



Impacts of understory species removal and/or addition on soil respiration in a mixed forest plantation with native species in southern China

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ABSTRACT

Although the removal or addition of understory vegetation has been an important forest management practice in forest plantations, the effects of this management practice on soil respiration are unclear. The overall objective of this study was to measure and model soil respiration and its components in a mixed forest plantation with native species in south China and to assess the effects of understory species management on soil respiration and on the contribution of root respiration (R_r) to total soil respiration (R_s). An experiment was conducted in a plantation containing a mixture of 30 native tree species and in which understory plants had been removed or replaced by *Cassia alata* Linn. The four treatments were the control (Control), *C. alata* addition (CA), understory removal (UR) and understory removal with *C. alata* addition (UR+CA). Trenched subplots were used to quantify R_r by comparing R_s outside the 1-m² trenched subplots (plants and roots present) and inside the trenched subplots (plants and roots absent) in each treatment. Annual soil respiration were modeled using the values measured for R_s , soil temperature and soil moisture. Our results indicate that understory removal reduced R_s rate and soil moisture but increased soil temperature. Regression models revealed that soil temperature was the main factor and soil moisture was secondary. Understory manipulations and trenching increased the temperature sensitivity of R_s . Annual R_s for the Control, CA, UR and UR+CA treatments averaged 594, 718, 557 and 608 g C m⁻² yr⁻¹, respectively. UR decreased annual R_s by 6%, but CA increased R_s by about 21%. Our results also indicate that management of understory species increased the contribution of R_r to R_s .

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1. Introduction

The effects of forest management on soil respiration (R_s) in forest plantations are still largely unknown yet crucial to both our understanding and management of global carbon flux (Concilio et al., 2005). In southern China, forest plantations represent an important land use category (China State Forestry Bureau, 2005). Although monoculture plantations of *Eucalyptus urophylla* or *Acacia mangium* prevail in this region, mixed plantations with native species are increasing. Understory vegetation removal or replacement by a selected species is a common management practice of forest plantations in southern China. The understory vegetation removal can reduce the competition between canopy species and understory species. Many studies have found that this practice has important impacts on biological and/or environmental parameters

such as soil water content, soil temperature, and thus evapotranspiration (Kelliher et al., 1986), tree growth and soil N cycling (Gurlevik et al., 2004; Matsushima and Chang, 2006, 2007) and soil properties (Perie and Munson, 2000; Xiong et al., 2008). Furthermore, addition of understory species such as *Cassia alata* Linn., a rapidly growing and potentially N fixing shrub after understory removal, has found to increase soil fertility in the plantations (Li et al., 2010a). However, very few studies have directly examined the effects of such understory removal or addition treatment on soil respiration of forest plantations, especially a mixed native species plantation in southern China.

As an important component of ecosystem respiration, soil respiration plays a critical role in the global carbon cycle (Raich and Schlesinger, 1992; Bond-Lamberty and Thomson, 2010). Soil respiration is the sum of autotrophic (root) respiration (R_r) and heterotrophic (microbes, soil fauna) respiration (R_h). Partitioning soil respiration into R_r and R_h is important to understand the mechanisms controlling carbon exchange between soil and the atmosphere (Hanson et al., 2000; Li et al., 2005) as well as to esti-

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mate net ecosystem productivity (NEP). We used trenched subplots (plants and roots absent) to estimate R_h (Rey et al., 2002; Boone et al., 1998). Although trenching method is labor intensive and needs some time to allow the decomposition of the roots inside the trenched plots after trenching, it is convenient and can be carried out in most ecosystems (Rey et al., 2002; Sayer and Tanner, 2010). Soil respiration is primarily influenced by environmental factors such as soil temperature and soil moisture (Davidson et al., 1998; Chen et al., 2000; Li et al., 2006) as well as biotic factors such as plant metabolism (Hogberg et al., 2001; Rey et al., 2002) or the decomposition of recently produced organic material (Trumbore, 2000; Giardina et al., 2004). Harvesting management in uneven-aged managed forests affected soil respiration through changes in tree root respiration (Peng and Thomas, 2006). Thus understory management was expected to influence soil respiration as the result of the changes in soil environments and root dynamics. However, it is poorly known how understory management treatment such as removal and/or addition may influence the soil respiration of a mixed forest plantation of native species in southern China.

Dicranopteris dichotoma (Thunb.) Bernh and *Miscanthus sinensis* Anderss are the two most dominant understory species in forest plantations in southern China. In newly established mixed plantations of native species, these understory species can reach as high as 1 m and cover most ground surface, hence they directly compete resources such as light, water and nutrient with native overstory species. In this study, the effects of understory vegetation removal or/and replacement on soil respiration in a mixed forest plantation of native species were examined. For understory replacement, we planted *C. alata*, a rapidly growing and potentially N fixing shrub, to replace the original herbages after slashing. Furthermore a trenching method was used to partition soil respiration into heterotrophic and autotrophic respiration (Hanson et al., 2000; Li et al., 2005). We hypothesized that understory removal would increase soil temperature, decrease soil moisture, and decrease soil respiration. We also hypothesized that *C. alata* addition would have the opposite effects. The objectives of this study were to: (1) describe the seasonal pattern of R_s and the effects of understory removal and addition on R_s dynamics; (2) quantify the relationship between soil respiration and soil environment factors, i.e., soil temperature and soil moisture; (3) estimate annual R_s , R_h and R_f in this ecosystem and to assess the effects of understory removal and addition on the contribution of R_f to R_s .

2. Materials and methods

2.1. Study site description and experimental design

The study was conducted at Heshan Hilly Land Interdisciplinary Experimental Station (112°50'E, 22°34'N), Guangdong province, China, where a large-scale and long-term manipulative experiment was carried out in 2005. The experimental site covers an area of 50 ha. The climate of the region is characterized by the typical subtropical monsoon with a distinct wet season from March to September and a dry season from October to February. The mean annual precipitation of the site was 1290 mm between 1984 and 2007 and the average temperature was 21.7 °C. The soil is a Acrisol (FAO, 2006) or lateritie (Chen et al., 2009). The study was conducted in a mixed forest plantation composed by 30 native tree species, including *Magnoliaceae glanca* Blume, *Liquidambar formosana* Hance and *Tsoongiodendron odorum* Chun, etc. The saplings were planted at 3 m × 2 m spacing in 2005. The trees were about 4 years old, 2.2 cm in breast-height diameter and 2.4 m in height when the current experiment was started in 2008. The canopy coverage was about 53%. Understory vegetation were dominated by *D. dichotoma* (Thunb.) Bernh and *M. sinensis* Anderss with few shrub

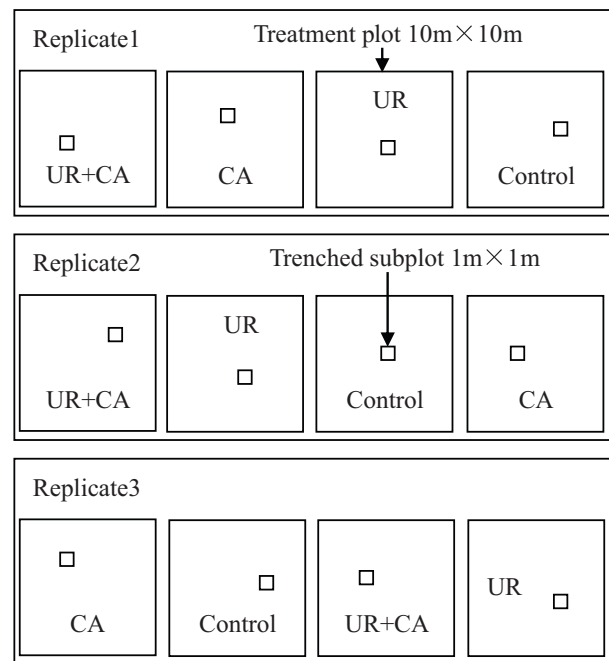


Fig. 1. Layout of the experimental site: four 10 m × 10 m treatment plots were randomly assigned to each of three replicates with a 1 m buffer around. Treatments were (1) Control, (2) *Cassia alata* Linn. addition (CA), (3) understory removal (UR), and (4) understory removal with *C. alata* addition (UR+CA). A 1 m × 1 m trenched subplot was set in each plot.

species such as *Melastoma candidum*, *Rhodomyrtus tomentosa* and *Ilex asprella*.

A 2 × 2 factorial design with three replicates for each treatment was used in April 2008. The four treatments were the control (Control), *C. alata* addition (CA), understory removal (UR) and understory removal with *C. alata* addition (UR+CA). Four treatment plots (10 m × 10 m) were randomly established in each of the three replicated plantation with a 1 m buffer zone to eliminate the edge effects (Fig. 1). Each plot contained a 1 m × 1 m trenched subplot. The size of the subplot was in the range of reported in different studies (Epron et al., 1999; Rey et al., 2002; Lee et al., 2003; Li et al., 2004; Zhou et al., 2007). We refer to the 10 m × 10 m plots as untrenched plots and to the 1 m × 1 m subplots as trenched subplots (Fig. 1). The subplots were trenched to a depth of 0.5 m (deeper than the bottom of the root zone of this young plantation) with care to minimize soil disturbance. PVC sheets were installed to prevent lateral root entry and to minimize nutrient and water exchange. Trenches were back-filled with the same soil. All understory manipulations were completed in March 2007. *C. alata* was planted in both CA and UR+CA treatments with a spacing of 1 m × 1 m. Trenching was completed in early April 2008. All vegetation was removed from the trenched subplots throughout the experiment. Native understory vegetation in the UR and UR+CA plots were removed by hand with help of machete knife frequently and carefully without disturbing the soil so that understory vegetation was continuously absent during the experimental period.

2.2. Soil respiration, temperature and moisture measurements

One PVC soil collar with 20 cm in diameter and 6 cm in height was inserted 3 cm into the soil in each trenched subplot. Another PVC collar was inserted 3 cm into the soil and 2 m outside of the trenched subplot but within the untrenched plot. We referred the soil respiration rates measured from trenched subplots to heterotrophic respiration (R_h) because there were no roots and plants

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