Ecological Engineering 74 (2015) 213–222

Contents lists available at ScienceDirect

Ecological Engineering

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

Choosing an optimal land-use pattern for restoring eco-environments in a semiarid region of the Chinese Loess Plateau

Yunqiang Wang [a,b,c,*], Ming'an Shao [b], Chencheng Zhang [c], Xiangwei Han [b], Tianxu Mao [c], Xiaoxu Jia [b]

[a] State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an, Shaanxi 710075, China
[b] Key Laboratory of Ecosystem Network Observation and Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[c] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Chinese Academy of Sciences & Ministry of Water Resources, Yangling 712100, China

ARTICLE INFO

Article history:
Received 9 May 2014
Received in revised form 20 September 2014
Accepted 1 October 2014
Available online 29 October 2014

Keywords:
Deep soils
Dried soil layer
Aboveground net primary productivity
Soil water
Grassland
Shrubland

ABSTRACT

The natural environments in the semiarid regions of the Chinese Loess Plateau (CLP) are fragile due to the serious soil erosion and the weak ecological services of the plants. To ascertain and then evaluate a sustainable land-use pattern in these regions, we selected six typical land-use patterns (i.e., a farmland, a natural grassland, a homogeneous shrubland (S), a mix of shrubland and cultivated grassland (S–Alf), a mix of shrubland and orchard (S–O) and a mix of shrubland and grassland (S–G)) on the plateau and then measured the soil water, related soil properties and plant root indices to a depth of 1800 cm. We also measured the aboveground net primary productivities (ANPPs). The mean soil water content (SWC) within the 0–1800 cm profile was significantly highest (15.2%) in farmland, followed by grassland (11.4%) and S–Alf (8.0%). The available water (AW), the ratio between AW and AW capacity, and the thickness of the dried soil layers also demonstrated that farmland had the best conditions of soil water, followed by grassland and shrubland. The aboveground biomasses of grassland in both non-growing (140 g m^{-2}) and growing (370 g m^{-2}) seasons were significantly higher than those of shrublands. The ANPPs of the grassland (2.0 g m^{-2} d^{-1}) demonstrated a similar trend. The patterns of land use (including the mixtures of different plant species) greatly affected the patterns of vertical distribution and quantities of soil water within the 1800-cm profile. The data for the soil–water regime and the ANPP further indicated that grassland would be an optimal use of the land for these semiarid regions. This information should be useful to the ecological scientists and policy makers for developing strategies for the sustainable management of vegetation on the CLP and possibly other water-limited regions around the world.

1. Introduction

Soil water content (SWC) depends on a number of factors such as meteorological conditions, topographical elements, soil properties and land cover (Chen et al., 2007a) and is a crucial factor affecting plant growth and many ecological and environmental processes (Hu et al., 2010). Plants in turn affect soil water by forming a preferential pathway for the transport of soil water to the atmosphere via their root systems, which results from a number of complex and mutually interacting physiological and ecological processes (Stephen et al., 2001). Information on the levels, distributions, and dynamics of SWC within soil profiles is thus vital for the sustainable management of water resources, strategies of revegetation, and hydrological, ecological and climatic modeling (Josa et al., 2012; Wang et al., 2013).

In water-limited arid and semiarid environments and some humid regions where water shortage occurs seasonally, the role of the uptake of deep water (>800 cm) by roots has been a major discovery during the last 20 years (Nepstad et al., 1994). Considerable interest has since been generated around the world in the assessment of vertical distribution and influencing factors (Li et al., 2008; Yang et al., 2012), depletion and replenishment (Li and Huang, 2008; Liu et al., 2010), dynamics and simulations (Jipp et al., 1998; Markewitz et al., 2010; Zhao et al., 2008) of SWC in soils to a depth of roughly 1000 cm. The depth of depletion of SWC, inferred

* Corresponding author at: Institute of Earth Environment, Chinese Academy of Sciences, State Key Laboratory of Loess and Quaternary Geology, 10 Fenghui South Road, Xi'an High-Tech Zone, Xi'an, Shaanxi 710075, China Tel.: +86 29 88325936; fax: +86 29 88325936.
E-mail address: wangyunq04@163.com (Y. Wang).

http://dx.doi.org/10.1016/j.ecoleng.2014.10.001
0925-8574/

to be a function of root uptake, has recently been reported to be 1800 cm in an Amazonian forest (Davidson et al., 2011) and to be 1550, 2240 and 2150 cm (based on the comparison of soil–water conditions between shrublands/forests and permanent farmland) in alfalfa grassland, *Caragana korshinskii* shrubland and pine forest, respectively, on the Loess Plateau of China (Wang et al., 2009).

The increasing depth of depletion of SWC within a soil profile by plants is a feedback of negative water balance (Davidson et al., 2011) which may result in a decrease in inputs (i.e., rainfall) and/or an increase in outputs (i.e., evapotranspiration) (Liu and Sang, 2013; Wang et al., 2011). The formation of a dried soil layer (DSL) was reported to be a typical response to the negative water balance (Li, 1983). Definitions, basic characteristics, dynamics, evolution, regional distributions and factors influencing the DSL have been reported (Chen et al., 2008; Wang et al., 2008; Wang et al., 2011), but the sampling depth in most published studies was shallower than 1000 cm.

The level of negative water balance may be aggravated by (1) the ongoing global warming that is generally, but not universally, expected to increase evapotranspiration and thus cause declines in SWC (Breshears et al., 2005; Zavaleta et al., 2003) and (2) the irrational management of land such as planting trees at high densities and introducing exotic species that may extract a large amount of deep soil water over short periods of time (Chen et al., 2008; Wang et al., 2008). Deeper soil water participates in biogeochemical processes via root systems of plants that generally extend below 1000 cm in regions covered by deep soils. The quantity and distribution pattern of SWC and its response to environmental factors in soils below 1000 cm, however, are not clear, but this information is increasingly needed.

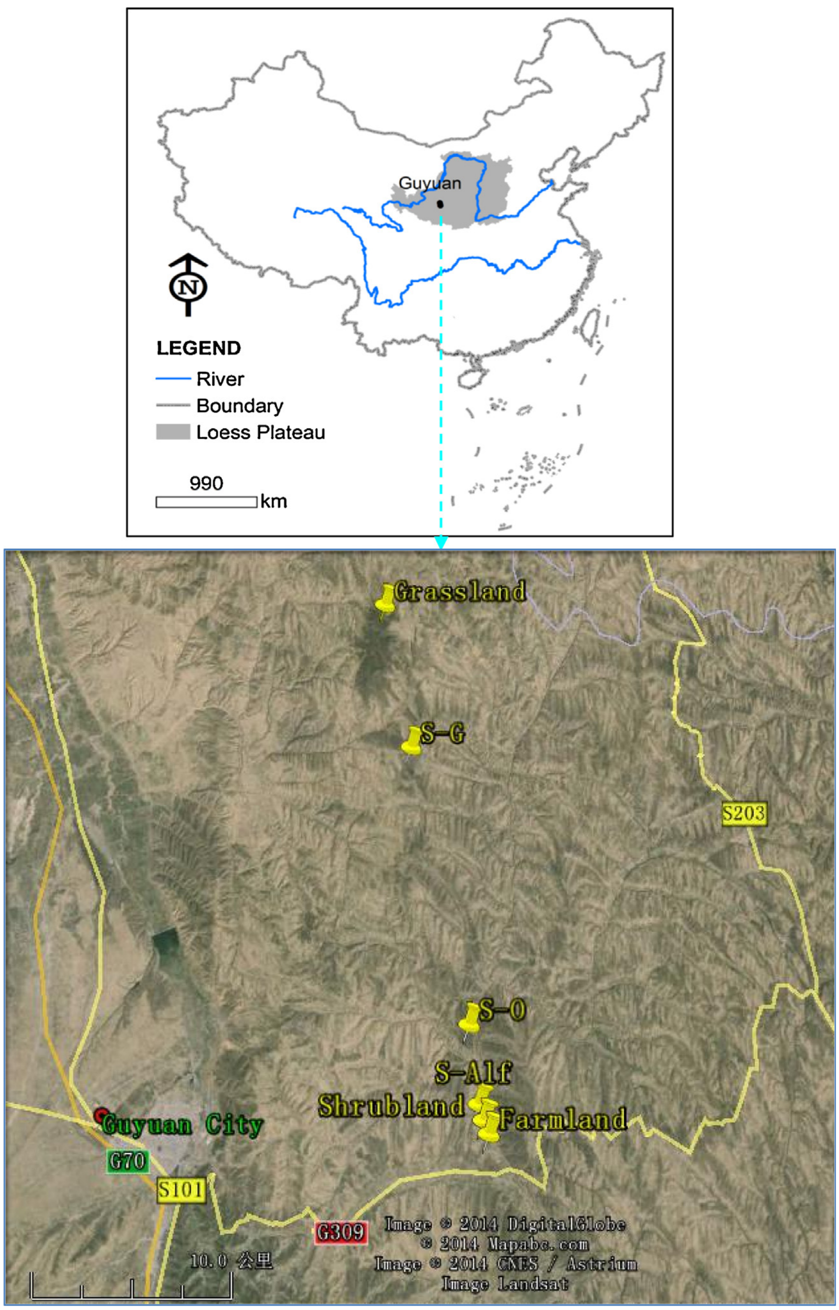

Fig. 1. Location of the Loess Plateau in China and the distribution of sampling sites in the semiarid region of the Loess Plateau (S–G, a mix of shrubland and grassland; S–Alf a mix of shrubland and cultivated grassland, S–O: a mix of shrubland and orchard).