



Temperature sensitivity of total soil respiration and its heterotrophic and autotrophic components in six vegetation types of subtropical China



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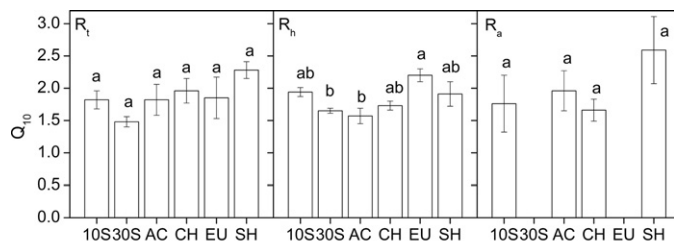
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HIGHLIGHTS

- Soil temperature is not a key driver of seasonal variations in R_a .
- The temperature sensitivity of R_h was significantly affected by vegetation type.
- Vegetation type had minor effects on the temperature sensitivity of R_t and R_h .
- Q_{10} of R_t and its components were related to different environmental variables across six vegetation types.

GRAPHICAL ABSTRACT



We examined the effects of vegetation type on the temperature sensitivity (Q_{10}) of total soil respiration (R_t), heterotrophic respiration (R_h) and autotrophic respiration (R_a). Vegetation types included a mixed plantation of 10 tree species (10S), a mixed plantation of 30 tree species (30S), an *Acacia crassicarpa* monoculture (AC), a *Castanopsis hystrix* monoculture (CH), a *Eucalyptus urophylla* monoculture (EU) and a shrub and herb land (SH). Some Q_{10} values were missed for R_a because of the nonsignificant relationship between soil temperature and R_a .

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ABSTRACT

The temperature sensitivity of soil respiration (Q_{10}) is a key parameter for estimating the feedback of soil respiration to global warming. The Q_{10} of total soil respiration (R_t) has been reported to have high variability at both local and global scales, and vegetation type is one of the most important drivers. However, little is known about how vegetation types affect the Q_{10} of soil heterotrophic (R_h) and autotrophic (R_a) respirations, despite their contrasting roles in soil carbon sequestration and ecosystem carbon cycles. In the present study, five typical plantation forests and a naturally developed shrub and herb land in subtropical China were selected for investigation of soil respiration. Trenching was conducted to separate R_h and R_a in each vegetation type. The results showed that both R_t and R_h were significantly correlated with soil temperature in all vegetation types, whereas R_a was significantly correlated with soil temperature in only four vegetation types. Moreover, on average, soil temperature explained only 15.0% of the variation in R_a in the six vegetation types. These results indicate that soil temperature may be not a primary factor affecting R_a . Therefore, modeling of R_a based on its temperature sensitivity may not always be valid. The Q_{10} of R_h was significantly affected by vegetation types, which indicates that the response of the soil carbon pool to climate warming may vary with vegetation type. In contrast, differences in neither the Q_{10} of R_t nor that of R_a among these vegetation types were significant. Additionally, variation in the Q_{10} of R_t among vegetation types was negatively related to fine root biomass,

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whereas the Q_{10} of R_h was mostly related to total soil nitrogen. However, the Q_{10} of R_a was not correlated with any of the environmental variables monitored in this study. These results emphasize the importance of independently studying the temperature sensitivity of R_t and its heterotrophic and autotrophic components.

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1. Introduction

Total soil respiration (R_t) is one of the most important ecological processes, because it is the second largest carbon flux in terrestrial ecosystems (Schlesinger and Andrews, 2000) and has the potential to induce considerable variation in atmospheric carbon dioxide concentration in a world with changing climate (Andrews et al., 1999). The temperature sensitivity of R_t has been widely used to estimate the feedback intensity of R_t to increasing temperature (Reichstein et al., 2003; Davidson and Janssens, 2006). The Q_{10} value, a proportional change in soil respiration with a 10 °C increase in temperature, is one of the most common parameters used to describe the temperature sensitivity of soil respiration.

Most of the previous studies on the temperature sensitivity of soil respiration have focused on R_t . However, R_t is overwhelmingly constituted of heterotrophic (R_h) and autotrophic respiration (R_a), which could respond differently to different environmental variables (Gaumont-Guay et al., 2008; Savage et al., 2013; Matteucci et al., 2015) and make distinct contributions to soil carbon sequestration (Kuzaykov, 2006). In addition, previous studies have shown that R_h and R_a exhibit different temperature sensitivities (e.g. Boone et al., 1998; Rey et al., 2002), which indicates that they respond differently to global warming, and this consequently increases the uncertainty in attempting to estimate future changes in the soil carbon pool. According to the Arrhenius equation and Michaelis–Menten kinetics, the difference in temperature sensitivity between R_h and R_a may be attributed to differences in substrate availability (Davidson and Janssens, 2006; von Luetzow and Koegel-Knabner, 2009). Additionally, temperature sensitivity estimates based on field monthly measurements include not only the response of soil respiration to soil temperature (ST) but also to other ecological processes such as litter fall and root growth (Davidson et al., 1998; Vargas and Allen, 2008). Consequently, both the different dominant drivers of R_h and R_a and the asynchronous dynamics of these drivers may also contribute to the differences in temperature sensitivity.

Early soil respiration models treated Q_{10} as a spatially invariant value (Aber et al., 1997; Tian et al., 1999; Friedlingstein et al., 2006), which could introduce bias regarding feedback intensity (Zhou et al., 2009). Recent studies have revealed that the Q_{10} of R_t is highly variable at both global and local scales (Lenton and Huntingford, 2003; Peng et al., 2009; Xu et al., 2015). Vegetation type is one of the most common variables related to the variation of Q_{10} (Raich and Tufekcioglu, 2000; Song et al., 2013; Diaz-Pines et al., 2014). The Q_{10} of R_t is affected by both soil and plant attributes, including soil water content (SWC) (Wen et al., 2006; Yan et al., 2013), ST (Wen et al., 2006), soil organic matter (Zheng et al., 2009), plant photosynthesis and productivity (Boone et al., 1998; Wan and Luo, 2003; Subke and Bahn, 2010), and plant phenology (Yuste et al., 2004; DeForest et al., 2006).

There have, however, only been a few studies that have focused on the effects of vegetation type on the temperature sensitivity of R_h and/or R_a in the field. Currently, there is no consensus on whether vegetation type affects the temperature sensitivity of R_h and R_a . Some studies have reported a positive effect of vegetation type on the Q_{10} of R_h (Lee et al., 2010; Uchida et al., 2010), whereas other studies have shown that vegetation type has a neutral effect on the Q_{10} of R_h (Vesterdal et al., 2012; Shi et al., 2015). There have been few studies that have explored the effect of vegetation type on the temperature sensitivity of R_a , and these have reported different results (Luan et al., 2011; Yan et al., 2015). It is still not clear why these discrepancies exist. Additionally, there is

currently little information on how temperature sensitivity of R_h and R_a vary with vegetation types, and those studies that have been conducted have reported conflicting results. For example, Lee et al. (2010) found that the Q_{10} values of R_t , R_h , and R_a for a coniferous plantation were higher than those in a *Quercus*-dominated forest, which indicated that the Q_{10} values of R_t , R_h , and R_a varied similarly with vegetation types. However, Wang et al. (2013) showed that the Q_{10} of R_a was significantly different between a pine plantation and a larch plantation, but that the Q_{10} of R_t and R_h was similar.

In the present study, our main objectives were (i) to separate R_t into R_h and R_a , thereby enabling us to independently quantify their temperature sensitivity in six typical vegetation types in subtropical China, and (ii) to examine how the Q_{10} values of R_t , R_h , and R_a vary according to vegetation type.

2. Materials and methods

2.1. Site description and trenching

The study site is located at Heshan National Field Research Station of Forest Ecosystem (Heshan station), Heshan County, in the central part of Guangdong Province, south China (112°54'E, 22°41'N; 80 m above sea level). This area is characterized by a typical south subtropical monsoon climate. The mean annual temperature is 21.7 °C and the highest and lowest mean monthly temperatures are 28.7 °C (in July) and 13.1 °C (in January), respectively. The mean annual effective accumulated temperature (≥ 10 °C) is 7597.2 °C. The mean rainfall is 1700 mm and the mean evaporation is 1600 mm. The soil is classified as a Ultisol developed from sandstone (FAO, 2006).

In the present study, six vegetation types, five plantations and a naturally recovered shrub and herb land (SH), were selected. The five plantations were as follows: a mixed species plantation containing 10 tree species (10S), a mixed species plantation containing 30 tree species (30S), an *Acacia crassicaarpa* monoculture (AC), a *Castanopsis hystrix* monoculture (CH), and a *Eucalyptus urophylla* monoculture (EU). The trees planted in 10S comprised seven native species (*Castanopsis hystrix*, *Liquidambar formosana*, *Machilus chinensis*, *Cinnamomum burmannii*, *Tsoongiodendron odorum*, *Bischofia javanica*, and *Schima superba*) and three exotic species (*Magnoliaceae glanca*, *Jacaranda acutifolia*, and *Dillenia indica*). The 30S plantation contained all the species planted in 10S and a further 17 native species (*Michelia macclurei*, *Ormosia pinnata*, *Sterculia lanceolata*, *Garcinia oblongifolia*, *Garcinia cowa*, *Dracontomelon dao*, *Elaeocarpus japonicus*, *Cinnamomum parthenoxylon*, *Radermachera sinica*, *Maesa japonica*, *Dolichandrone caudafelina*, *Michelia chapensis*, *Syzygium cumini*, *Elaeocarpus apiculatus*, *Castanopsis fissa*, *Acronychia pedunculata*, *Schefflera octophylla*) and three exotic species (*Delonix regia*, *Grevillea robusta*, and *Pterocarpus indicus*). The plantations were established in May 2005, and a complete randomized design was employed for plantation configuration. There were three replications for each vegetation type. The trees were planted with a spacing of 3 × 2 m and the area used for each replication was 1 ha.

Four subplots in SH and Six subplots (1 m × 1 m) in other vegetation types between the trees and 8–10 m apart from each other were established. Half of these subplots were trenched in the early spring of 2007, and the other three untrenched plots served as controls. For the trenched treatments, a trench of width 0.2 m wide and depth 1 m was dug around each subplot. After lining the trench with polyvinyl chloride (PVC), soil was refilled back into the trench according to the original soil profile, and was subsequently kept free of seedlings and herbs by

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