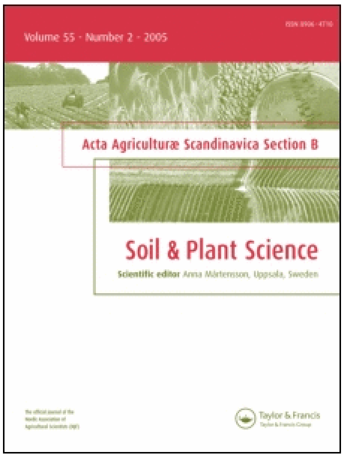

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SHORT COMMUNICATION

Evergreen broad-leaved forest improves soil water status compared with tea tree plantation in Ailao Mountains, Southwest China

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Abstract

In this paper, the spatial-temporal dynamics of soil moisture content was investigated in an evergreen broad-leaved forest and a tea tree plantation in Ailao Mountains, which was dominated by Fagaceae (*Castanopsis wattii* and *Lithocarpus xylocarpus*). Soil moisture content was studied between January 2005 and December 2006 at different depths (from 0–150 cm) with a neutron probe. The results showed that mean soil moisture content in the evergreen broad-leaved forest was usually higher than in the tea tree plantation in the dry season, whereas it was lower than the tea tree plantation in the rainy season. In addition, mean soil moisture content was depth dependent, and in the 10–50 cm layer the spatial variability was due to the active root zone within this depth area in two types of land use. From 50–150 cm, the spatial variability was slightly increasing in the evergreen broad-leaved forest or relatively stable in the tea tree plantation. Our study also showed that soil moisture content was higher and more stable under the evergreen broad-leaved forest than the tea tree plantation, hence we stress that evergreen broad-leaved forest plays an important role in holding soil moisture. It is suggested that the protection of evergreen broad-leaved forest should be strengthened.

Keywords: *Ecological protection, soil water deficit and recharge, spatial variability, temporal dynamics, two-year comparison.*

Introduction

Soil moisture is a key state variable for a wide variety of hydrological processes acting under a range of spatial and temporal scales. Soil moisture in the root zone of a particular species also serves as an intermediary between rainfall and plant-available water (Breshears & Barnes, 1999; Loik et al., 2004). Field studies indicate that differences in interception, infiltration and evapotranspiration related to ecosystem type can lead to soil moisture variations (Kurc & Small, 2004; Gutierrez-Jurado et al., 2007; Vivoni et al., 2007). Therefore it is evident that a thorough understanding of the soil moisture is of primary importance for soil hydrological research and land-use management (Lunt et al., 2005). As is known, tea tree plantations are more popular and occupy more land area in recent years in Yunnan province due to the great profits; however comparative studies of the effects of evergreen broad-leaved species on land use, relative to tea plants, are very scarce. Evergreen broad-leaved forest is mainly distributed in the east shore of subtropical areas, with the biggest area in China (Zhou, 2004). Ailao Mountain National Natural Reserve of 504 km^2 is suggested to be the largest tract of natural evergreen broad-leaved forest in China (Liu et al., 2002), with the evergreen broad-leaved forest occurring at 2200–2600 m, and the dominant species being *Castanopsis wattii* and *Lithocarpus xylocarpus* (Qiu, 1997). Studies on soil moisture in this area are very rare.

The spatio-temporal variability of soil moisture is influenced by topographic features (Nyberg, 1996), soil properties (Crave & Gascuel-Odoux, 1997), vegetation types (Mohanty et al., 2000), land use (Famiglietti et al., 1999) and climatic fluctuations

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(Hupet & Vanclooster, 2002). The observed soil moisture variability within a field is likely to reflect the combined influences of the above-mentioned factors acting at different spatial scales. In this paper, soil moisture contents were measured with a neutron probe. The main objectives of this paper are (1) to analyse the temporal dynamics of the soil moisture spatial variability and to probe the role of governing factors for the different soil depths and (2) to assess the impact of different vegetation types on soil water recharge of the Ailao Mountains.

Materials and methods

The study site was located at Xujiaba (24°32′N, 102°01′E, 2400–2600 m) within the centre of Ailaoshan National Natural Reserve. Six experimental sites were in a 10 000 m^2 evergreen broad-leaved forest within 100 m of each other, and two experimental sites in a 1200 m^2 tea tree plantation. All experimental sites were located on land sloping at $<2°$ and at an attitude of 2500 m above sea level. The station (Ailaoshan Station for Subtropical Forest Ecosystem Studies), affiliated to Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, is a member of both the Chinese Ecosystem Research Network (CERN) and the Chinese National Ecosystem Observation and Research Network (CEORN).

According to the Ailao Mountain Station, the mean annual precipitation is 1931 mm with 85% from May to October. Mean annual evaporation is 1485 mm. Mean annual temperature is 11.3°C, which of the warmest month (July) is 16.4°C and the coldest (January) is 5.4°C. The frost-free period is 200 days. Soils are typically yellow-brown earths developed over schist, gneiss and diorite. Soil texture is loam, with acidic pH (4.4–4.9). A litter layer (3–7 cm thick) covers almost all the soil surface. Surface organic C, total N and total P are 12.91, 0.52 and 0.06%, respectively. The exchangeable K is 0.69 meq 100 g^{-1}. C/N ratio varies from 14.4 to 15.3 at the surface at 30–50 cm depth (Qiu, 1997; Liu et al., 2002).

The investigation for the vegetation was done in December 2005, which included the height, diameter at breast height (dbh) and species of every tree, and the species and density of the shrub layer and the herb layer. The canopy was very dense in the evergreen broad-leaved forest in Ailao Mountain, which was obviously composed of tree layer, shrub layer and herb layer. The dominant species were *Castanopsis wattii* and *Lithocarpus xylocarpus*, and the average height of the trees above 25.0 m, with the highest tree 32.0 m, and the density was above 85%. The bamboo (*Sinarundinaria nitida*) accounted for most of the shrub layer, with the density about 35%. There were mainly *Plagiogyria communis* and *Carex teinogyna* in the herb layer. Epiphytes were very abundant, these being mainly *Aeschynanthus buxifolius* and *Araiostegia perdurans*. Vines were also common, mainly *Kadsura coccinea* and *Embelia procumbens*.

About 18 trees (*Vaccinium duclouxii*) were in the tea tree, 2.1–4.6 m in height. *Camellia sinensis* occupied most ground, 0.2–1.9 m in height and above 80% in density. And the dominant grass was *Agrostis myriantha*. There were no epiphytes and vines in the tea plantation plots. These tea trees were weeded and fertilized every year.

Soil water content was monitored with a neutron probe (CNC503DR, China) according to the method of Bell (1973). The probe was calibrated against volumetric gravimetric moisture content determinations in the local soil over a wide range of moisture content in December in 2005 and 2006. Readings were taken once every 5-day intervals in the evergreen broad-leaved forest and once every 10-day intervals in the tea tree plantation between January 2005 and December 2006. Water content was measured in six access tubes in the evergreen broad-leaved forest and in two access tubes in the tea tree plantation at 0.1 m intervals to a depth of 0.5 m, then at 0.2 m intervals to 1.5 m.

Results and discussion

Temporal changes in soil water content

Total precipitation over two years was 3135.5 mm, however it was drier in 2006 (1348.1 mm) than 2005 (1787.4 mm), and the precipitation of May–October occupied 86.5% of the total precipitation (Figure 1). Figure 2 indicates that although the temperature was higher and the plants needed more water in June–October, the soil water content was higher due to abundant rain; hence precipitation played an important role on the soil moisture content; however this role lagged behind the rainfall, especially in evergreen broad-leaved forest. The reason was that the deeper litter layer reduced the rate of water permeating in evergreen broad-leaved forest. As a result, although the precipitation was highest in May–June, the highest soil moisture content emerged in July–August. Although the soil water was lost gradually in November–January in both plots, the soil water content was still higher for lower evapotranspiration and less rainfall. Because of evapotranspiration and scarceness of rain, the lowest soil water content was found in May in the same year. These results were in accordance with Yin et al. (2003). Compared with the tea tree plantation, there

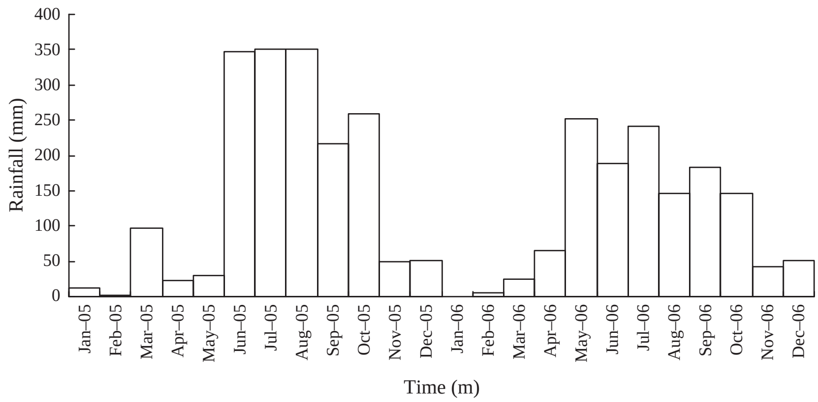

Figure 1. Monthly rainfall from January 2005 to December 2006.

was a deeper litter layer and denser canopy in evergreen broad-leaved forest; therefore it showed that the mean soil moisture content in evergreen broad-leaved forest was usually higher than tea tree in dry season, whereas it was lower than tea tree in the rainy season.

Spatial changes in soil water content

Figure 3 showed the spatial variance of the mean soil moisture content under different depths, and it revealed the mean soil moisture content was depth dependent. Indeed, in the two types plots, for the 0–20 cm layer the mean soil moisture content was between 0.20–0.40, for the 20–30 cm was 0.30–0.40, for the 30–50 cm was 0.30–0.45, and for the 110 cm was 0.35–0.42 $cm^3\,cm^{-3}$. Loague (1992) also observed similar results. The soil moisture content of the 0–10 cm layer was the smallest with a maximum standard deviation in 0–150 cm depths in the two plots. For the 10–50 cm layer which can be considered as the active root-zone (Singhl et al., 1998), the spatial variability tended to decrease with depth in the evergreen broad-leaved forest. In the tea tree plantation, although the trend was different from the evergreen broad-leaved forest, the spatial variability could also be explained by the active root-zone from 0–50 cm layer (Singhl et al., 1998). In light of these results, it is not surprising that terrain indices would in some cases perform weakly in explaining soil moisture variability as was observed by Western et al. (1999). However from 50–150 cm, we observed that the spatial variability was slightly increasing in evergreen broad-leaved forest or relatively stable in the tea tree plantation during the experiment. As a matter of fact, because the main factors controlling the temporal dynamics of the soil moisture variability at this scale were acting mainly on the superficial layers, it is not surprising the results were different from other studies (Singhl et al., 1998).

Soil moisture deficit and recharge

In the negative balance (January–May), the soil moisture deficit appeared, and the rate of decrease of water content of the uppermost 150 cm of soil was much greater under tea tree than evergreen

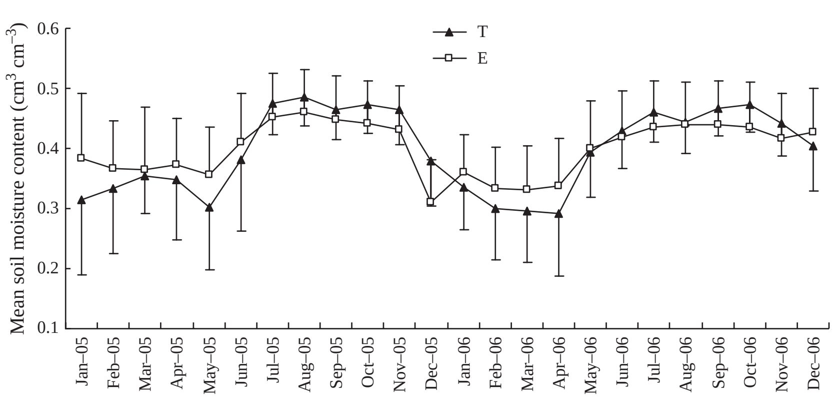

Figure 2. Mean soil moisture content in 2005–2006 in two plots: (E) evergreen broad-leaved forest; (T) tea tree plantation. Data are the means $\pm$ SE (n = 3).

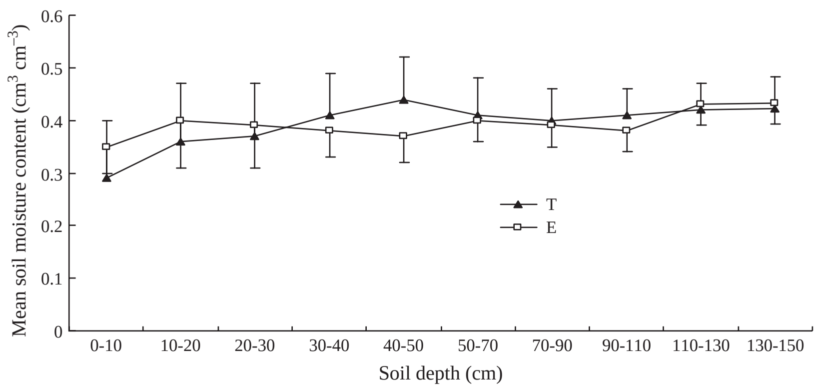

Figure 3. Mean soil moisture content of different depths in 2005–2006 in two plots: (E) evergreen broad-leaved forest; (T) tea tree plantation. Data are the means $\pm$ SE (n = 3).

broad-leaved forest. In the positive balance (June–October), the soil was recharged by the bigger rain, and the rate of increase under tea tree was greater than evergreen broad-leaved forest. Furthermore the mean soil moisture content was larger under evergreen broad-leaved forest (0.399 ± 0.045 cm^3 cm^{-3}) than under tea tree (0.396 ± 0.069 cm^3 cm^{-3}). Hence, the soil moisture was more stable and there was more soil moisture content under evergreen broad-leaved forest than tea tree. Indeed the evergreen broad-leaved forest played an important role on holding the soil moisture while the land use (tea tree plantation) did not help to keep soil moisture; therefore people must be careful when they grow tea plants for monetary profit. It is suggested that the protection of evergreen broad-leaved forest should be strengthened.

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