Forest Ecology and Management 424 (2018) 428–438

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Evapotranspiration partitioning and its implications for plant water use strategy: Evidence from a black locust plantation in the semi-arid Loess Plateau, China

Lei Jiao[a], Nan Lu[b,c,*], Bojie Fu[b,c], Jian Wang[b,c], Zongshan Li[b,c], Weiwei Fang[b,c], Jianbo Liu[b,c], Cong Wang[b,c], Liwei Zhang[a]

[a] School of Geography and Tourism, Shaanxi Normal University, Xi'an 710119, China
[b] State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China
[c] University of Chinese Academy of Sciences, Beijing 100049, China

ARTICLE INFO

Keywords:
Evapotranspiration partitioning
Net primary productivity
Drought
Water use strategy
Black locust

ABSTRACT

Evapotranspiration (ET) partitioning is crucial for understanding the impacts of ecophysiological and physical processes on water balance and plant water use strategy. Black locust (*Robinia pseudoacacia*) is one of the most widely planted species in the semi-arid Loess Plateau, China. The effects of its water use on stand soil water storage (S) and its water use strategy raised much concern due to soil water depletion and its growth degradation. In this study, meteorological factors, soil water content (SWC), ET components and net primary productivity (NPP) were observed in a black locust plantation during a drier (2015) and a wetter (2016) growing season. ET was 160.0 mm in 2015 and 255.0 mm in 2016, which accounted for 104.1% and 68.6% of the precipitation (P), respectively. Soil evaporation (E) accounted for the majority of ET (45.4–69.4% at monthly scale), while transpiration (T) was the smallest component of ET (9.7–28.8%). These results showed that it is E that consumed more soil water rather than T in the black locust plantation. E should be carefully considered and improved in predicting or modeling water budgets (e.g. soil water, ET partitioning and runoff) in the reforested catchments in this area. Additionally, the monthly T/ET decreased with P increasing, suggesting that black locusts could transpire water more effectively to survive under drier conditions with less P. Our study can not only improve the understanding of water budget in the reforested catchment in the semi-arid Loess Plateau but also provide the significant evidences of investigating the plant water use strategy from the point of ET partitioning.

1. Introduction

Evapotranspiration (ET) is the main pathway that water is lost from an ecosystem (Schlesinger and Jasechko, 2014), directly modifying the hydrological cycle by transferring water from plant-soil system to atmosphere (Sepaskhah and Ilampour, 1995; Raz-Yaseef et al., 2012). In the areas of afforestation, the increase of ET may cause the water yield (precipitation - ET) reduction and soil water depletion, hence altering regional water balance and hydrological cycling (Feng et al., 2012). In addition, the ET components, including plant transpiration (T), evaporation from soil (E) and evaporation from the rainfall intercepted by canopy (I) (Mitchell et al., 2009) , have different functions and water use implications (Wang et al., 2014). E and I are physical processes that are not directly linked to vegetation productivity (Kool et al., 2014; Wang et al., 2014), considered as non-productive evaporation. By contrast, T is the flux that water loses from leaf stomata. T directly related to the biological process, concurrent with photosynthesis for plant productivity (Granier et al., 1999). Thus, T is considered as productive evaporation. The ratio of transpiration to evapotranspiration (T/ET) is an indicator that is often used to assess the effects of T on the water balance in an ecosystem (Kato et al., 2004; Blum, 2009). Soil water is the primary source of both T and E in the deeply rooted ecosystem in the water-limit areas (Cavanaugh et al., 2011; Raz-Yaseef et al., 2012). Furthermore, in the areas of reforestation, increasing water demand of planted trees exerted the negative influences on hydrological processes and regional water resources in the water scarce region (Huxman et al., 2005; Oki and Kanae, 2006; Feng et al., 2016). Therefore, partitioning ET is useful not only to identify the impacts of

* Corresponding author at: Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China. University of Chinese Academy of Sciences, Beijing 100049, China.
E-mail address: nanlv@rcees.ac.cn (N. Lu).

https://doi.org/10.1016/j.foreco.2018.05.011
Received 16 January 2018; Received in revised form 5 April 2018; Accepted 8 May 2018
0378-1127/

physiological and physical processes on water balance and soil water storage but also to provide implications for plant water use strategy (Waterloo et al., 1999).

The semi-arid Loess Plateau of China receive low rainfalls and face the water scarcity problem (Feng et al., 2016). During the past decades, regional vegetation cover increased by 25% after implementation of "Grain to Green Programme (GTGP)" since 1999, which converted 16,000 km^2 of slope cropland to planted vegetation (Feng et al., 2016). Feng et al. (2016) reported that ET increased by 4.3 ± 1.7 mm yr^{-2} from 2000 to 2010 in the Loess Plateau. Consequently, the soil water storage declined and soil desiccation layer emerged (Wang et al., 2010b; Jian et al., 2015). Black locust (*Robinia pseudoacacia*), which is native in North American, was introduced to be widely planted on the slopes in this region during the past three decades (Jiao et al., 2016a). As a dominant forest type, black locust plantations have played key roles on erosion reduction, soil quality improvement and carbon sequestration (Feng et al., 2010; Li et al., 2015). It is important to keep the plantations healthy and stable in this water-limited region. However, ecohydrological issues including severe soil desiccation (defined as soil water content (SWC) less than 60% of the field capacity (FC)) and growth degradation emerged at an early age in the plantations (Wang et al., 2011b). It is assumed that the problems were closely linked to increased water use and unbalanced water budget (ET larger than precipitation). Therefore, it is crucial to investigate the ET processes to provide better understanding of the mechanism of plant water strategy and hydrological changes in this region.

At the regional scale, ET has been estimated based on satellite data and hydrological models (Feng et al., 2012). At the site or field scale, ET could be measured using eddy covariance and micro Bowen ratio energy balance methods, which require a homogeneous surface (Kool et al., 2014). The semi-arid Loess Plateau is an gully-hilly area with heterogeneous topography. Therefore, ET measurements were not adequate partly due to difficulty in application of eddy covariance and micro Bowen ratio energy balance in this region. . Moreover, a low T/ET ratio was assumed to be the primary reason for plants degradation because more water consumed by soil evaporation not by plant transpiration in the water-limited areas (Guo et al., 2010; Qiu et al., 2015). However, this assumption remains untested in the black locust plantations. ET partitioning would provide the significant evidence for testing this assumption.

In this study, ET components, soil water storage and net primary productivity (NPP) were quantified in a black locust plantation during two growing seasons in the semi-arid Loess Plateau, China. Our objectives are to: (1) quantify the actual ET and partition ET during growing seasons in a black locust plantation; (2) investigate the effects of ET partitioning on stand soil water storage; (3) assess the productivity and water use strategy of black locust from the point of ET partitioning.

2. Materials and methods

2.1. Study site

This study was conducted in the Yangjuangou catchment (36°24′N, 109°31′E), which is located in the central Loess Plateau of China (Fig. 1). The area of the catchment is 2.02 km^2, and the altitude ranges from 1050 to 1295 m a.s.l. The study area has a semi-arid temperate continental climate. The 50-year mean annual precipitation (MAP) is 531 mm (Jiao et al., 2016a). On average, 58.8% of annual precipitation occurred from July to September, defining this period as the rainy season (Fig. 2). The 50-year mean annual temperature (MAT) is 9.8 °C. The soil type is Calcaric Cambisol, which is vulnerable to water erosion, with a depth of 50–200 m. The vegetation consists of replanted forest, shrub, orchard, abandoned grass and crop. Black locust is the dominant forest species, which was planted on the abandoned slope farmlands since 1980s. The growing season for most of the deciduous species is from May to September.

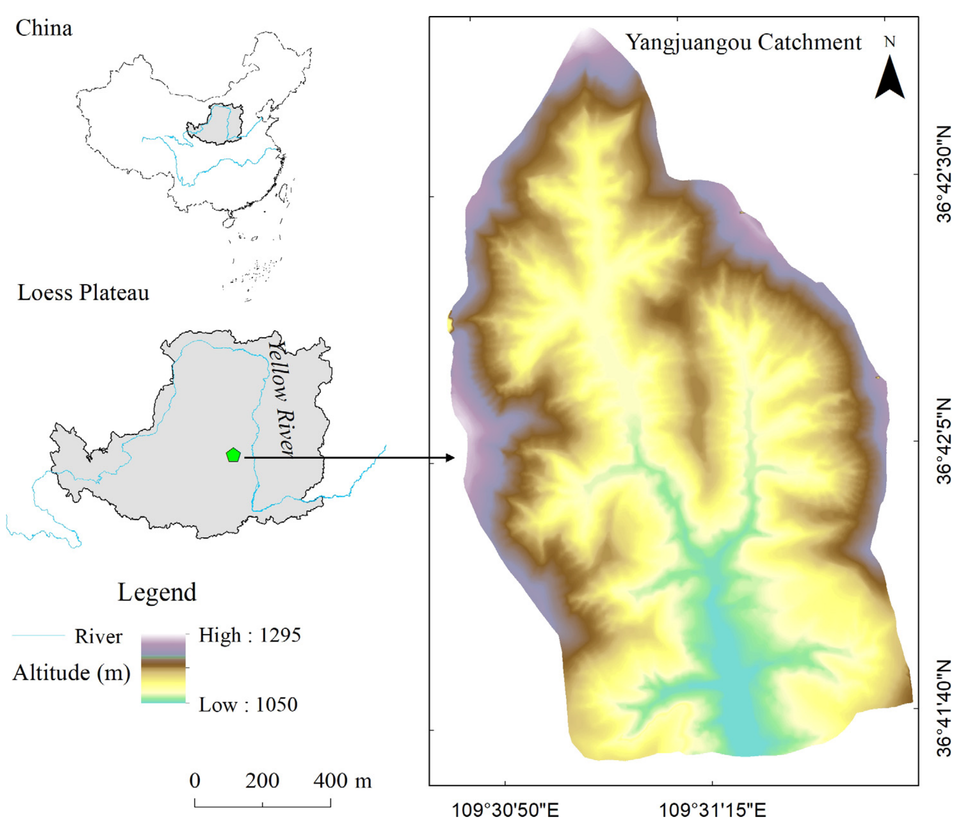

Fig. 1. Geographic location of the study site.