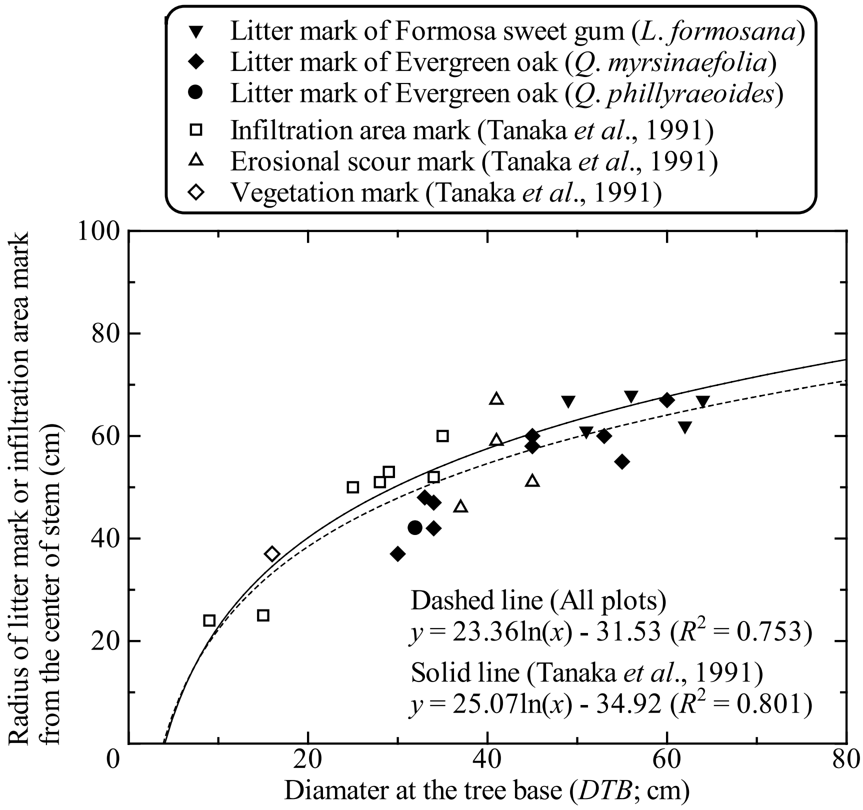

Fig. 5 Relationships between the diameter at the tree base and the radius of litter mark or infiltration area mark from the center of the stem.

Including the data cited from Tanaka *et al.* (1991), we obtained the following relationship:

$$y = 23.361n(x) - 31.53 \quad (1)$$
$$R^2 = 0.753$$

where x is *DTB* (cm) and y the radius of infiltration area of stemflow inputs and litter marks from the center of the stem (cm). The essentially similar relationship as Tanaka *et al.* (1991) suggests that litter mark is a useful indicator of A_i.

4. Concluding remarks

It can be suggested that the infiltration area of stemflow-induced water (A_i) is estimated by the litter marks. Litter marks result from the infiltration excess overland flow caused by stemflow-induced water, and the extent of the litter mark depends on the intensity of stemflow and the magnitude of infiltration capacity. The observed litter marks are attributed to the rainfall event with the maximum stemflow yielded after the defoliation. Although the relationship between the diameter at the tree base and the radius of litter mark almost corresponds to that reported by Tanaka *et al.* (1991), the rainfall amount and intensity are different each other. Therefore, it is necessary to clarify the relationship between the intensity of stemflow and the infiltration capacity in a future study, to use the litter mark for the estimation of A_i.

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