Journal of Hydrology: Regional Studies 5 (2016) 324–335

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

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

Effects of ecological engineering on water balance under two different vegetation scenarios in the Qilian Mountain, northwestern China

Fei Tian[a,b], Yi He Lü[a,*], Bo Jie Fu[a], Yong Hui Yang[c], GuoYu Qiu[d], Chuanfu Zang[e], Lu Zhang[b]

[a] State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, 18 Shuangqing Road, Haidian District, Beijing 100085, China
[b] CSIRO Land and Water Flagship, Canberra, ACT 2601, Australia
[c] Key Laboratory of Agricultural Water Resources, Center for Agricultural Resources Research, Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, 286 Huaizhong Road, Shijiazhuang 050021, China
[d] Key Laboratory for Urban Habitat Environment Science and Technology, School of Environment and Energy, Peking University, Shenzhen 518055, China
[e] Forestry College of Inner Mongolia Agricultural University, Daxue East Road, Saihan District, Huhehaote, 010018, China,

ARTICLE INFO

Article history:
Received 5 May 2015
Received in revised form
12 November 2015
Accepted 15 November 2015
Available online 28 November 2015

Keyword:
SWAT
Water balance
Ecosystem restoration
Qilian Mountain

ABSTRACT

Study region: The Qilian Mountain, northwestern China.
Study focus: Land degradation is a global eco-environmental issue. To minimize soil erosion and land degradation, China has implemented several ecological engineering such as "Grain for Green" program (GFG) since 1999. Relationship between vegetation and water budgets in catchments has been widely studied, however very few studies addressed the effects of eco-environmental restoration on water balance in mountain areas, especially with a focus on soil moisture content. Therefore SWAT model was used to quantify the effects of ecological engineering actions (taken place in 2005) on water balance in Qilian Mountain.
New hydrological insights for the region: After the ecological engineering, water yield and soil water content experienced an increment of 32%, and 46%. The opposite trend was monitored in runoff and evapotranspiration, which decreased by 48% and 4%, respectively. Therefore ecosystem restoration have increased soil water retention capacity, a greater proportion of precipitation reaching the catchment is absorbed by the soil rather than flowing out of the region as runoff. Therefore trade-offs between environmental sustainability and water resources security should be carefully addressed in arid region that experienced severe water shortages.

1. Introduction

As the originate district of freshwater resources, mountain accounting for 24% of the earth's land area, but providing more than 80% of terrestrial freshwater resources, while in arid and semi-arid areas, this ratio can even achieve 90% (FAO, 2000), thus mountain ecosystems play a significant role in the subsistence of the global ecosystem (Chase et al., 1999; Huss et al.,

* Corresponding author at: State Key Laboratory of Urban and Regional Ecology, Research Center for Eco–Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China.
E-mail address: lyh@rcees.ac.cn (L. Zhang).

http://dx.doi.org/10.1016/j.ejrh.2015.11.015
2214-5818/

2008). Hydrological processes are one of the most important elements in interaction between different ecosystems (Buttle et al., 2000; Hanjra and Qureshi, 2010), mountain hydrology has been intensively studied (Huber et al., 2005; Moran-Tejeda et al., 2014).

Several studies have been conducted to assess the impact of climate change on mountain hydrology with specific regard to runoff (Wang and Li, 2006), water yield (Huss et al., 2008; Sun et al., 2006), and rarely evapotranspiration (Calanca et al., 2006). Hydrological cycle not only subject to weather conditions, but also closely associated with vegetation type (Wang et al., 2011a,b), thus the relationship between vegetation and water budgets in catchments have been widely studied and became the subject of intense debate from hydrological as well as ecological point of view (Yang et al., 2005). For example, Yu et al. (2010) stated runoff reduction rate of 25.6 mm per 10% forest increase at watershed scale by employing 23 scenarios, that runoff at the site scale will be reduced to zero when grass- or shrub-lands are converted to forest in arid Qilian Mountain. Farley et al. (2005) and Sun et al. (2006) reported that this runoff reduction would be more severe in humid regions. To our knowledge, very few studies have addressed the effects of terrestrial ecosystem restoration on water balance in mountain areas, especially with a focus on soil moisture content. Due to the limitation of scale, and research methods, it was considered as unresolved central issues in the related fields (Mu et al., 2007).

Qilian Mountains is an important ecological functioning zone nourishing the oasis in northwest China (Yu et al., 2010). Due to the unsustainable use of the forest, the oasis ecosystem was seriously damaged and experienced deterioration of its ecological environment (Chen and Xia, 1999). To alleviate desertification and alleviate soil erosion, government has adopted ecological engineering such as "Grain for Green" program (GFG), "Natural Forest Protection Project", and "The Three-North Shelter Forest Program" since 2005 in this region.

In arid and semiarid region, some researchers indicated that increasing forest and grassland cover will reduce the total runoff volume and strengthen drought (Huber et al., 2008; Sun et al., 2006), Qiu et al. (2011) showed that the ecological engineering have increased soil water retention capacity, a greater proportion of precipitation reaching the catchment is absorbed by the soil rather than flowing out of the region as runoff, water resources were more efficiently used and the ecological environment was protected. Water supply in the up mountain area limits ecological water use in the middle and lower reaches of the river (Jin et al., 2005; Li et al., 2012), however, they have not determine whether ecosystem restoration reduce or increase regional runoff volume in the mountains of arid inland river basins, the effects of ecosystem restoration on water balance is unclear.

While answer this question will play a key role in sustainable development of water resources, and guide the recent massive forestation and ecological restoration campaigns. In this study, Landsat TM remote sensing images (30m - resolution) obtained in 2000 and 2010 were used to monitor the vegetation changes and identify the magnitude of ecosystem restoration. In an effort to fully address the scarcity of this information, the Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998) was used to quantify the effects of terrestrial ecosystem restoration on water balance in Qilian Mountains.

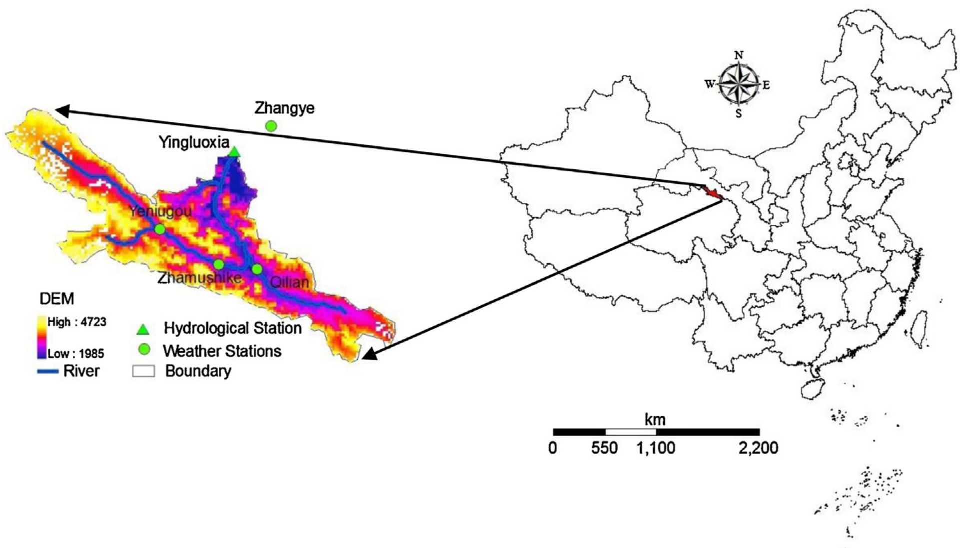

Fig. 1. Location of the up Qilian Mountains with its hydro-meteorological stations.