Ecological Engineering 90 (2016) 6–11

Contents lists available at ScienceDirect

Ecological Engineering

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

Short communication

Enhanced photosynthetic capacity by perennials in the riparian zone of the Three Gorges Reservoir Area, China

Aiying Zhang[a,b,1], Dayong Fan[a,1], Zhaojia Li[a,b], Gaoming Xiong[a], Zongqiang Xie[a,*]

[a] State Key Laboratory of Vegetation and Environment Change, Institute of Botany, Chinese Academy of Science, Beijing 100093, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China

ARTICLE INFO

Article history:
Received 2 August 2015
Received in revised form
20 December 2015
Accepted 26 January 2016
Available online 10 February 2016

Keywords:
Leaf traits
Leaf nitrogen concentration
Sink–source
Stem mass ratio
Photosynthetic capacity

ABSTRACT

The flood-dry-flood cycle in the reservoir riparian zone (RRZ) of the Three Gorges Dam has dramatically changed the ecosystem structure and riparian vegetation. Previous field investigations have shown that perennial herbaceous species are dominant in the riparian zone. However, how perennials respond to flooding disturbance remains largely unclear. Intermediate disturbance (*e.g.* grazing, insect pest) can enhance photosynthesis *via* "physiological compensation" mechanism. The aim of this study is to investigate whether perennials enhance their photosynthetic capacity during dry periods and understand the mechanisms driving this. Eight species from different families in a RRZ site and a paired Upland site were chosen. We compared 12 plant traits including photosynthesis, leaf structure and nutrients, as well as soluble sugar (indicate sink–source relationship) between the two sites. Results showed that perennials in RRZ had a significant higher area-based photosynthetic capacity (A_{area}) than those in Upland. Meanwhile, stomatal conductance (G_s), leaf nitrogen concentration (LNC_a) and Stem mass ratio (SMR) were also significantly higher in RRZ than Upland individuals. However, there was no sign of an unbalanced sink–source relationship in RRZ as evidenced by no difference in soluble sugar content in roots and stems between sites. The results of this study suggest that perennials have enhanced photosynthetic capacity in RRZ mainly attributed to higher LNC_a and G_s but sink strength was not enhanced. These data provide insight into the ecosystem functioning of riparian areas and could be used to improve restoration practices.

1. Introduction

Dams are affecting riparian ecosystems globally. It is estimated that two-thirds of the world's fresh water flowing to the oceans is obstructed by more than 45,000 large dams (defined as more than 15 m in height) and approximately 800,000 small dams (Fuggle and Smith, 2000). These hydrological alterations change ecosystem structures and have a dramatic impact on riparian vegetation (Jansson et al., 2000; Nilsson and Keddy, 1988).

The Three Gorges Dam (TGD) is the largest dam in China (Wu et al., 2004). The TGD hydrological regime of the Yangtze River changes from 175 m (following the elevation of Wusong) in winter to 145 m in summer and has formed a reservoir riparian zone (RRZ) with an area of 348 km^2 since 2007. This flood-dry-flood cycle is repeated annually (Fan et al., 2015). The original herbaceous communities were unable to deal with the significantly shorter growing season and long-term winter submergence every year resulting in novel plant communities (New and Xie, 2008). Previous studies have reported that perennial and annual herbaceous species are dominant in this riparian zone, with very few shrubs and trees (Fan et al., 2015; He et al., 2007; Mitsch et al., 2008; Su et al., 2012; Wang et al., 2012). It is important to study the physiological and ecological mechanisms of adaptability of the dominated species to reduce degradation and improve restoration practices.

Simulated experiments have shown that some plants can tolerate long-term winter submergence and can survive in the Three Gorges Reservoir Area (Chen et al., 2008; Guo et al., 2012; Wang et al., 2008). However, how perennials respond during the dry periods remains largely unclear. Intermediate disturbance (*e.g.* grazing, insect pest) has been shown to enhance photosynthesis *via* "physiological compensation" mechanism (Anten and Ackerly, 2001; Harrison et al., 2010; Peng et al., 2007). Jie et al. (2012) measured leaf traits of 42 species in the riparian zone of Three Gorges Reservoir Area and found that RRZ plants have significantly enhanced photosynthesis rates. The underlying mechanisms of this phenomenon remain unclear. The observed responses of perennials

* Corresponding author.
E-mail address: xie@ibcas.ac.cn (Z. Xie).
[1] These authors contributed equally to this paper.

http://dx.doi.org/10.1016/j.ecoleng.2016.01.075
0925-8574/

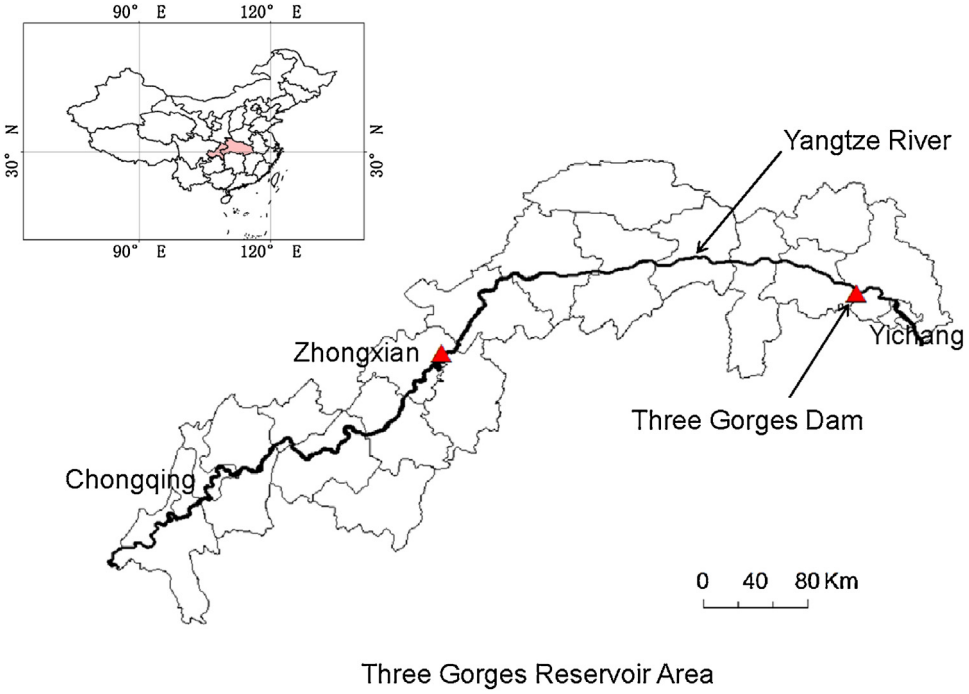

Fig. 1. The Three Gorges Reservoir Area, China.

could be transient and could diminish as time since formation of the RRZ increases. In the study of CO_2 enrichment on photosynthesis, it has been shown that rising CO_2 stimulates photosynthetic capacity early on but enhancement is diminished in mid- and long-term (Ainsworth and Long, 2005; Long et al., 2004, 2006).

In 2013, we chose 12 plant traits of eight perennial herbaceous species found in both the RRZ and adjacent non-flooded upland (Upland) sites of the Three Gorges Reservoir Area. The following questions were addressed: (1) Do perennials enhance their photosynthetic capacity in response to the flood-dry-flood? (2) What are the mechanisms driving photosynthetic enhancement?

2. Material and methods

2.1. Study site

Field surveys were conducted on the northern bank of the Yangtze River in Shibao Town, Zhongxian of Chongqing city, southwestern China (Fig. 1). The site lies in the subtropical monsoon zone. The average annual temperature is 18.2 °C and the average annual precipitation is 1200 mm, with mean relative humidity of 80%. The study site is located on abandoned farmland terraces 0.045 km^2 in area. The submergence time of the site changes by altitude and year (Fig. 2). The community is dominated by perennial herbaceous species with some annuals and few shrub and tree species. Before the TGD was built, the width of natural riparian zone was about 10 meters and there was no difference in species composition between RRZ and non-flooded upland areas (Bai et al., 2005; Wang et al., 2002).

2.2. Traits selection and measurements

The species chosen in this study (Table 1) were distributed in RRZ (flooded for 101–160 days, 165–170 m above sea level) and Upland (flooded for 0 day, 176–180 m above sea level) sites. This excludes the effect of large inter-specific variation on functional traits (Ackerly and Cornwell, 2007; Cornwell and Ackerly, 2009). The submergence time is shown in Fig. 2. We tested 12

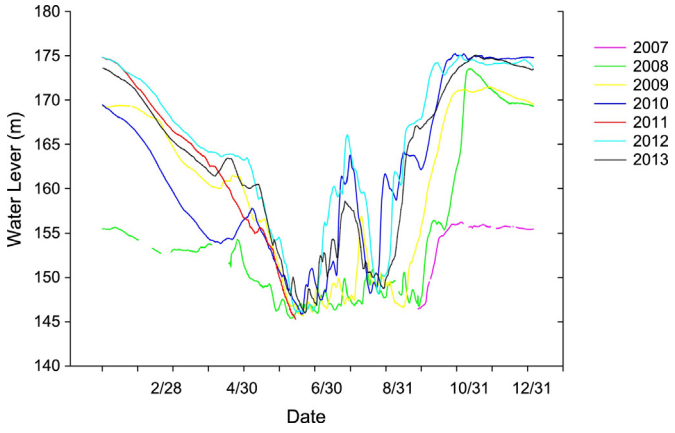

Fig. 2. Annual water fluctuations at the Zhongxian site from 2007 to 2013.

photosynthesis-related traits (Table 2) of these species (Wang et al., 2012; Yang et al., 2012).

Leaf traits — Leaf economic traits have been shown to have a strong affect on plant growth globally (Bloor and Grubb, 2003; Poorter, 1999). Wright et al. (2004) defined six key leaf features that capture leaf economic traits: specific leaf area (SLA), maximum net photosynthesis rate (A_{area}), Leaf nitrogen concentration (LNC_a), Leaf phosphorus concentration (LPC_a), Dark respiration rate

Table 1
Species selected in this experiment.

Species	Life form	Family
Alternanthera philoxeroides	Perennial	Amaranthaceae
Chenopodium ambrosioides	Perennial	Chenopodiaceae
Cynodon dactylon	Perennial	Gramineae
Dendranthema indicum	Perennial	Compositae
Ficus tikoua	Perennial	Moraceae
Paspalum thunbergii	Perennial	Gramineae
Physalis alkekengi	Perennial	Solanaceae
Solanum lyratum	Perennial	Solanaceae