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Virtual land use change in China 2002–2010: Internal transition and trade imbalance

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ABSTRACT

As the second largest economy with the largest population in the world, China encounters crucial land availability for food security and socio-economic development. In the context of China's booming economy over the past 3 decades, this study intends to reveal the impacts of domestic demand and international trade on land use distribution of China in the period 2002–2010. This study aims to systematically analyze China's land use-related issues comprehensively, considering multi-type land use, high sectoral resolution, and time series input–output data. Obviously, primary industry is the largest virtual land occupier which covers both the local land use and land use trade, while the importance of secondary and tertiary industries should not be ignored. Mainly due to the land use embodied in the secondary and tertiary industries, China is found as a net exporter of cultivated land use. This figure exceeds by 25 times the cultivated land use loss due to built-up land use occupation, which means that the "red line", China's cultivated land area constraint set as 120 million hectares (ha), is gradually losing its original meaning. With respect to all types of land use, China exports 20 million ha of land use per year, accounting for 1/50 of the total land area. The huge land use trade imbalance raises an alarm for China. In the recent past, the land occupation type is gradually translating from the original "colonial" land to inter-national land use trade imbalance, and obviously China has not been familiar with such hidden aspects remaining in global trade. As both the direct and indirect land use associated with consumption and trade flows become increasingly significant, suggestions from the virtual perspective are urgently needed to initiate a new horizon.

Introduction

As the second largest economy with the largest population in the world, land availability is crucial for China, especially in the aspect of food security and economic development. Although China has a total area of some 960 million hectares (ha), which is the third largest in the world, only about 14.8% is cultivated with field crops and horticultural products. Cropland areas are shrinking due to both urban sprawl and demand for other requirements (Fan et al., 2013; Qiang et al., 2013). On balance, China lost some 980,000 ha of cultivated land to construction activities between 1988 and 1995 (Fischer et al., 1998). In the case of forestland and grassland, over-exploitation, degradation, and conversion from cultivated land deserve certain attention as well (Fischer et al., 1996; Liu, 1998).

During the last couple of decades, local factors are no longer the most significant determinants of land use decisions. When the modern economic mode creates possibility to rematch resources supply and commodity demand by expanding the production and trading chains, the indirect land use associated with consumption and trade flows has been increasingly significant. This has major implications for the ways in which we conceptualize and explore the land use change (Huang et al., 2011). As land resources are becoming scarcer throughout the world due to population growth, urbanization, and changing consumption patterns, land use change analysis will be increasingly important for nations with land use insufficiency.

To analyze the land use in the complex globalized economic systems, input–output analysis (IOA) method can be readily employed, allowing resource flows and environmental impacts to be assigned to final demand through inter-industrial connection (Chen and Chen, 2013). This method was developed and refined by Leontief

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(1986) and has played an important role in macro-economic policy implications (Hubacek and Giljum, 2003). As a powerful systematic accounting method, IOA is widely applied in the analysis of various ecological elements and environmental emissions in the system concerned (Chen and Zhang, 2010; Han et al., 2014; Peters and Hertwich, 2008). Land use assessment based on IOA can be dated back to 1998, when Bicknell et al. (1998) adopted the method and applied it to New Zealand. The methodology was further updated by Lenzen and Murray (2001) in a multi-regional input–output framework for Australia's land use displacement. Subsequently, a series of studies made contributions to the field of land use accounting based on IOA (Lenzen et al., 2003, 2007; Wood et al., 2006). Currently, this method has been widely adopted for land use accounting at global, national, and urban scales (Galli et al., 2012; Hubacek et al., 2009; Wiedmann et al., 2006, 2007), showing its great significance for land use analysis and policy implications. Especially in the research conducted by Yu et al. (2013) and Weinzettel et al. (2013), the global land use in the years of 2004 and 2007 were fully elaborated under a global multi-regional input–output model and attributed to different global economic sectors.

However, only a limited number of studies focus on China's specific land use based on IOA. Hubacek and Sun (2001) calculated China's land requirements by input–output modeling to access how the changes in the economy and society affect land use and land cover. Zhou and Imura (2011) calculated the land use for China 2000 based on a multi-region input–output model to trace the origin of regional consumption and systematically account for the ecological impacts embodied in interregional trade. Guo et al. (2014) conducted an embodiment analysis on China's cultivated land use with high sectoral resolution and time series input–output data, aiming at demonstrating how cultivated land in China is utilized to meet the requirements of domestic consumption and international trade. These studies have contributed significantly to the development of the land use assessment in China. However, in consideration of the diversity and complexity of China's land issues, a systematic analysis on China's land use change with multi-type land use, high sectoral resolution, and time series input–output data is still lacking. Such a case is needed to depict detailed relationships of different land use types as well as consumption and trade patterns of China's land use change.

To present a comprehensive and systematic analysis of the land-related issues existing in China, this study performs an IOA based assessment on China's land use with multi-type land use, high sectoral resolution, and time series input–output data. The study is to shed light on the land use change trend in China and to provide insight into the consumption and trade patterns of land use. The remainder of the paper is structured as follows: the section "Method and data sources" articulates the method employed in this study, the section "China's land use change 2002–2010" summarizes the detailed results, the land use distribution and trade patterns are discussed in the section "Discussion", and in the final section "Concluding remarks" are drawn.

Method and data sources

To quantify the virtual land use of final use for each economic sector, applied in this study is the environmentally-extended IOA method, which can transform the quantity of the direct land use into that of the virtual land use by means of the economic input–output table (NBSC, 2006, 2009). Based on Leontief's input–output model (Leontief, 1986), the environmentally-extended IOA method integrates environmental elements into economic network to reveal the resources and emissions profile associated with all the economic flows (Chen et al., 2013).

Input–output analysis method

Issued by National Bureau of Statistics of China, China input–output tables are adopted to reflect the systems structure and industrial interaction of the mainland China economy (NBSC, 2006, 2009). Extended from the economic input–output tables, environmentally-extended input–output tables for national economy are built up to integrate economic system and its physical driving forces such as land use. Thus, the environmentally-extended IOA is conducted based on the relationship between monetary flows and land use, with the direct land use of each economic sector assigned equal to the virtual land use for the final use of the sector. For an economy with n sectors, this transformation of production-based direct accounting into demand-based accounting requires:

$$u_i + \sum_{j=1}^{n} \varepsilon_j z_{j,i} = \varepsilon_i x_i,$$

$$x_i = \sum_{j=1}^{n} z_{i,j} + f_i,$$

where u_i represents direct land use of Sector i, ε_j represents virtual land use intensity of Sector j, $z_{j,i}$ represents intermediate output from Sector j to Sector i, x_i represents gross output of Sector i, and f_i represents final use of Sector i.

Subsequently, the land use matrix form can be expressed as:

$$U + EZ = E\hat{X},$$

in which, $U = [u_i]_{1\times n}$, $E = [\varepsilon_i]_{1\times n}$, $Z = \left[z_{i,j}\right]_{n\times n}$ and diagonal matrix $\hat{X} = \left[x_{i,j}\right]_{n\times n}$, where $i, j \in (1, 2, \ldots, n)$, $x_{i,j} = x_i$ $(i = j)$, and $x_{i,j} = 0$ $(i \neq j)$.

With properly given direct land use matrix U, intermediate input matrix Z, and total output matrix X, the virtual land use intensity is obtained as:

$$E = U(\hat{X} - Z)^{-1}.$$

E stands for the land directly and indirectly utilized in the productive process to meet one monetary demand of the output, indicating an essential correlation between the product in monetary value and the induced land use.

Data sources

The land data in China are obtained from China Land and Resources Statistical Yearbook, which are derived from the nationwide field investigation carried out by the Ministry of Land and Resources (MLR, 2001, 2003, 2006, 2008, 2013). The earliest data released by the Ministry of Land and Resources is for the year of 2001. The changes in the land use data collecting procedure have a negative impact on data quality and consistency, which increases difficulties for time-series study. However, as land use patterns are comparatively stable at the national scale, the data discrepancy introduced from collecting procedure changes is considered to be acceptable for this study.

IOA was proposed by Leontief in the 1930s, identifying the economic linkages among production and consumption activities based on the cross sector balance (Leontief, 1936; Zhang et al., 2013). The national input–output tables published by National Statistical Bureau of China are used in this study (CIOA, 2015; NBSC, 2006, 2009). The first official input–output table for China is that for 1987, and since then the benchmark tables are compiled every five years. Besides, extended tables have been also compiled based on the latest benchmark tables every five years since 1990. Up to present, there are ten official national input–output