Accounting the Virtual Water and Virtual Land Based on Input-output analysis-- A Case Study of Zhangye City

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Abstract

Water and land are the basic elements of ecological protection, economic development and human life in Zhangye city. The virtual water and virtual land accounting are the core research content to achieve sustainable development in this area. In this paper, the virtual trade of water and land in Zhangye city is analyzed via environmental input-output analysis. It is found that the virtual water and land in this area are in a net outflow state. From the perspective of sectors, the agricultural sector is the largest net outflow sector of virtual water and virtual land, while the manufacturing sector is the net inflow sector. The accounting in this paper can provide a solid foundation for the formulation of industrial and trade policies.

Keywords: virtual water, virtual land, input-output analysis

1. Introduction

The original intention of the concept of virtual water and virtual land is to alleviate the sustainable development of water shortage and land-deficient countries or regions, and to provide a new way for the management of water and land resources. Virtual water refers to the water that has been used by human economic and social system and is stored in commodities by the transformation of part of the resource water. It is equivalent to the amount of water used under specific socio-economic and technological conditions, i.e. the amount of water used to produce goods and services [1]. Compared with virtual water, the study of virtual land resources is less, and referring to the theory of virtual water, virtual land is not real land, but is hidden in products in the form of “virtual”.

For areas with scarce water and land resources, it is an attractive choice to alleviate the local resource crisis by importing virtual water and virtual land, because this method is equivalent to completing the secondary allocation of resources via trade [2]. These virtual resources reflect the utility nature of the resources in the economic and social system. They have important theoretical guiding significance and technological support to protect regional resources and realize the sustainable development of regional eco-economic systems [3].

The concepts of virtual water and virtual land emerged in order to analyze the relationship between the activities of the economic sector [4-6]. Wang et al. constructed the virtual water network in the urban scale economic system based on input-output analysis, and analyzed the virtual water relationship formed by the internal economic system association [7]. Fang et al. conducted the linkages analysis to explore the embodied water and energy flows in urban economy [8]. On the national scale, Chen et al. accounted the virtual water consumption triggered by final demand, resident consumption and infrastructure via multi-regional input-output analysis, analyzed the virtual water flow between different departments in different provinces, identified the key virtual water outflow into provinces and sectors, analyzed the trade pattern of virtual water in China, and provided the virtual water strategy for China [9].

The existing research on virtual land mainly focuses on the transfer of virtual water resources and land caused by food trade. For example, Zou Jun et al. studied the virtual water consumption of grain production, put forward the concept of regional grain production dominance degree, used quantitative evaluation model to calculate the dominance degree of grain production in provincial regions, constructed the adjustment index of grain production distribution as the basis for the optimization and adjustment of grain production in different regions of China, and classified the direction of regional grain production adjustment. This paper explores the ideal distribution pattern of grain production in China under the background of virtual water strategy [10]. Based on multi-regional input-output and complex networks, Chen et al. calculated the flow
of virtual land and virtual water resources caused by the trade of more than 160 crops among 188 regions worldwide [11]. However, there are few studies on virtual water and virtual land trade in Zhangye. Considering the shortage of water resources, high-quality land resources, especially arable land in Zhangye city, it is urgent to account the virtual water and virtual land in this area.

2 Method
At present, 2012 Zhangye Input-Output table is available, which is applied in this study. The 42 sectors have been aggregated into six, which are Agriculture (Ag), Mining (Mi), Manufacturing and Construction (Ma), Electricity Supply (Ei), Water Supply (Wa) and Services and transportation (St).

In the input-output table, the water or land direct intensity can be expressed as Eqs. (1)-(2):
\[ \theta_w = \frac{V_{wi}}{X_i} \quad (1) \]
\[ \theta_l = \frac{V_{li}}{X_i} \quad (2) \]

Where \( \theta_w \) and \( \theta_l \) is the water or land direct intensity in terms of economic output of sector \( i \) in Zhangye respectively; \( V_{wi} \) refer to the direct water consumption in the sector \( i \). Similarly, \( V_{li} \) refer to the direct land consumption in the sector \( i \). The virtual water and virtual land by sector can be expressed as Eqs. (3):
\[ V = \theta^{diag} (I - A)^{-1} NE \quad (3) \]

\( V \) is the vector of sectoral virtual water or land consumption triggered by net outflows \( \theta^{diag} \) is a diagonal matrix transformed from \( \theta_w \) or \( \theta_l \); \( A \) is the direct requirement matrix calculated by monetary flows among sectors divided by corresponding economic outputs. \( I \) refers to the identity matrix. \( NE \) is the vector of net outflows of corresponding sector.

3 Results and discussion
Fig. 1 shows the virtual water net outflow of six sectors in Zhangye City. Agriculture has the largest net outflow, which means that the net output of agricultural products in Zhangye area is large. At the same time, the sectors of net inflow are mining, construction and manufacturing industries, indicating that the local industrial base is weak and a large number of mineral and industrial products need to be imported. In general, there is a large amount of virtual water outflow in Zhangye city, and agricultural outflow is dominant.

4 Conclusion
Combined with the net outflow of virtual water and virtual land of Zhangye city, the agricultural sector is the largest outflow sector of water and land resources in the region, and occupies an absolute dominant position. Because of the drought and lack of rain in Zhangye and the insufficient arable land area, it is necessary to optimize the local industrial structure, especially the agricultural structure, in order to achieve sustainable development without affecting food security.
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Reference