Ecological Indicators xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Ecological Indicators

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

Spatial analysis of dual-scale water stresses based on water footprint accounting in the Haihe River Basin, China

Chunhui Li[a,d], Meng Xu[a,b], Xuan Wang[a,d], Qian Tan[c,*]

[a] Ministry of Education Key Lab of Water and Sand Science, School of Environment, Beijing Normal University, Beijing 100875, PR China
[b] School of Public Administration, Zhejiang University of Finance & Economics, Hangzhou 310018, PR China
[c] College of Water Resources & Civil Engineering, China Agriculture University, Beijing 100083, PR China
[d] State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing 100875, PR China

ARTICLE INFO

Keywords:
Blue water footprint
Gray water footprint
Haihe River Basin
Exploratory spatial data analysis
Water footprint accounting

ABSTRACT

Water scarcity and degradation of water quality in river basins are among the major issues addressed by water resources management authorities. Moreover, two typical challenges associated with water resources management include naturally unbalanced distribution and administrative disparities under multiple jurisdictions at the watershed scale. Effective accounting and management methods are thus desired to deal with such challenges. Water footprint accounting is widely used for assessing natural water resources availability and supporting optimal allocation among multiple jurisdictions, representing a useful tool for improving watershed sustainability. Not only will this enable successful revealing of the direct water consumption by relevant agents, but also indirect water consumption by concerning users. Such a method is particularly useful for addressing water-related issues in numerous watersheds of developing countries, which are subject to diverse water stressors. Hence, this study aimed at conducting water footprint accounting under city/regional and basin scales for the investigation of the amounts of blue and gray water in the Haihe River Basin (HRB), China. The Blue Water Footprint Index (BWFI) and the Gray Water Footprint Capacity Coefficient (K) were introduced to comprehensively evaluate water scarcity in terms of quantity and quality. The results revealed that all cities of the HRB suffered from extreme water scarcity. The industrial sector was identified as the primary contributor to the blue water footprint at the watershed. The agricultural gray-water footprint of the HRB accounted for 54% of the total. The exploratory spatial data analysis (ESDA) was adopted to analyze the spatial auto-correlation features of blue and gray water in the HRB. The results indicated that Dezhou and Binzhou had the highest water deficiency in both of the water stresses, and that Xinxiang, Puyang, Anyang and Jiaozuo had the highest water problem predominantly due to water quality stress.

1. Introduction

Limited availability of fresh water jeopardizes human well-being, hampers economic growth, and contributes to losses of ecosystem functions and biodiversities (Launiainen et al., 2014). Currently, one-third of the world population are facing water scarcity (Manzardo et al., 2014). According to the UNEP (2008), the turning point will arrive in 2025 when almost half of the world's population would be living in declining situations of water stress due to increased water use (Sultana et al., 2014). One of the prominent problems of water scarcity in some areas is the severe discrepancy of the spatial distribution among the water resources, population and the economic development (Zhang and Anadon, 2014). The spatial imbalance and mismatch of the water endowments and demands have led to significant adverse ecological impacts, posing an immense challenge for the sustainable development of cities and river basins in arid regions (Foster et al., 2004). The increasing pressures on water resources have created the need for critical techniques and strategies related to sustainable water use and management (Sultana et al., 2014).

Currently, virtual water (VW) and water footprint (WF) are identified as important indications for sustainable water management. The concept of VW was proposed by Tony Allan in 1993 (Allan, 2003) to reveal the amount of embedded freshwater used to produce agricultural and industrial goods. In the early 2000s, this concept was further extended by the idea of "water footprint" (WF) by Hoekstra (Chapagain and Hoekstra, 2007; Hoekstra and Chapagain, 2007; Hoekstra and Hung, 2005; Ma et al., 2006) to uncover the hidden link between consumption and water use, which can be set as the basis for

* Corresponding author.
E-mail address: qian_tan@cau.edu.cn (Q. Tan).

http://dx.doi.org/10.1016/j.ecolind.2017.02.046
Received 28 November 2016; Received in revised form 31 January 2017; Accepted 13 February 2017
1470-160X/ © 2017 Published by Elsevier Ltd.

the formulation of new strategies of water governance (Hoekstra et al., 2011). From the perspective of water footprint, final consumers, retailers, food industry, and traders of water-intensive products could enter the scenario as potential 'change agents'. They can be addressed not only for their role as direct water users, but also for their role as indirect ones (Hoekstra et al., 2011).

In recent years, a large number of studies have been carried out on WF assessment at different scales. At a global level, O'Bannon et al. (2014) have reconstructed the network of agricultural pollution based on international trade records, commodity, and nation-specific gray WFs for the period between 1986 and 2010. Ercin and Hoekstra (2016) have developed forecasts of global WF scenarios for 2050 based on a number of drivers of change: population growth, economic growth, production/trade patterns, consumption patterns, and technological development to understand the changes in the WF of production and consumption for possible future developments by region, thus elaborating main drivers of this change. At a national level, several scholars have tried to compile the life cycle assessment (LCA) concept in the WF accounting for a sound analysis on the VW contents in various agricultural or livestock products. For instance, Lamastra et al. (2014) assessed the WF of Italian wine production throughout its entire life cycle. Haro et al. (2014) estimated the WF of sugarcane in Mexico. Zonderland-Thomassen et al. (2014) assessed the WF of beef cattle and sheep produced in New Zealand and compliant with LCA principles. Besides WF accounting for the products, the WF assessment approach was predominantly used in the VW accounting for analyzing national policies on water conservation via VW trade. For example, Mekonnen and Hoekstra (2014) conducted research on water resources conservation via the VW trade of Kenya. Winter et al. (2014) highlighted incongruent terms in VW balance by comparing the indexes denoting the ratio of virtual water exchanged during the swap and the ratio of the economic values of the swapped products for an illustration of the swap-product trade. Feng et al. (2014) incorporated a water stress index as well as an indicator for ecosystem damage into the assessment of interregional virtual water flows across 30 Chinese provinces. Cazcarro et al. (2014) complemented the WF estimations for Spanish tourism via an input-output analysis. El-Sadek (2010) introduced VW trade as a solution for the water scarcity in Egypt. In recent years, researches have also been conducted on the WF assessment at the regional level. The WF accounting is no longer restricted to the agricultural products, and some studies on industrial products have been undertaken by applying an input-output analysis. Such analyses help to assess annual changes in the WF of a region, identify the key economic sectors and factors leading to the changes, and quantitatively evaluate the contributions of those sectors and factors to the changes. Consequently, policy-makers can take water-saving actions focusing on the key economic sectors or factors. Zhang et al. (2011) quantitatively evaluated the water footprint and virtual water trade of Beijing by applying a provincial-level, interregional input–output model. Mubako et al. (2013) applied an input–output analysis to evaluate water use and to quantify virtual water transfers between California and Illinois. Relevant studies have also been undertaken in semi-arid and arid areas of European, South American, and African regions and other semi-arid and arid areas (Ene et al., 2013; Mekonnen et al., 2012; Nana et al., 2014; Pena and Huijbregts, 2014; Perez-Blanco and Thaler, 2014; Yan et al., 2013; Zhang and Anadon, 2014; Zoumides et al., 2014).

WF is a multidimensional indicator of freshwater consumption volumes by sources as well as of polluted water volumes by types of pollution. It is further analyzed as blue water footprint (blue WF), green water footprint (green WF), and gray water footprint (gray WF). The blue WF refers to the consumption of blue water resources (surface and groundwater) along the supply chain of a product. The green WF refers to the consumption of green water resources (rainwater insofar as it does not become run-off). The gray WF is defined as the volume of freshwater that is required to assimilate the load of pollutants, given natural background concentrations and existing ambient water quality standards (Hoekstra et al., 2011). Based on these concepts, researches have been conducted to assess regional blue, green, and gray water footprints. Two main shortcomings remain for the WF assessment. First, most of the previous studies mainly concentrated on agricultural and livestock productions, but few touched industrial and residential aspects due to limitations in accounting methods and difficulties in data collection (Chapagain and Hoekstra, 2007, 2008; Chapagain et al., 2006; Hoekstra and Chapagain, 2007; Mekonnen and Hoekstra, 2011; Zhao et al., 2010; Yan et al., 2013). With the expansion of urban areas and the prosperity of the modern life style, industrial production and residential activities developed into the fundamental cause of the current ecological crises. Thus, the study of the WF for industrial productions and residential activities is a significant field of research, which can scientifically reveal the multiple impacts on freshwater resources, caused by industrial and residential processes, ultimately improving sustainable and equitable water use in these fields (Yan et al., 2013). Secondly, few current studies have analyzed the three types of water footprints at a river basin scale, in particular, the assessment of these three types of WFs in different economic sectors of the cities level. Such studies would be quite helpful for water allocation in river basins, as there are wide variations in water and other natural resource endowments among different cities/regions inside river basins. In addition, it will make it feasible with a more detailed WFs accounting based on the city scale for the further optimal allocation of the water resources among river basins.

Therefore, the objective of this study was to conduct an in-depth WF accounting for different economic sectors and cities at river basins, and thus to reveal the spatial distributions of water stress and water pollution stress within the study area. The study would improve the evaluation accuracy of WFs for river basins via accounting efforts downscaled to cities, and enhance the WF-based methods of water stress analyses through applying an explore spatial distribution analysis (ESDA) model. With the Haihe River Basin (HRB) being the study area, the research entails the following tasks: (a) to evaluate blue and gray WFs in different sectors of the cities within HRB as well as for the entire basin; (b) to conduct blue and gray WF analyses based on indicators of both water stress and water pollution stress; and (c) to analyze the spatial distribution correlation of the cities based on the water stress and water pollution stress analyses indicators. In detail: (i) the blue and gray WFs of the three main sectors for 26 cities in the HRB will be analyzed, respectively, via the Environmental Input-Output Model; (ii) the water stress and water pollution stress will be analyzed via the Water Footprint Index and the Gray Water Footprint Capacity Coefficient at the city and basin scales; (iii) the ESDA Model will be applied to identify the spatial cluster properties of the cities in terms of the water stress and water pollution stress indicators. The results of this study reveal the water stress on both the quantity and quality of the river basin in various economic sectors. Thus, the further concerning instructions on water allocation strategies can be formulated accordingly.

2. Methodology

2.1. Environmental input-output (IO) model

2.1.1. Internal & external water footprint

The general IO model was set up by Leontief (1941) to represent the monetary trade of intermediate products between different sectors in an economic system. This IO model was further developed into the Water IO model by Zhang et al. (2011) This model portrays how the production of an economy depends upon interactions between different sectors and final demand (Zhi et al., 2014). Water is a primary input into economic production, and this relationship is reflected through freshwater use coefficients for each economic sector (Mubako et al., 2013). Thus, the water IO model can be summarized in Eq. (1) (Zhang and Anadon, 2014):

Download English Version:

https://daneshyari.com/en/article/8845263

Download Persian Version:

https://daneshyari.com/article/8845263

Daneshyari.com