Agricultural Water Management 198 (2018) 53–64

Contents lists available at ScienceDirect

Agricultural Water Management

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

Comparison of the water budget for the typical cropland and pear orchard ecosystems in the North China Plain

Yucui Zhang[a], Huimin Lei[b], Wenguang Zhao[c], Yanjun Shen[a,*], Dengpan Xiao[d]

[a] Key Laboratory of Agricultural Water Resources & Hebei Key Laboratory of Agricultural Water-Saving, Center for Agricultural Resources Research, Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, Shijiazhuang 050021, China
[b] State Key Laboratory of Hydroscience and Engineering, Department of Hydraulic Engineering, Tsinghua University, Beijing, 100084, China
[c] Kimberly Research and Extension Center, University of Idaho, 3793 N. 3600 E., Kimberly, ID 83341, USA
[d] Institute of Geographical Sciences, Hebei Academy of Sciences, Shijiazhuang, 050011, China

ARTICLE INFO

Article history:
Received 21 January 2017
Received in revised form
17 December 2017
Accepted 25 December 2017

Keywords:
Pear orchard
Wheat
Maize
Evapotranspiration
Energy flux
Water balance

ABSTRACT

The North China Plain (NCP) has a severe water shortage. About 70% groundwater has been exploited for irrigation. Winter wheat – summer maize and pears are typical representative cereal crops and commercial fruit trees in this area, respectively. Water budget for the typical cropland and orchard ecosystems has a significant importance for agricultural production, especially in the NCP. Therefore, evapotranspiration (ET) and water balance were studied in the annual winter wheat – summer maize rotation (cropland) and pear orchard. Latent and sensible heat fluxes were measured by eddy covariance. Annual ET for pear trees was 764 mm and for both crops was 690 mm. The difference of ET between these two ecosystems was about equal to one irrigation. Transpiration was the main loss with the mean proportion of 63% for crops and 76% for pear trees. Wheat growth period is in the dry season and requires much more irrigation than maize. Mainly transpiration (80%) occurred from April through September in the both ecosystems which was also the growing period for pear trees. The annual precipitation was 469 mm and 444 mm in the pear orchard and cropland, respectively, although 80% of it occurred from June to September. Compared with the precipitation, annual mean water deficit was 294 mm for the pear trees and 244 mm for crops. The water shortage was severe in May while surplus water presented in July and August. Energy and ET fluxes were determined by atmospheric demand and the response of plants as controlled by plant phenology and crop selection. As the water shortage situation becomes more serious in the NCP, sustainability of the agricultural ecosystems could be improved by changing crop planting patterns, specifically, increasing the area ratio of maize to pear trees.

1. Introduction

More than a hundred countries are facing water shortage of varying severity in the world (Saeijs and Van Berkel, 1995). Roughly, 40% of the global population is situated in heavily water deficit basins that are occasionally experienced agricultural failure due to a lack of water for irrigation (Shen et al., 2014). Meanwhile, water shortage and agricultural production are large challenges for China. About 20% of the cultivated land in China is in the North China Plain (NCP), while the water resource accounts only for 3% of the country. About 75% of cropland and 22% of orchard were irrigated by groundwater in the NCP. Therefore, about 70% groundwater of the total exploitation were used in irrigation (Shen et al., 2013; Zhang et al., 2013). This status leads to groundwater depletion, land subsidence and seawater intrusion. In the NCP, winter wheat, summer maize and pears are typical representative cereal crops and commercial fruit trees with 40% and 22% of total harvest, respectively. Given the extent of groundwater depletion in the NCP, a quantitative study of water balance for two common agricultural production systems is an important step to explore information pertinent to decision-making related to these production systems.

Evapotranspiration (ET) plays one of the important roles in the water and energy budget. There are many methods for ET measurement, monitoring, and modeling (Farahani et al., 2007; Shuttleworth, 2008). The eddy covariance (EC) method is a reliable and widely used in the micrometeorological flux research (Schmidt et al., 2012; Shuttleworth, 2007; Twine et al., 2000). It provides information on water, energy, and carbon dioxide fluxes by covariance calculation of atmospheric physical parameters (e.g. temperature, water vapors and CO_2 concentration) and vertical

* Corresponding author.
E-mail address: yjshen@sjziam.ac.cn (Y. Shen).

https://doi.org/10.1016/j.agwat.2017.12.027
0378-3774/

wind velocity. ET depends on the atmospheric and water supply conditions, soil characteristics and vegetation type. In a comparison of five different irrigation treatments, maximal yield was obtained when the optimal amount of irrigation was 298 mm yr^{-1} and ET was 426 mm yr^{-1} for winter wheat during 1999–2002 in the NCP (Sun et al., 2006; Yuan and Shen, 2013). In contrast, Yang et al. (2014) reported only 252.4 mm annual cumulative ET during 2010 for spring wheat in semi-arid farmland (the Loess Plateau, in China). Therefore, finding a suitable method to measure ET for the typical cropland and orchard ecosystems is required for more accurate water balance calculation.

In addition, ET partitioning is a fundamental factor to accurately hydrological monitoring system and water management practices (Kool et al., 2014). In particular, ratio of transpiration (T) to ET reveals the fraction of water used for biomass production. Transpiration or evaporation can be calculated by subtracting one or the other from ET (Uddin et al., 2013; Montoro et al., 2016). Microlysimeter is a classical method for soil evaporation (E) measurement (Boast and Robertson, 1982). Combined the micrometeorological technique with microlysimeter method can be used in partitioning the ET flux. Tree transpiration can be measured by heat pulse – sap flow method (Granier, 1987). The ratio of T/ET ranged from 0.64 to 0.74 for olive trees during November to April in Chile (López-Olivari et al., 2016). Measured transpiration was also used in the model parameterization and verification (Villegas et al., 2015; Evaristo et al., 2015). However, few studies have been performed on the partition of ET over an entire growing season, and especially, for the comparison of two typical irrigated ecosystems in the NCP.

In addition, policy guidance plays an important role in the grain and fruit industries. Hebei province is located in the 38° N zone and comprises 80% of the NCP land area. It is one of the best area in China for growing deciduous fruit trees. Fruit growth brings more economical benefit than crops. However, policies and government cannot just considered the financial benefits. However, a systematic water consumption data of crops and fruit trees is lacking for scientific decision that would help greater sustainability by changing various possible planting patterns.

To realize a reasonable and sustainable agricultural water management, the main objectives of the present study were: 1) to find out the differences of water balance and water consumption for pear trees and crops (winter wheat–summer maize) ecosystems, and 2) to give some reasonable suggestions for improved planting patterns.

2. Materials and methods

2.1. Site description

The experiments were conducted in the NCP of Hebei Province, at the Zhaoxian site (37°47′44″N, 114°55′57″E, altitude: 40 m) and the Luancheng Agro-ecosystem Experimental Station (37°53′22″N, 114°41′34″E, altitude: 50.1 m), which represent the typical irrigated pear orchard and cropland ecosystems respectively (Fig. 1). The distance between these two sites was about 20 km. The data were collected for four years from October 1, 2011 to September 30, 2015 (seasonal division details see Table 1). In Hebei Province, pear cultivation and crops accounted for 20% and about 10% of the total cultivated areas for these commodities in China, respectively (Hebei Rural Statistic Yearbook, 2013). More than 90% of the cropland and pear orchard were irrigated by groundwater in Luancheng and Zhaoxian. Water table fell by about 0.8 m y^{-1} (Shen et al., 2013)

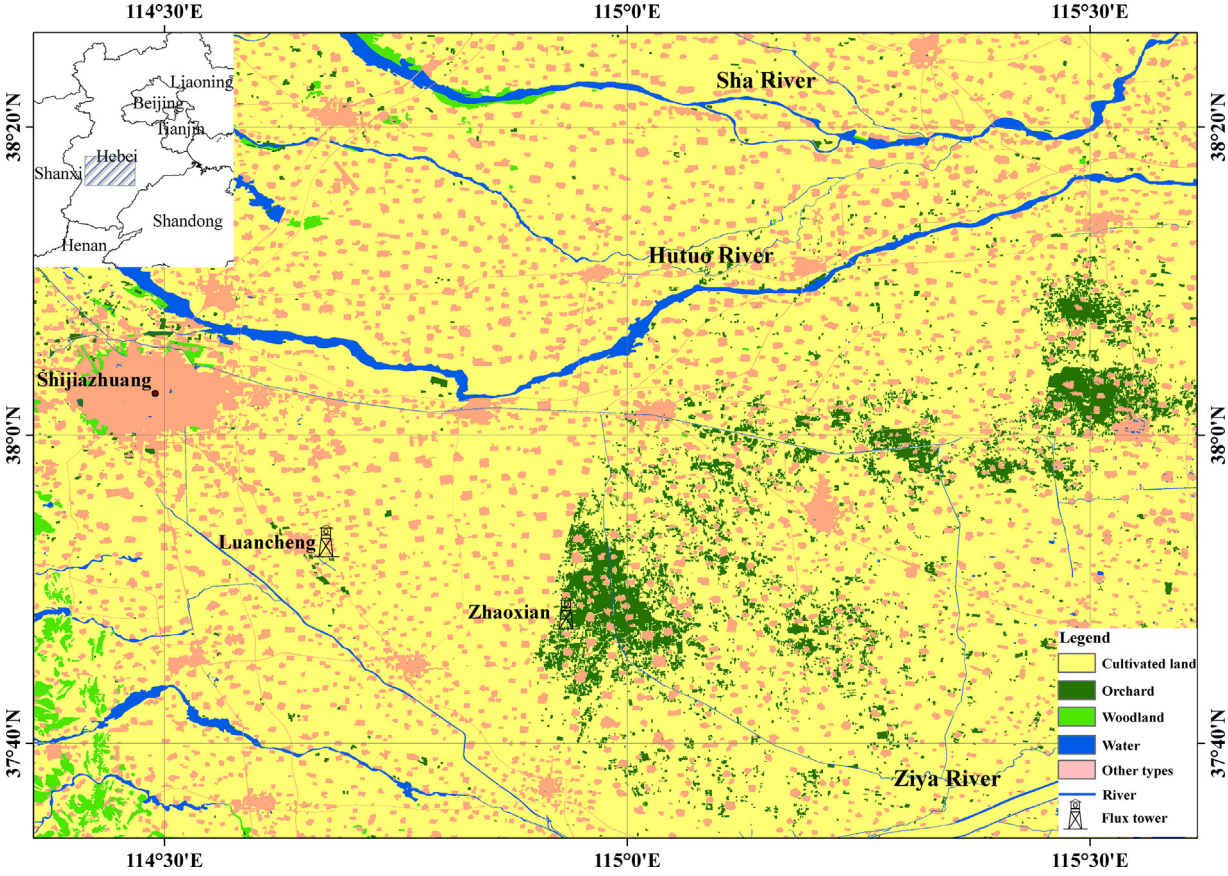

Fig. 1. Locations of the monitoring sites at Zhaoxian (37°47′44″N, 114°55′57″E, altitude: 40 m) and Luancheng station (37°53′22″N, 114°41′34″E, altitude: 50.1 m) in the North China Plain.