VIRTUAL LAND USE IN CHINA
OVER TIME AND SPACE

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CERTIFICATE OF ORIGINALITY

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GUO Shan

Abstract

As all human beings fundamentally depend on nature, natural capital accounting becomes increasingly prominent. Productive land is a good proxy for natural capital and it can provide a wealth of materials needed by humans. Globalization increases worldwide economic links. The displacement of land use from one place to another occurs when goods are traded among industries and regions, thus shifting the pressures of local land resources. Exploring land occupation of the Chinese economy is a great concern given the modern economic organization of China and its growing trade connections.

The fast population increase, rapid economic growth, accelerated commodity consumption and expansion of domestic and foreign trade present increasing challenges for China's sustainable land use. Temporal nexus studies for exploring the dynamics and evolution of China's virtual land use change are important to meet the sustainability needs of future land use. Spatial nexus studies provide a useful basis for understanding China's regional displacement of land use and facilitating regional cooperation and partnerships to achieve sustainability. Resource challenges are interconnected. Land and water are the two basic elements that have the most significant effects on China's agricultural production. Studies of land-water nexus identify the increasing interconnections and tradeoffs of China's land and water use.

This research aims to explore systematically the temporal nexus, spatial nexus, and resource nexus of China's land use to provide insight into "virtual land" given the complex globalized economic network. This can facilitate China's sustainable land management by

establishing a comprehensive database of historical and spatial virtual land use data, and data on the land-water nexus.

The specific research objectives are as follows:

(1) To investigate the changing pattern of China's virtual land using time series input–output data;
(2) To explore regional land footprint distribution patterns and regional spatial transfer of virtual land use;
(3) To understand the linkages and tradeoffs between land and water by identifying China's land–water nexus;
(4) To draw policy implications for achieving sustainable land management by providing insight into the temporal nexus, spatial nexus, and resource nexus of China's virtual land use.

This study first employs time-series data to investigate the land occupation of the Chinese economy over time with multiple land use types, including cultivated land, forest land, pasture land, and construction land. The calculated results are a solid reference to recognize the historical characteristics of China's virtual land. These findings also provide a detailed historical database to guide sustainable land use management. Second, this study identifies the land occupation of the Chinese economy over space with China's four land use types. A spatial database is provided to help establish integrated sustainable land use policies considering all kinds of land use types in China's 30 regions. Third, this study simultaneously analyzes China's farm land and water embodied in consumption and interregional trade. Determining the nexus of farm land and water use in a complex and interrelated economy is crucial as various environmental indicators usually interact and complement each other. Lastly, policy implications are developed and provided in accordance with a systematical analysis of the temporal nexus, spatial nexus, and resource nexus.

The key findings obtained in this study are as follows. First, *Agriculture* and *Food Processing* are two key sectors that contribute the largest volumes of embodied cultivated, forest and pasture land to meet the household food demand in 2012. *Construction* and *Food Processing* are crucial sectors that consume the largest embodied construction land. Although the total consumption-based land use in China fluctuates, embodied cultivated, forest, pasture and construction land intensities in 1987-2012 and 2000-2012 have a downward trend, showing China's effort to improve various land use efficiencies and effectiveness. With respect to trade pattern, *Agriculture* sector is the largest net importer of cultivated, forest and pasture land in China, *Petroleum Extraction* sector is the largest net importer of construction land, whereas *Garments* sector is the largest net exporter of the four types of land use. China is a net exporter of embodied cultivated, forest, pasture and construction land throughout the concerned years.

Second, the imbalanced spatial distribution between the supply and demand of land use is observed. Some developed regions, such as Shandong, Jiangsu, and Guangdong, are the most significant driving factors of cultivated, forest, and pasture land consumption, although these regions have relatively less land. The net transfer of cultivated and forest land flows are mainly from undeveloped regions, such as Heilongjiang, Inner Mongolia, to developed regions, such as Shandong, Jiangsu and Shanghai. Net flows of pasture land come principally from Xinjiang, Inner Mongolia and Qinghai. Three economic regions of

China with the most active trade activities attract a significant amount of embodied construction land, mainly derived from nearby provinces. Third, Shandong, Henan, Guangdong and Yunnan are the most important drivers of farm land and water consumption in China. Heilongjiang is the largest farm land and water supplier, and Shanghai is the largest receiver.

This study reconsiders land occupation of the Chinese economy in different time and space to prioritize sustainable land use. A systematical analysis of the temporal nexus, spatial nexus, and resource nexus of China's land use is conducted by considering the complex globalized economic networks. Temporal nexus can help identify significant historical characteristics and the key driving factors. Spatial nexus identifies the issues of spatial transfer of land resource pressures and the spatial distribution patterns of land footprint. Land–water nexus is crucial to recognize the interdependencies, synergies and tradeoffs of farm land and water resources, allowing for an integrated sustainable agricultural development plan. This systematical analysis of China's land use is vital to customize and prioritize policy recommendations on sustainable land management in China.

Publications

Refereed Journal Papers:

1. Guo, S., Shen, G.Q.P., Peng, Y., 2015. Embodied agricultural water use in China from 1997 to 2010. Journal of Cleaner Production. 112, (4): 3176-3184. (SSCI, SCI, EI, IF=**4.167**)

2. Guo, S., Shen, G.Q.P., Yang J., Sun B.X., Xue F., 2015. Embodied energy of service trading in Hong Kong. Smart and Sustainable Built Environment. 4 (2): 234-248.

3. Guo, S., Shen, G.Q.P., 2014. Multiregional Input–Output Model for China's Farm Land and Water Use. Environmental Science & Technology 49 (1): 403-414. (SSCI, SCI, EI, IF=**5.481**)

4. Guo, S., Shen, G.Q.P., Chen, Z.M., Yu, R., 2014. Embodied cultivated land use in China 1987–2007. Ecological Indicators 47, 198-209. (SSCI, SCI, EI, IF=**3.444**)

5. Hong, J.K., Shen, G.Q.P., Guo, S., Xue, F., Zheng W., 2015, Energy use embodied in China′s construction industry: A multi-regional input–output analysis. Renewable and sustainable energy reviews. 53: 1303-1312. (SCI, EI, IF=**5.901**)

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Chapter 1 Introduction

1.1 Research background

Fundamentally human beings all depend on nature, therefore natural capital accounting becomes increasingly prominent. Productive land is a good proxy for natural capital and it can provide a wealth of materials needed by humans, such as food and timber (Wackernagel et al., 1999). Given the finite character of land with its biophysical[1] wealth, there is an urgent need to conserve the scarce productive land resources for supporting the complex social–economic–ecological systems of humans (Chen and Chen, 2006a). Globalization increases worldwide economic links. The displacement of land use from one place to another occurs when goods are traded among industries and regions, thus shifting the pressures of local land resources (Lambin and Meyfroidt, 2011). Land occupation of the Chinese economy[2] is a great concern given the modern economic organization of China and its growing trade connections.

As a country with approximately one-fifth of the world's population but only 7% of the land area of the world, China faces a severe land resource problem of low per capita availability (Chen, 2007). Moreover, high resource consumption is needed to support China's rapid economic development. China is under unprecedented pressures on how to

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[1] Biophysical factors include soil quality, land-cover, biodiversity and etc.

[2] Land occupation of the Chinese economy refers to the hidden land costs behind China's economic activities, which can be used to determine how China's economic activities use parcels of land.

properly allocate its scarce land resources to meet future demands for goods and services because of the increasing food demand, expanding biofuel production as well as the rapid industrialization and urbanization in recent years (Qiang et al., 2013). Local factors cannot be considered as determinants to address these concerns because of globalization. The modern economic organization mode can balance resource supply and commodity demand by expanding the production and trade chain or network. Thus, China needs to focus more on indirect land use, which is associated with domestic and foreign trade flows, to protect land in the country.

Ecological footprint (EF) was proposed by Rees and Wackernagel in the 1990s (Rees, 1992, 1996; Wackernagel and Rees, 1996) to estimate how fast natural resources are consumed at a global scale. EF is defined as "the total area of productive land and water area required continuously to produce all the resources consumed and to assimilate all the wastes produced, by a defined population, wherever on earth that land is located" (Rees and Wackernagel, 1996). Despite the significance of EF in land resource accounting, EF is criticized for failing to depict the mutual interrelationships of economic activities and to assign indirect environmental burden from inter-industrial dependencies (Costello et al., 2011). Although this concept aims to address consumer responsibility, it disregards the real linkages between a specific consumption and actual resource use; thus, EF fails to reveal cause–effect relationships to trace back to the places where ecological effects really occur (Lenzen et al., 2007b). Production versus consumption-based method has been extensively explored in greenhouse gas emissions accounting field. The production accounting principle typically focuses on local production emissions but does not consider all the emissions, including the direct and indirect emissions caused by the entire chain of production, which are allocated to final consumers (Wiedmann, 2009). The consumption accounting principle is proposed to estimate carbon emissions, which are associated with consumption (Wiedmann, 2009). In this study, producers are responsible for local land resources, and consumers are responsible for land resources they consumed.

The ever-closer economic relationship among various industries in different regions through interregional trade exacerbates the pressure on resource displacement. Land-intensive commodities or services are generally consumed in economically developed regions but produced in resource-rich regions. The issues of resource pressure transfer and responsibility allocation, as well as the total direct and indirect resource consumptions in the entire supply chain (i.e. the embodied resource utilization), have gained significant attention in environmental accounting field (Costello et al., 2011; Hertwich and Peters, 2009; Kanemoto et al., 2012). The concept of "virtual land" is put forward to understand the total (including direct and indirect) land consumption (Wichelns, 2001; Würtenberger et al., 2006). Interchangeable with "embodied land", this concept refers to the total land required for the whole production process of goods or services. Virtual land is considered as an efficient proxy for embodied land resource impacts in trade flows, for example, to measure how much land areas are occupied by certain traded crops. "Land footprint" is used to describe the real amount of land to satisfy consumption (Weinzettel et al., 2013).

From the perspective of virtual land, we need to reconsider the relationships of land occupation in different time and space. Criticisms on land ecological resource constraints are severe. Urbanization in China is unprecedented and large-scale. This human movement will likely exceed the carrying capacity of nature. Thus, the investigation of changing pattern of virtual land is essential to assess the limitations or boundaries of resource consumption. In the context of economic globalization, social inequity is a great challenge that is accompanied by high social division because of industrial specialization. Highly social division occurs when a region only focuses on limited products and services to increase productivity. Thus, the exploration of regional spatial transfer of virtual land associated with the domestic and foreign trade is necessary to understand the regional inequity of resource consumption and its related responsibility allocations.

Input-output analysis (IOA) is a well-established approach in virtual land accounting that enables resource flows and environmental effects to be assigned to categories of final consumption through inter-industrial net connections, and it is a quantitative methodology adopted to represent sectoral virtual land flows with economic flows based on physical balance (Chen and Chen, 2011a). Multi-regional input-output (MRIO) is also used to present the interactions among various industries within several associated economic regions considering the regional characteristics and industrial effects (Wiedmann, 2009).

Given the effect of the global economic trade on regional resource displacement, this study aims to conduct a systematical analysis of China's virtual land use over time and space. The systematical analysis can motivate the Chinese government to prioritize sustainable land use and to avoid promoting economic development at the expense of precious land resources.

1.2 Scope of the study

The research scope of China's land use is broad (including land use change, and its relevant environmental, social, and economic effects). Thus, defining the specific scope of this study is necessary.

First, this study mainly focuses on China's virtual land, though China's actual land use change is crucial and has been discussed by many researchers. The significance and implication of virtual land are gaining increasing research attention.

Second, four land use types are discussed in this study, i.e., cultivated land, forest land, pasture land, and construction land. Irrational utilization of these biologically productive areas will mainly cause biodiversity loss. According to China's Land Management Law, land use classification includes agricultural land, construction land, and unused land. Agricultural land (or farm land) is mainly divided into cultivated land, forest land, pasture land, and other types of agricultural land. Per capita farm land in China is only approximately 0.08 hectares (Yang et al., 2009). Cultivated land supplies food, which is one of the most essential resources for human survival. To raise a large population, the Chinese government employs legislative measures to establish a "red line" limitation, i.e., 120 million hectares, for its cultivated land (Wang et al., 2012; Yang, 2013). Forest land provides timber products and absorbs carbon dioxide. The per capita forest area in China is 0.13 hectares, which is less than a quarter of the world average. By contrast, Chinese timber demand has increased by approximately 80% in the past decade (Nie et al., 2010). Pasture land is used for grazing to raise livestock for meat, dairy or animal products. Global climate change and livestock grazing are the major drivers of serious degradation and deterioration of grassland in China over the past 30 years (Yu et al., 2011). Construction land includes land used for residential, industrial or mining site, transportation and water conservancy facilities (MLR, 2008). A significant area of newly construction land will replace cultivated land as China undergoes urbanization at an unprecedented rate (Xu et al., 2011).

Thirdly, China's virtual land use is examined from the temporal and spatial perspectives. Temporal integration is a key element for the systematical analysis, as changing pattern of virtual land use can be examined by observing more clues over time. Spatial integration also plays an important role in this study. If only land resource consumption is considered from the local perspective, additional consumption may be generated during the whole life period and transferred from or to other regions in consideration of the fact that environmental issues are occurring worldwide.

1.3 Research questions

In the past 20 years, China has experienced rapid economic growth, accelerated resource and commodity consumption, as well as domestic and foreign trade expansion. In the complex economic environment, China's land resource governance faces increasing complexity, particularly when the linkages and interdependence of industrial economies over time and space are considered. Water and land are the two basic elements that have the most significant impact on agricultural production worldwide. The relevance of the interconnection of these two factors is increasing, and growing tradeoffs are also being identified. Land–water nexus is to describe the complexity and interconnects of land and water resource utilization system, allowing for more integrated and effective sustainable evaluation and planning (FAO, 2014). Thus, this study explores the temporal nexus, spatial nexus, and resource nexus of China's virtual land to achieve sustainable land management goals in the context of complex economic and environmental considerations. The specific research questions are as follows:

(1) What is the changing pattern of China's virtual land with multi-type land use over time? (temporal nexus)
(2) What are the regional land footprint distribution patterns and regional spatial transfers of virtual land use in China? (spatial nexus)
(3) How does China allocate farm land and water resources to meet unbalanced food demands by identifying the land–water nexus? (resource nexus)

1.4 Research aim and objectives

To address the research questions, this research aims to explore systematically the temporal nexus, spatial nexus, and resource nexus of China's land use to provide insight into "virtual land" given the complex globalized economic network. This can facilitate China's sustainable land management by establishing a comprehensive database of historical and spatial virtual land use data, and data on the land-water nexus. The specific research objectives are as follows:

(1) To investigate the changing pattern of China's virtual land using time series input–output data;
(2) To explore regional land footprint distribution patterns and regional spatial transfer of virtual land use;
(3) To understand the linkages and tradeoffs between land and water by identifying China's land–water nexus;
(4) To draw policy implications in achieving sustainable land management by providing insight into the temporal nexus, spatial nexus and resource nexus of China's virtual land use.

1.5 Value and significance of the research

China is experiencing rapid industrialization and urbanization, thus the demand for natural capital accelerates. To avoid developing economy at the expense of precious land resources, how to transform China into an environment–friendly society that respects and conserves land resource becomes an important issue. Globalization increases the interregional economic links, and trade plays an increasingly crucial role in redistributing land resource. Under this context, a systematical analysis of China's land use is conducted in this study. The findings can help to reveal the regional and sectoral land use efficiency, and the impacts of consumption and trade on regional land use in China.

In terms of theoretical contribution, the concept of "virtual land", which serves as a proxy for total land impacts embodied in trade flows, is used in this study to reconsider the relationships of land occupation of the Chinese economy in different time and space. Comparing with policies that focus only on local land resources, the findings considering "virtual land" can motivate Chinese government to prioritize sustainable land use management from a consumption-based perspective. Besides, this study conducts a systematical analysis of the temporal nexus, spatial nexus, and resource nexus of China's land use by providing insight into "virtual land", given the complex globalized economic network. This analysis can help policymakers to identify policies with unsustainable or unfair effectiveness, such as policies with effectiveness in the short period but little detectable effect in the long run or in one specified region but adverse effects on other regions. This analysis can eventually contribute to an integrated, long-term and multi-spatial land use planning strategy.

In terms of practical contribution, temporal analysis can facilitate extracting significantly historical statistics and other characteristics based on the time series data. This can also help to identify the driving factors for China's virtual land change. Spatial nexus is to identify the characteristics of interregional virtual land flows combined with geographical properties. Identifying the issues of spatial transfer of land use pressure, and the spatial distribution patterns of land footprint in the whole supply chain, is vital to customize and prioritize regional land use policy recommendations. Establishing the land–water nexus is significant to recognize the complex linkages and feedbacks of China's farm land and water. According to these insights, improving land resource end-use efficiency, optimizing industrial and regional trade structures, allocating regional responsibility based on the land-demand-driven strategy, and building synergies of resource utilization goals are all needed to be addressed to achieve China's sustainable land use goals.

1.6 Structure of the thesis

This thesis is composed of seven chapters.

Chapter 1 presents the overall introduction that highlights the essential information on the entire research, including the background, research questions and objectives, scope and design of the research, research methods, and structure of the thesis.

Chapter 2 describes a comprehensive literature review on China's actual and virtual land uses. Three literature categories are reviewed regarding actual land use: the overall changes in China's land use, their related environmental effects, and relevant research on specific land use categories. Three literature categories are also reviewed regarding virtual land use: the definition of virtual land, studies on virtual land accounting, and studies on China's virtual land accounting. Research gaps are identified in this research to improve the significance of the study.

Chapter 3 presents the methodology. This chapter discusses both single regional input-output (SRIO) and MRIO models to conduct temporal and spatial analyses of China's land use. With regard to each analytical method, the data collection, which is used to gather information on the objective, the algorithm, which is adopted to calculate the embodied land flows, and the indicators used to assess the temporal and spatial characteristics of China's land use, are all described in detail.

Chapter 4 presents the temporal nexus of four land use types, namely, cultivated land, forest land, pasture land, and construction land. A temporal comparison of virtual land use over the recent 20 years is presented in this chapter to depict the changing trends of virtual land use. Moreover, this chapter conducts a horizontal comparison among sectors within the same time frame in 2012 to show the "common but differentiated" industrial responsibilities for land protection.

Chapter 5 identifies the spatial nexus of China's four land use types, namely, cultivated land, forest land, pasture land, and construction land. Actual land cover distribution patterns, regional land footprint distribution patterns, and regional spatial transfer of virtual land use are described in detail in this chapter.

Chapter 6 simultaneously assesses China's regional virtual farm land and water use. The two basic elements of land and water have the most significant effect on agricultural production activities worldwide. Thus, a set of indicators is also proposed to reveal the intensity of regional and sectoral farm land and water use as well as the effects of consumption and trade on regional farm land and water use. In addition to conducting responsibility allocation under the land or water demand requirements, agricultural policies can also be formulated to improve resource end-use efficiency and optimize industrial and regional trade structures.

Chapter 7 summarizes the main research findings and examines how the research objectives, which are proposed at the beginning of the study, are achieved. The theoretical and practical contributions are highlighted. Finally, the limitations of this research and directions for future studies are discussed.

1.7 Chapter summary

This chapter provides an outline of the dissertation, including the research background, scope of study, research questions, research aim and objectives, and research significance. Why and how this research is conducted is answered in this chapter. This study can fill the knowledge gap in China's sustainable land management in virtual land accounting. The structure of this thesis is also outlined. The research gap is further explored in the next chapter based on a series of literature reviews.

Chapter 2 Literature Review

2.1 Introduction

The literature relevant to China's actual and virtual land is reviewed. The research hotspots in China's land use change, the environmental effects of these changes and specific land use categories are identified first. By identifying the significance of virtual land, this study recognizes the definition of virtual land, virtual land accounting method, and China's virtual land studies. Based on the literature review, research gaps in the scope of existing studies are identified.

2.2 China's actual land use

2.2.1 China's total land use change

China is a populous country with approximately one-fifth of the world's population, but it occupies only 7% of the world's land area. Thus, the country faces a severe food security issue (Chen, 2007). China's land use has been discussed by many scholars around the world (Feng et al., 2014; Guanghui et al., 2015; Liu et al., 2014a; Liu et al., 2014b; Liu et al., 2014c; Long, 2014; Wang et al., 2014). Significant changes in land use have been recently experienced in China, and they are attributed to rapid urbanization, industrialization, and globalization. Many scholars have attempted to analyze the characteristics and changing trends of China's land use. Major land use problems in China in the context of rapid urbanization are analyzed by Liu et al. (2014a). This research determines that the inconsistencies of urban–rural built land, and requisition–compensation balance of cultivated land are the targeted problems in the implementation of current policies. However, China lacks a comprehensive study to assess these problems. Analyzing the spatial–temporal characteristics of land use change is essential for sustainable land use management.

2.2.2 Land use change and its environmental impacts

Aside from studies on the characteristics of land use, the cause–effect relationships between the changes in land use and climate change, bioenergy production, and ecological functions (e.g., biodiversity) are also the research hotspots recently.

The most significant anthropogenic effects on climate are greenhouse gas emissions and land use change (Kalnay and Cai, 2003). Many scholars have attempted to determine the effects of land use change on climate change (Dale, 1997; Olesen and Bindi, 2002; Pielke, 2005; Pielke et al., 2002; Stern et al., 2006; Watson et al., 2000). Pielke et al. (2002) quantified the effects of land use change on regional and global climate. However, Dale (1997) pointed out that the vast majority of land use change is not significantly related to climate change in recent centuries. He also considered non-climatic causes of land use change (e.g., socioeconomics and politics) as necessary to better realize sustainable ecological functions on regional and global scales.

Global climate change has increased the demand for bioenergy production because burning fossil fuels emit a lot of greenhouse gases. The land use dynamics of bioenergy crop production is essential for the sustainable development of bioenergy. Many studies have focused on the effects of bioenergy production on land use change (Campbell et al., 2008; Don et al., 2012; Fischer et al., 2010; Johansson and Azar, 2007; Miyake et al., 2012; Walsh et al., 2003). Miyake et al. (2012) reviewed the bioenergy-driven land use changes in four regions (Brazil, Indonesia and Malaysia, the United States of America, and the European Union) and confirmed that bioenergy-driven land use change would continue to severely affect the land-abundant developing regions where economic development is prioritized over sustainable land use policies.

Land resources provide the basic functions for human beings to grow crops, raise animals, obtain timber, and build cities. In addition to these essential ecosystem goods, land resources provide a range of other ecosystem functions, such as freshwater supply, regulation of climate and biogeochemical cycles, maintenance of soil fertility, and provision of habitat for biological diversity (DeFries et al., 2004). Balancing the tradeoffs between satisfying the current human requirements and maintaining ecosystem functions requires quantitative information on ecosystem responses to land use. Therefore, researchers have made their contributions on the ecological function analyses of land use change (De Groot, 2006; DeFries et al., 2007; DeFries et al., 2004; Dramstad, 1996; Foster et al., 2003; Wang et al., 2014; Zhou et al., 2014). Foster et al. (2003) concluded that land use activities would affect the ecosystem structure and function for decades after these activities are carried out. Land use changes can also affect ecosystem service values (ESV). Wang et al. (2014) used crop yield data, ESV empirical data on different terrestrial ecosystems, land use data, and development policies in China to examine the effects of land use change on ESVs to optimize China's land use structure and maximize the total ESVs using a linear programming model. Zhou et al. (2014) examined the impact of urban growth on ecological security.

2.2.3 Specific land use types

The previous couple of sections provide an overall description of China's land use change. The specific land use types, such as cultivated land, forest land, pasture land, and construction land, have also been discussed extensively. Among the different kinds of land use, cultivated land is the one received the greatest attentions from scholars and policymakers worldwide (Buyanovsky and Wagner, 1998a; Buyanovsky and Wagner, 1998b; Chen et al., 2007b; Chen et al., 2014; Dang et al., 2015; Deng et al., 2006; Fischer et al., 2010; Guo et al., 2014; Islam and Weil, 2000; Li and Wang, 2003; Liu et al., 2005; Song, 2014; Song and Pijanowski, 2014; WU et al., 2006; Yang and Li, 2000; Yunlong and Yaqin, 2006; Zeqiang et al., 2001; Zhang et al., 2009). Driving by the increasing food demand, expanding biofuel production as well as the rapid industrialization and urbanization in recent years, China is under unprecedented pressure to properly allocate its scarce cultivated land resources to meet future demands for goods and services (Qiang et al., 2013). To cope with this, the Chinese government employed legislative measures to establish a "red line" limitation, i.e., 120 million hectares, for its cultivated land (Wang et al., 2012; Yang, 2013). The effects of cultivated land use change on food safety (Yang and Li, 2000; Zeqiang et al., 2001) and the spatial and temporal changing patterns of cultivated land (Liu et al., 2005) are popular research topics.

China's forest resource is relatively scarce, but the demand for forest resources is increasing as China has become the second largest consumer of timber. Based on the supply–demand contradiction, studies on forest land management in China have also gained the interest of scholars and policymakers (Dixon et al., 1994; Fang et al., 2001; Menzies, 1994; Rudel et al., 2005; Wenhua, 2004; Zhang et al., 2000). More than 40% of China's total land area is pasture land, which covers almost 4 million km^2 (Ni, 2002). Pasture land plays an important role in livestock production and conservation of water and soil. Despite many efforts to prevent land desertification in China, pasture land degradation continues to proliferate through overgrazing, cropland misuse, and unregulated collection of fuel plants (Akiyama and Kawamura, 2007). Many researchers have contributed to China's pasture land protection (Akiyama and Kawamura, 2007; Bai et al., 2004; Conant et al., 2001; Kang et al., 2007; Ni, 2002; Ren et al., 2008). Construction land will enter the rapid growth phase because of the rapid urbanization of China. The relationship between urbanization and construction land has been examined by researchers (Deng et al., 2010; DU and CAI, 2010; Li and Zeng, 2004; Mu et al., 2007; Tan et al., 2005; Wu and Zhang, 2012; Xu, 2008; Zhu, 1999).

Studies have discussed the cause–effect relationships between land use change and climate change, bioenergy production, and ecological functions. The cause of land use change, which is a combined action of the outcomes of human and biophysical processes, is complicated and includes biophysical, socioeconomic, cultural, and political factors. Local factors are not applicable to local land use strategies given the economic globalization. The significance of the effects of economic activities on land use change will increase in policymaking or further academic studies. Land resource accounting, which is associated with the globalized economic network, is reviewed in the following section. The literature reviews on the analysis of China's land resource accounting is also be included.

2.3 China's virtual land use

2.3.1 Virtual land definition

China, which has been driven by increasing food demand, expanding biofuel production, and rapid industrialization and urbanization in recent years, is under unprecedented pressure to properly allocate its scarce land resources to meet future demands for goods and services

(Qiang et al., 2013). When modern economic organization mode creates the possibility to rematch resource supply and commodity demand by expanding the production chain or network, indirect land use, which is associated with consumption and trade flows, will become a priority for land protection.

The concept of "virtual land" is put forward to understand the total (including direct and indirect) land consumption (Wichelns, 2001; Würtenberger et al., 2006). Interchangeable with "embodied land", this concept refers to the total land required for the whole production process of goods or services. In the context of globalization, a comprehensive understanding of virtual land use is an indispensable foundation to develop effective land management strategies.

Seabrooke et al. (2004) questioned local policy in achieving the sustainable development by only considering the short-term local advantages. In this study, the theory of virtual land gives a sustainable view of considering producers and consumers of hidden land flows in a global market economy. Multiple responsibility entities are considered in the context of globalization to cope with the complex sustainable development issues (Guo and Chen, 2013).

2.3.2 Virtual land accounting

The interest on land use accounting in terms of consumption and trade can be traced back to the concept of EF, which was proposed by Rees and Wackernagel in the 1990s (Rees, 1992, 1996; Wackernagel and Rees, 1996). EF is defined as "the total area of productive land and water area required continuously to produce all the resources consumed and to assimilate all the wastes produced, by a defined population, wherever on earth that land is located" (Rees and Wackernagel, 1996). A standardized method, i.e., the National Footprint Account (NFA), was later developed for EF accounting (Wackernagel et al., 1999; Wackernagel et al., 1997) and it is widely used in different spatial scales, including global (Wackernagel et al., 2013; Yu et al., 2013), national (Galli et al., 2012; Wiedmann, 2009) and urban scales (Chen, 2007). In 2003, Wackernagel and his colleagues established the Global Footprint Network (GFN), an international think tank working to advance sustainability using EF based on NFA, which publishes the database of EFs for nearly 150 nations (Wackernagel et al., 2013).

Despite its significance in land resources accounting, EF is criticized for failing to depict the mutual interrelationships of economic activities and to assign indirect environmental burden from inter-industrial dependencies (Costello et al., 2011). For example, although the concept aims to address consumer responsibility by combining all the direct and indirect ecological impacts originated from a specific activity, it neglects the intrinsic linkages between consumption and resource depletion. Thus, EF fails to reveal the causal relationship to trace back to the places where the ecological impacts actually occur (Lenzen et al., 2007b).

By contrast, IOA is a well-established approach that enables resource flows and environmental effects to be assigned to categories of final consumption through inter-industrial connection (Chen and Chen, 2013). The methodology provides a quantitative solution to represent the sectoral embodied ecological flows along with their economic counterparts based on physical balance (Chen and Chen, 2011a). Resource uses and environmental emissions based on IOA were quantified in different categories, such as energy consumption, water use, land use, and greenhouse gas emissions (Guan et al., 2008;

Guo and Chen, 2013; Guo et al., 2012a; Han et al., 2013; Ji et al., 2013; Peters, 2008; Su and Ang, 2010; Weinzettel et al., 2013; Wiedmann, 2009). Many studies have substantially contributed to the knowledge on resource utilization and environmental emissions. These studies can be categorized as MRIO and SRIO based on the scope of the studies. MRIO aims to compare the resource utilization for each region and to clarify the relationship between spatial distribution of resources and interprovincial trades (Liang et al., 2007; Su and Ang, 2010, 2011b; Wiedmann, 2009; Zhou and Imura, 2011). Unlike MRIO, SRIO focuses on the overall resource utilization of a single region. Studies on China's single-region carbon emissions provide efficient data to support efforts on resource protection (Chen and Zhu, 2013; Dhakal, 2010; Geng et al., 2011; Vause et al., 2013; Zhang et al., 2011a).

Land use assessment based on IOA can be traced back to 1998 when Bicknell et al. (Bicknell et al., 1998) proposed the method and applied it to New Zealand. Three years later, Ferng et al. (2001) enhanced the applicability of the method by introducing several necessary corrections. Henceforth, a series of scholars have made lots of contributions to the development of IOA in the field of land use accounting (Galli et al., 2012; Lenzen et al., 2007a; Lenzen et al., 2003; Wood et al., 2006). This method is widely adopted for land use accounting on the global, national, urban, and organizational scales (Hubacek et al., 2009; Lenzen and Murray, 2001; Wiedmann et al., 2007; Wiedmann et al., 2006), thus indicating its great significance in policy implications.

2.3.3 China's virtual land accounting

In terms of China's land use, GFN publishes an annual EF report on China using the NFA method (WWF et al., 2012). Many Chinese researchers have applied or modified the EF methodology. Liu and Peng (2004) calculated the time series of EF in China in 1962–2001. Chen and his colleagues assessed the natural resource use of China using the modified EF method in a series of studies (Chen and Chen, 2006b, 2007; Chen et al., 2006a; Chen et al., 2007a; Chen et al., 2006b; Shao et al., 2013). As regards China's virtual land use, Hubacek and Sun (2001) calculated China's virtual land requirements by utilizing an IO model to determine how the economic and societal changes affect land use and land cover. MRIO was used to present the interactions among various industries within several associated economic regions to consider the regional characteristics and industrial effects (Wiedmann, 2009). Many studies applied MRIO to analyze resource endowment or pollution emissions (Lenzen, 2009; Liang et al., 2007; Su and Ang, 2014; Zhang et al., 2013; Zhang and Anadon, 2014; Zhou and Imura, 2011). Zhou and Imura (2011) calculated EFs for China in 2000 based on the MRIO model to trace the origin of regional consumption and systematically account for the ecological impacts embodied in interregional trade. However, no study has targeted the systematical analysis of China's land use from both the temporal and spatial perspectives. To fill this gap, the current study presents an embodiment analysis on China's land use with high sectoral resolution, long-time-serial, and multi-spatial IO data, to demonstrate how land resources in China are utilized to meet the requirements of increasing domestic consumption and international trade.

China is experiencing dramatic land use changes. The relation between economic activities and environmental effects from the temporal perspective is a significant concern particularly with the advent of globalization. In the past 20 years, China has experienced substantial economic reforms. As its economy develops, many serious environmental problems emerge. Therefore, studies on the time variation in virtual land are highly significant to establish sustainable economic and administrative policies to meet the needs of development and conserve nature. A few studies are related to China's virtual land in a time series. Chen and Han (2015) systematically and comprehensively analyzed China's land use-related issues, considering multi-type land use, high-sectoral resolution, and time series input–output data. Guo et al. (2014) conducted an embodiment analysis on China's cultivated land use using a long-time series in 1987–2007 and determined historical trends in land use changes.

The geographic distribution of China's land resources is unbalanced (Zhang and Anadon, 2014). The close economic relationship among various industries in different regions through interregional trade exacerbates the pressure on resource displacement. Land-intensive commodities or services are generally consumed in economically developed regions but produced in resource-abundant regions. The resource pressure transfer and responsible allocation, as well as the total direct and indirect resource consumptions in the entire supply chain (i.e., embodied resource utilization), are known issues in environmental accounting (Costello et al., 2011; Hertwich and Peters, 2009; Kanemoto et al., 2012). IOA is a useful tool to comprehensively clarify the interweaving economic linkages among industries, and it helps track the origin of resources or where these resources are utilized through a complex economic network (Larsen and Hertwich, 2009; Peters et al., 2011; Skelton et al., 2011). To take account of the regional characteristics and industrial impacts, MRIO is utilized to present the interactions among various industries within several associated economic regions (Wiedmann, 2009).

To systematically analyze the temporal nexus and spatial nexus of land use, this study conducts a systematical embodiment analysis of China's land use change in cultivated land, forest land, pasture land, and construction land to identify China's land occupation over time and space.

2.4 Research gaps

Many scholars have substantially contributed to the research on China's land use. A critical review of previous studies in the preceding sections helps map this field. The knowledge gaps are identified and filled in this study.

Previous studies discussed China's actual land use change, its relations to climate change, bioenergy production, and ecological functions, and physical characteristics of specific land use types. However, these studies mainly focus on local land use strategy by considering local land use issues, regardless of cross-border and large-scale land displacement through international and domestic trade. Local factors are not sufficient to make a comprehensive local land use strategy in the wave of economic globalization. Changes in consumption and trade patterns or policies in one place may cause displacement or leakage of land resources elsewhere. "Virtual land" or "embodied land" is used in this study to understand the total (including direct and indirect land use) land required for the whole production process of goods or services, including virtual land fluxes flowing into, within, and out of China.

Few studies are specially targeted at China's land use based on embodied concepts, although there are already some studies concerning China's EF. However, EF is criticized for failing to depict the mutual interrelationships of economic activities and to assign indirect land use burden from inter-industrial dependencies. Systems IOA provides a quantitative solution to represent the sectoral embodied environmental flows along with their economic counterparts based on physical balance. Although embodiment analysis based on IOA has been widely applied in calculating and analyzing resource utilization (energy, water, materials and etc.) and environmental impacts (carbon emissions, pollution emissions, heavy metal pollution and etc.), studies concerning China's virtual land using IOA are still lacking. The characteristics of China's virtual land use have not been comprehensively investigated. To fill in this gap, this study explores the dynamics and evolution of China's virtual land use change and identifies the regional displacement of land use in China through the interregional supply chain.

2.5 Chapter summary

This chapter reviews the research focus on China's actual land use change, its environmental effects, and crucial issues on specific land use categories. The effect of economic activities on land use is significant. Thus, virtual land is an indispensable foundation to develop effective land management strategies. This chapter comprehensively describes previous works on the definition of virtual land, virtual land accounting, and China's virtual-land accounting. Research gaps in the scope of the existing literature are also identified.

Chapter 3 Methodology

3.1 Introduction

The system input–output (IO) model, which is a popular environmental accounting methodology from a macro-economic and top-down perspective, quantitatively represents the sectoral embodied ecological flows with economic flows (Yang et al., 2013). IO-based studies can be categorized into either SRIO or MRIO analysis depending on the scope of the study area and specific research question. In this study, the temporal analysis targets at the changing pattern of virtual land in a single region, that is, China. The research object of spatial analysis is the interregional transfer of virtual land use within China's 30 regions. Therefore, both the SRIO and MRIO models are discussed in this chapter to conduct the temporal and spatial analysis of China's land use.

In this chapter, we firstly collect data to gather information on the targeted objective. IO model attempts to incorporate environmental elements into economic IO data, thus, environmental and economic data are both collected. Then the algorithm is described in detail to calculate embodied land flows, whose origin could be traced back to Odum's ecological and general systems theory (Odum, 1983, 2000). Lastly, indicators are identified to assess the temporal and spatial characteristics of China's land use. The details are explained below.

3.2 Temporal analysis: Single-regional input-output model

3.2.1 Data

3.2.1.1 Environmental data

To analyze effectively the time serial land use data, a detailed review of the developmental history of the statistical record system of China's land is helpful. The land statistical record system of China was inexistent before 1999. Thus, land data were integrated and released by certain comprehensive statistics reports, such as the Annual Report of the National Bureau of Statistics China, instead of specific land use reports. Since 1999, land use data have been published regularly by the Ministry of Land Resources through several specific reports, including the China Land and Resources Almanac (1999–2015) and China Land and Resource Statistical Yearbooks (2005–2015). The latest updated report released in 2016 provides land use information for 2014. Despite the changes in the land use data acquisition programs, in the departments responsible for collecting data, and in the monitoring tools for the data, they all have negative effects on the time-serial data quality. Nevertheless, China's land use pattern is stable on a macro scale, and the annual variation of land use data is minimal. Thus, obtaining land use data from several official land use data acquisition programs is a reliable approach.

Official statistical reports show that land resources can be categorized into farm land, construction land, and unused land. Farm land is used for agricultural production and includes cultivated land, forest land, pasture land, and other agricultural land types. Farm land is the main focus of this study because of its importance in food production (Gibbs et al., 2010; Qiang et al., 2013). Construction land can be categorized into residential land, industrial or mining sites, land for transportation, and land for conservancy facilities. Although construction land makes up a relatively small proportion of total land, this land type is vital because it provides dwelling places to humans. This study mainly focuses on four land use types, including cultivated, forest, pasture and construction land.

As for the targeted four land use types in this study, more rich data sources concerning cultivated land use could be obtained, as China is a large agricultural country. On the basis of the data sources above, the Ministry of Agriculture synthesized the data on cultivated land data between 1983 and 2008 in the Agricultural Development Report (2001-2013) and China Agriculture Yearbook (1980–2013). Data on the cultivated land of China used in the current study (i.e., data in the period of 1987–2012) are obtained from the statistical report and yearbook released by the Ministry of Agriculture. Data on the other three land use types in 2000–2012 are derived from the China Land and Resources Statistical Yearbook.

3.2.1.2 Economic data

IOA was proposed by Leontief in the 1930s, which could be used to clarify the economic linkages among production and consumption activities based on the cross-sector balance (Zhang et al., 2013). The national IO tables, which are published by the National Statistical Bureau of China, are used in this study. The first official IO table for China is that for 1987, since which the benchmark tables are compiled every five years. Besides, extended tables are also compiled based on the latest benchmark tables every five years since 1990. Up to present, eleven official national IO tables for China are currently available, namely, the tables for 1987, 1990, 1992, 1995, 1997, 2000, 2002, 2005, 2007, 2010, and 2012 (Cao and Xie, 2007). The current study conducts a time-serial research in 1987–2012 for cultivated land use and in 2000–2012 for forest land, pasture land, and construction land by utilizing the available economic IO tables and land use data in China. To reflect the purchase power change during the research period, corresponding gross domestic product GDP deflators (see Table 3.1) are used to adjust price level to the base year of 1987. The terms industry and sector are used interchangeably in this study to describe an area of the economy that shares the same or related products or services.

Table 3.1 GDP deflators in 1987–2012 (calculated from CSY (2013))

Year	1987	1990	1992	1995	1997	2000	2002	2005	2007	2010	2012
GDP deflator	100.00	120.65	150.16	211.07	254.98	320.63	379.53	513.30	666.56	875.63	1029.52

3.2.2 Algorithm

In an attempt to calculate and quantitatively compare the embodiment of land in different economic activities from the perspective of time series, i.e., production, consumption, export, and import, the SRIO model is used in this study. The origin of the SRIO can be traced back to Odum's ecological and general systems theory (Odum, 1983, 2000). The model integrates ecological endowments into the economic network to identify the resource profiles associated with all the economic flows in and out the concerned system (Chen et al., 2013b; Guo et al., 2012b).

The IOA methodology is well developed, and some crucial assumptions and data aggregation have been discussed in a series of studies (Su and Ang, 2010, 2011a, 2013, 2014a; Su et al., 2013). The empirical results vary with different model assumptions. The current research adopts the following assumptions because of data availability:

(1) The approach used in this study assumes that imported commodities have the same embodied land intensities as domestic ones because of the limitation of import intensities, although imported commodities substantially differ from domestic ones (Su and Ang, 2013).

(2) Constrained by the availability of economic and environmental data in entrepot trade, the study uses the uniform export assumption and does not distinguish processing and normal exports (Su et al., 2013).

The embodied land use intensity of a specified sector is defined as the sum of direct and indirect land use in the entire supply chain to produce per unit monetary value of the targeted good or service (Yang et al., 2013). Embodied land use intensity differs from EF, which aggregates different kinds of land resources into one common denominator (Qiang et al., 2013). Calculating embodied land flows relies on a database, which includes the embodied intensities of each commodity within the economy. To establish the intensity database, the ecological IO table, which integrates direct land use and economic flows, is compiled in Table 3.2, where l_j is the direct land use by Sector j, z_{ij} is the economic value of intermediate inputs from Sector i to Sector j, f_j is the economic value of output from Sector j used as final consumption, e_{xj} is the economic value of export from Sector j, and x_j is the economic value of total output from Sector j.

Table 3.2 Basic structure of ecological IO table (revised from Chen et al. (2010))

Input / Output		Intermediate use				Final consumption					Export	Total output
		Sector 1	Sector 2	…	Sector n	Household consumption (Rural)	Household consumption (Urban)	Government consumption	Fixed capital formation	Inventory increase		
Intermediate inputs	Sector 1	z_{11}		…	z_{1n}			f_1			e_{x1}	x_1
	Sector 2											
	…	⋮		…	⋮			⋮			⋮	⋮
	Sector n	z_{n1}		…	z_{nn}			f_n			e_{xn}	x_n
Direct land use		l_1		…	l_n							

Based on the ecological IO table, the sectoral biophysical balance for the embodied land flows can be formulated as:

$$\varepsilon_j x_j = \sum_{i=1}^{n} \varepsilon_j z_{ij} + l_j \,, \tag{1}$$

where ε_j is the embodied land use intensity of goods or services from Sector j.

For all interactive sectors, the aggregate matrix form of Eq. (1) can be deduced as

$$EX = EZ + L, \tag{2}$$

where the direct land use matrix $L=[l_j]_{1\times n}$, the embodied land intensity matrix $E=[\varepsilon_j]_{1\times n}$, the intermediate input matrix $Z=[z_{ij}]_{n\times n}$, and the total output matrix $X=[x_{ij}]_{n\times n}$, in which $i, j\in(1,2,\ldots,n)$, $x_{ij}=x_j(i=j)$ and $x_{ij}=0(i\neq j)$.

Then the embodied land use intensity matrix E is calculated as:

$$E=L(X-Z)^{-1}. \tag{3}$$

3.2.3 Indicators

To conduct the temporal analysis of China's land use, some land use indicators, including time-serial land use intensity, land resource consumption and land resource trade, are provided in the current study as below.

(1) Land use efficiency

Land use efficiency depicts the total (including the sum of direct and indirect) land resource costs per unit monetary value of a particular good or service, and it is also referred to as embodied resource intensity (Costanza, 1980). Land use efficiency is considered the most basic indicator for the IOA of various resource endowments.

(2) Production- versus consumption-based embodied land use

This study calculates and compares production-based land use (direct land use related to production activities for a targeted sector or system) and consumption-based land use (embodied, i.e. direct and indirect land use related to consumption activities for a targeted sector or system) (Cadarso et al., 2012) flows in China, which are instrumental in determining the distributing burden of each agent for land protection.

Production-based land, which is notated as ELP, is equal to direct land use (Chen and Zhang, 2010), given as

$$ELP_j = L_j, \tag{4}$$

Consumption-based land, which is notated as ELC, is the land embodied in the entire supply chain of goods or services consumed by final consumption activities within a targeted system (Chen and Chen, 2011b). Final consumption activities are usually divided into five categories according to China's IO statistics, namely, rural consumption, household consumption, government consumption, fixed capital formation and change in inventories.

$$ELC_j = \varepsilon_j F_j , \tag{5}$$

where F_j is the final consumption from Sector j.

(3) Embodied land use in trade

International trade plays a significant role in redistributing land resources through trading products. Embodied land use in imports (ELI) and embodied land use in exports (ELE) are two important indicators to reflect trading patterns in terms of land resources (Chen et al., 2013a). The difference between ELE and ELI is defined as embodied land in trade balance (ELB). A region with a positive ELB is a net supplier of land resources in international trade (which means cultivated land deficit in footprint terminology) and a region with a negative value implies that it is a net receiver of land welfare from other countries (cultivated land overshoot in footprint terminology) (Chen and Chen, 2011c). The three indicators can be formulated as:

$$ELI_j = \varepsilon_j I_{mj}, \quad (6)$$

$$ELE_j = \varepsilon_j E_{xj}, \quad (7)$$

$$ELB_j = ELE_j - ELI_j, \quad (8)$$

where I_m denotes imports from other regions.

3.3 Spatial analysis: Multi-regional input-output model

3.3.1 Data

3.3.1.1 Environmental data

Land use data for 30 regions in China are obtained from the China Land and Resources Statistical Yearbook 2011 (MLR, 2008). The national total agricultural land area is 647.28 million hectares, which is composed of 135.27 million hectares of cultivated land (22.22%), 253.77 million hectares of forest land (41.69%), and 219.67 million hectares of pasture land (36.09%). The total construction land area in China is 5.02 million hectares. Regional land use structures significantly differ as shown in Table 3.3. Northeast regions and some municipalities are primarily composed of cultivated land, whereas southwest regions mostly have forest land. Inner Mongolia, Qinghai, Xinjiang, and Tibet have extremely large areas of pasture land. The regional distribution of construction land is significantly more even than that of agricultural land.

Table 3.3 China's regional land use areas in 2010

Region	Agricultural land						Construction land
	Cultivated land	Forest land	Pasture land	Cultivated land	Forest land	Pasture land	
	million hectares			%			million hectares
National total	**135.27**	**253.77**	**219.67**	**22.22%**	**41.69%**	**36.09%**	**5.02**
Beijing	0.22	0.74	0.00	23.17%	76.81%	0.02%	0.01
Tianjin	0.44	0.06	0.00	88.76%	11.24%	0.00%	0.01
Hebei	6.55	4.63	0.40	56.57%	39.94%	3.49%	0.28
Shanxi	4.06	4.87	0.03	45.32%	54.30%	0.38%	0.10
Inner Mongolia	9.19	23.28	49.64	11.19%	28.36%	60.45%	0.18
Liaoning	5.03	5.63	0.00	47.17%	52.80%	0.03%	0.18
Jilin	7.02	8.86	0.24	43.53%	54.98%	1.49%	0.25
Heilongjiang	15.86	21.83	1.10	40.87%	56.28%	2.85%	0.35
Shanghai	0.19	0.05	0.00	79.16%	20.84%	0.00%	0.01
Jiangsu	4.60	0.26	0.00	94.61%	5.39%	0.00%	0.31
Zhejiang	1.98	5.68	0.00	25.88%	74.12%	0.00%	0.07
Anhui	5.89	3.78	0.00	60.94%	39.05%	0.00%	0.29
Fujian	1.34	8.37	0.00	13.79%	86.21%	0.00%	0.06
Jiangxi	3.09	10.41	0.00	22.86%	77.13%	0.01%	0.19
Shandong	7.66	1.53	0.01	83.34%	16.60%	0.06%	0.41
Henan	8.18	3.50	0.00	70.02%	29.98%	0.00%	0.52
Hubei	5.31	8.65	0.00	38.03%	61.95%	0.01%	0.22
Hunan	4.14	12.28	0.01	25.18%	74.73%	0.09%	0.27
Guangdong	2.57	10.11	0.00	20.27%	79.72%	0.02%	0.13
Guangxi	4.42	13.34	0.01	24.90%	75.07%	0.03%	0.14
Hainan	0.73	1.21	0.01	37.47%	62.09%	0.44%	0.02
Chongqing	2.44	3.79	0.05	38.92%	60.36%	0.73%	0.11
Sichuan	6.72	22.19	10.96	16.85%	55.65%	27.49%	0.30
Guizhou	4.57	9.00	0.07	33.49%	65.97%	0.54%	0.11
Yunnan	6.24	23.06	0.15	21.19%	78.31%	0.50%	0.15
Shaanxi	3.99	11.23	2.20	22.92%	64.45%	12.63%	0.11
Gansu	5.40	6.11	5.93	30.96%	35.04%	34.00%	0.08
Qinghai	0.59	3.54	40.84	1.31%	7.88%	90.81%	0.01
Ningxia	1.29	0.77	1.51	36.08%	21.69%	42.24%	0.03
Xinjiang	5.12	8.98	35.81	10.26%	17.99%	71.75%	0.09
Tibet	0.44	16.03	70.70	0.51%	18.39%	81.10%	0.01

Unbalanced economic development is a key element in the imbalanced resource supply and demand. The unbalanced distribution of land resources has raised many debates on the sustainability of China's agricultural production and resource utilization. Thus, discussions must be conducted on how China could better allocate land resources to meet unbalanced food demands and satisfy the needs of regional economic growth.

3.3.1.2 Economic data

The MRIO model was first put forward by Isard in 1951 to illustrate the inter-industrial technical relationship and supply-demand balance (Isard, 1951). Chenery (1953), Moses (1960), Polenske (1970), and Miller (2009) significantly contributed to the development and application of the model. Studies on China's IO applications have been conducted extensively, but studies on MRIO are still lacking because interregional trade data are unavailable. China's State Information Center (2005) compiled China's first MRIO table with eight regions and 30 sectors in 1997, and then it assembled MRIO tables for more regions and sectors in 1987, 1997, 2002, and 2007 (Ichimura and Wang, 2007; Liu and Okamoto, 2002; Zhang and Qi, 2012). Global MRIO tables, such as the Global Trade Analysis Project, are readily accessible because of the availability of detailed interregional trade data. However, domestic trade data in China are unavailable. Therefore, many mathematical models, such as the gravity model and the maximum entropy model, have been established and applied to estimate interregional trade flows (Erlander and Stewart, 1990; Liu et al., 2012; Zhang and Anadon, 2014). This study adopted the most recent MRIO table in China in 2010, which was compiled by researchers from the Chinese Academy of Science and China's National Bureau of Statistics (Liu et al., 2012). This MRIO table includes 30 provinces with 30 sectors and is based on 30 SRIO tables and the calculated interregional trade matrixes using the gravity model (Liu et al., 2012; Zhang et al., 2013). These sectoral and regional classifications, which are used in the current study, are more detailed than those in previous studies.

3.3.2 Algorithm

MRIO presents the interactions among sectors within an economy, and provides the spatial linkages of multi-sector and multi-region economies (Zhang et al., 2013). Thus, the interlinked regional resource distributions and the influence of interregional trade on resources usages and environmental emissions can be estimated. MRIO has been a popular method for energy, water, land, and carbon accounting in relation to climate change, water crisis and land degradation in recent years (Cui and Kattumuri, 2011; Rees and Wackernagel, 1996; Su and Ang, 2011; Wiedmann, 2009; Zhou and Imura, 2011).

An MRIO simulation is used to analyze the virtual land flows associated with China's interregional trade network. The study compiles a revised MRIO table by integrating regional resource flows into economic flows. Table 3.4 is the MRIO table of 30 provinces with 30 sectors in China, and it is divided into intra-regional and inter-regional sectoral economic components and a land resource endowment component. As shown in the table, z_{ij}^{fr} represents the monetary value of goods or services sold by sector i in region f as intermediate use to sector j in region r, where f/r=1, 2, 3,⋯, 30 loops over the regions, i/j=1, 2, 3,⋯, 30 loops over the sectors; f_{it}^{fr} is the monetary value of goods or services from sector i in region r as final use supplied by region f, where t is the consumption categories, including rural household consumption, urban household consumption, government consumption, fixed capital formation, growing inventories and export; x_i^f is the monetary value of the total output of sector i in region f; and l_i^f is the value of direct land use of sector i in region f.

Table 3.4 Revised MRIO table for land use in China

<table>
<tr><td colspan="2" rowspan="3">Input/Output</td><td colspan="7">Intermediate use</td><td colspan="3">Final use</td><td rowspan="3">Total output</td></tr>
<tr><td colspan="3">Beijing</td><td>⋯</td><td colspan="3">Xinjiang</td><td rowspan="2">Beijing</td><td rowspan="2">⋯</td><td rowspan="2">Xinjiang</td></tr>
<tr><td>1</td><td>⋯</td><td>30</td><td>⋯</td><td>1</td><td>⋯</td><td>30</td></tr>
<tr><td rowspan="3">Beijing</td><td>1</td><td colspan="7" rowspan="7">z_{ij}^{fr}</td><td colspan="3" rowspan="7">f_{it}^{fr}</td><td rowspan="7">x_i^f</td></tr>
<tr><td>⋮</td></tr>
<tr><td>30</td></tr>
<tr><td>⋮</td><td>⋮</td></tr>
<tr><td rowspan="3">Xinjiang</td><td>1</td></tr>
<tr><td>⋮</td></tr>
<tr><td>30</td></tr>
<tr><td colspan="2">Direct land use</td><td colspan="7">l_i^f</td><td colspan="3"></td><td></td></tr>
</table>

Based on this MRIO table, the basic balance of economic flows of sector i in region f can be formulated as:

$$\sum_{r=1}^{30}\sum_{j=1}^{30} z_{ij}^{fr} + \sum_{r=1}^{30}\sum_{t=1}^{6} f_{it}^{fr} = x_i^f. \tag{9}$$

Combined with land flows, the total ecological balance of sector i in region f can be expressed as:

$$l_i^f + \sum_{r=1}^{30}\sum_{j=1}^{30} \varepsilon_j^r z_{ji}^{fr} = \varepsilon_i^f x_i^f, \tag{10}$$

where ε_i^f is the embodied resource intensity of sector i in region f, r_i^f is the direct resource consumption of sector i in region f.

For the whole economic system with 900 entries (30 sectors × 30 regions), the aggregate matrix form of Eq. (10) can be deduced as:

$$L + \varepsilon Z = \varepsilon \hat{X}, \tag{11}$$

where the embodied intensity matrix ε=[ε_1^1, $\varepsilon_{2,}^1$ ⋯, ε_{30}^1; ⋯⋯; ε_1^{30}, $\varepsilon_{2\,,}^{30}$ ⋯, ε_{30}^{30}]^T, the direct land resource consumption matrix L=[l_1^1, $l_{2,}^1$ ⋯, l_{30}^1; ⋯⋯; l_1^{30}, $l_{2\,,}^{30}$ ⋯, l_{30}^{30}]^T, $\hat{X}$ is the diagonal matrix of total output, i.e., $\hat{X} = \begin{bmatrix} x_1^1 & & & & & & \\ & \cdots & & & & & \\ & & x_1^{30} & & & & \\ & & & \cdots\cdots & & & \\ & & & & x_{30}^1 & & \\ & & & & & \cdots & \\ & & & & & & x_{30}^{30} \end{bmatrix}$ and the intermediate IO matrix $Z = \begin{bmatrix} \begin{pmatrix} z_{11}^{11} & \cdots & z_{130}^{11} \\ \vdots & \ddots & \vdots \\ z_{301}^{11} & \cdots & z_{3030}^{11} \end{pmatrix} & \cdots & \begin{pmatrix} z_{11}^{130} & \cdots & z_{130}^{130} \\ \vdots & \ddots & \vdots \\ z_{301}^{130} & \cdots & z_{3030}^{130} \end{pmatrix} \\ \vdots & \ddots & \vdots \\ \begin{pmatrix} z_{11}^{301} & \cdots & z_{130}^{301} \\ \vdots & \ddots & \vdots \\ z_{301}^{301} & \cdots & z_{3030}^{301} \end{pmatrix} & \cdots & \begin{pmatrix} z_{11}^{3030} & \cdots & z_{130}^{3030} \\ \vdots & \ddots & \vdots \\ z_{301}^{3030} & \cdots & z_{3030}^{3030} \end{pmatrix} \end{bmatrix}$.

The embodied land resource intensity matrix ε can be calculated as:

$$\varepsilon = L(\hat{X} - Z)^{-1}. \tag{12}$$

3.3.3 Indicators

To assess the efficiency of regional resource use and interregional resource transfer, the following land use indices are used in this study:

(1) Land use efficiency

Land use efficiency is also the most basic indicator to reflect the embodied land intensity for MRIO analysis.

(2) Land use embodied in regional consumption

IOA is a useful method for resource accounting from the perspective of consumption (Peters, 2008). Therefore, LEC is regarded as a representative indicator to reveal the consumption-based land resource occupations in a targeted region. LEC can be expressed as the total land resource consumption regardless of the origin of resources (inside or outside of the system boundary):

$$LEC^{r} = \sum_{f} \varepsilon^{f} F^{fr}, \tag{13}$$

where F represents the final consumption activities.

(3) Land use embodied in interregional trade (LET)

Interregional trade substantially reshapes the regional industrial structure and further affect resource allocation (Machado et al., 2001). LET is a relevant indicator that reveals intrinsic linkages between resource consumption and production by tracing back to where resource impacts actually occur. This indicator is composed of three parts: LEI, LEE, and LEB, which can be formulated as

$$LEI^{r} = \sum_{f} \varepsilon^{f} T^{fr}, \quad LEE^{r} = \sum_{f} \varepsilon^{r} T^{rf}, \quad LEB^{r} = LEE^{r} - LEI^{r}, \tag{14}$$

where T^{fr} is the monetary value of goods or services sold from region f to region r, and T^{rf} is the monetary value of goods or services sold from region r to region f.

3.4 Chapter summary

Data collection, algorithm design, and indicator identification are described in this chapter to elaborate the methodology used in this study. The primary results based on temporal nexus, which are evaluated using the SRIO model described in this chapter, are analyzed and discussed in Chapter 4. The spatial nexus based on MRIO analysis is presented in Chapter 5. Chapter 6 depicts the resource nexus based on the MRIO model. Besides the economic data and farm land use data described in Section 3.3.1, farm water data is added in Section 6.2 to analyze the farm land and water use associated with China's interregional trade network simultaneously.

Chapter 4 Temporal Nexus: Land Occupation of the Chinese Economy over Time

4.1 Introduction

This chapter aims to determine the temporal nexuses of the four land use types, namely, cultivated, forest, pasture, and construction land. Temporal analysis could facilitate extracting significantly historical statistics and other characteristics based on the time series data. This can also help to identify the driving factors of China's virtual land change. Temporal comparisons of virtual cultivated, forest, pasture and construction land use during 1987-2012 and 2000-2012 are presented in this chapter to depict the changing trends of four virtual land use types, thus providing insight into the underlying incentive factors for land use change, including technical improvement, policy implementation, and economic structure change. This chapter also describes a horizontal comparison between sectors within the same time frame of 2012 to show the "common but differentiated" industrial responsibilities for land protection. Results in this chapter are calculated based on the most recent available data, including cultivated land data (1987–2012), forest, pasture, and construction land data (2000–2012), and SRIO data (1987–2012) in China.

4.2 Cultivated land

4.2.1 Time series analysis

4.2.1.1 Temporal change in efficiency

The cultivated land use efficiency is a measure of the overall (including direct and indirect) cultivated land costs per economic output, which can be expressed as the embodied cultivated land intensity. Figure 4.1 compares the embodied cultivated land intensities of the concerned years. The embodied intensities for these 20 years show a downward trend, declining from 71.17 to 0.25 hectares/million Yuan. The exponential trend line is simulated with a high goodness of fit as represented by a high R^2 value of 0.9893. The result shows China's effort and effectiveness to improve cultivated land use efficiency through technical development, land policies and industrial and trade structures adjustments. However, the average annual decrement rate has been declining from 10.29 to 0.08 hectares/million Yuan during this period, which shows the potential of increasing efficient to conserve cultivated land use is quite limited in the future. Therefore, China needs to devote more effort to develop an integrated cultivated land use management mode combined with modern agricultural technology application and economic structure adjustment.

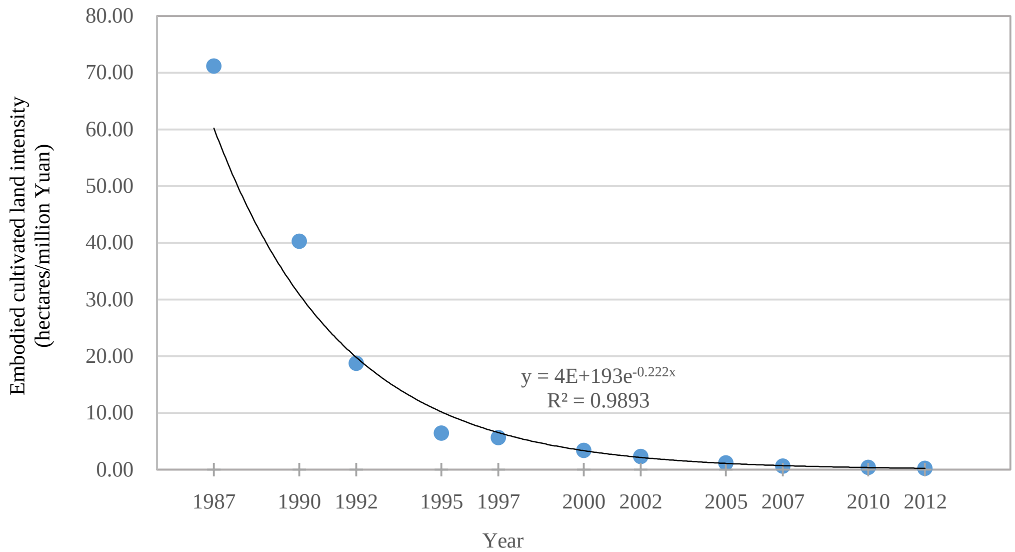


Figure 4.1 Embodied cultivated land intensity, 1987-2012

Industrial structure analysis is identified as an important aspect in IOA, thus industrial embodied cultivated land intensity changes in China during 1987–2012 are showed as Figure 4.2. In the intra-industry comparison, all the embodied cultivated land intensities of three major industries during the concerned years show downward trends: Embodied cultivated land intensity of primary industry declines significantly from 250.16 to 1.84 hectares/million Yuan, which can be attributed to the improvement of cultivated land use efficiency. By contrast, embodied intensities of secondary and tertiary industries drop slightly from 35.82 to 0.18 hectares/million Yuan and from 15.81 to 0.09 hectares/million Yuan, respectively. In the inter-industry comparison, a huge difference of three major industries is shown in 1987, that is, the intensity of primary industry is 5.98 and 14.83 times higher than the level of secondary and tertiary industries. But with the agricultural production technical development, the industrial difference of embodied cultivated land intensity has been narrowed over years. In 2012, the intensity of primary industry is reduced to the same level as the secondary and tertiary industries, demonstrating the limited improving potential of direct cultivated use efficiency in the future. Therefore, the industrial structure change will play an increasing important role in protecting cultivated land, and more emphasis should be given to the industrial structure adjustment in policy implications.

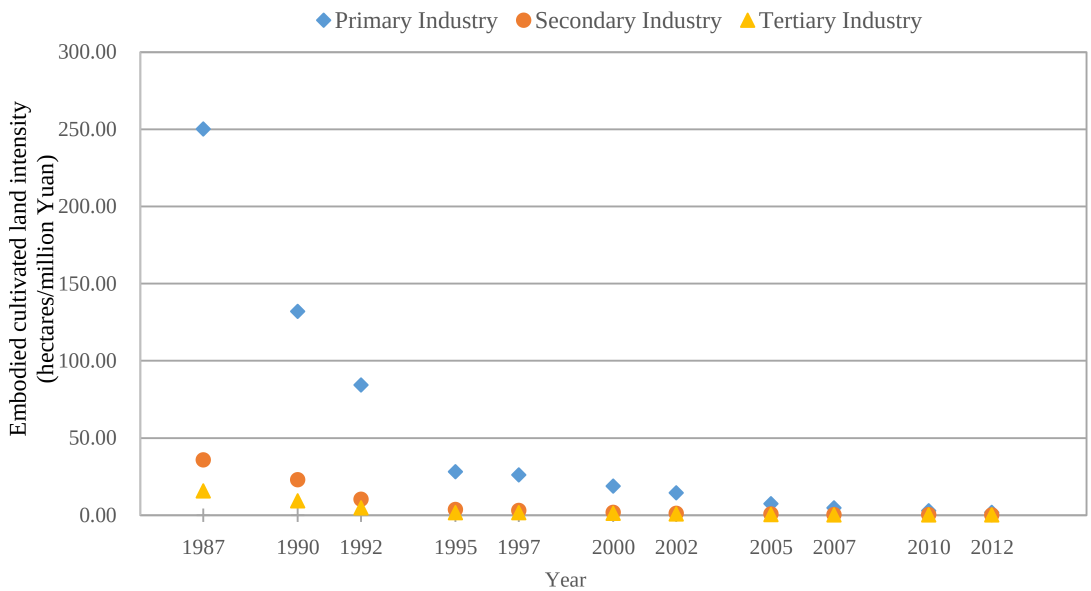


Figure 4.2 Embodied cultivated land intensity by three major industries, 1987-2012

4.2.1.2 Temporal change of trade pattern

From the perspective of trade balance, China is consistently a net exporter of cultivated land during 1987-2010 (see Figure 4.3), which demonstrates that China has been a cultivated land supplier for the globalized economy. Despite receiving embodied cultivated land deficit during the whole research period, China's ECLB varies significantly. The minimum ECLB of 2.71 million hectares is obtained in 1995 during 1987-2007, while the largest two values are received in 2007 and 1990 with 8.06 and 7.84 million hectares. The fluctuation can be attributed to the evolutions of China's international trade system and trade structure. Since the reform and opening up in 1978, the volume of international trade of China continues to climb. In 2003, China overtook the United States and became the largest trading nation in the world. With the increasing net export volume but decreasing embodied cultivated land intensity, the ECBL varies during 1987-2007. Since 2010, the ECLB quickly fell to 1.26 million hectares, and then transformed into a net importer in 2012 with the value of 0.23 million hectares. The reason could be contributed to that trade surplus in China has experienced a continuous decline after it reached the highest value in 2008. In 2010, China's increasing rate of import is larger than export, and it has almost reached the balance of import and export.

In the future, China will open itself wider to the outside world and the trade volume will keep in a high level. Therefore, how to balance the economic and environmental benefits and avoid the cultivated land loss are highly important for the country. Downsizing the cultivated-land-intensive industries and adjusting the trade structure are two main measures for relieving the cultivated land use pressures. China's trade structure has changed significantly during the past decades: export structure varied from primary products dominated to manufactured goods dominated in the 1980s, from light industrial and textile products dominated to mechanical and electronic products dominated in the 1990s, and from traditional products dominated to electronics and information technology commodities dominated in the 2000s (IOSC, 2013). All these changes follow the cultivated land resource-conserving principle, that is, from cultivated-land-intensive industries dominated to lower-intensity industries dominated.

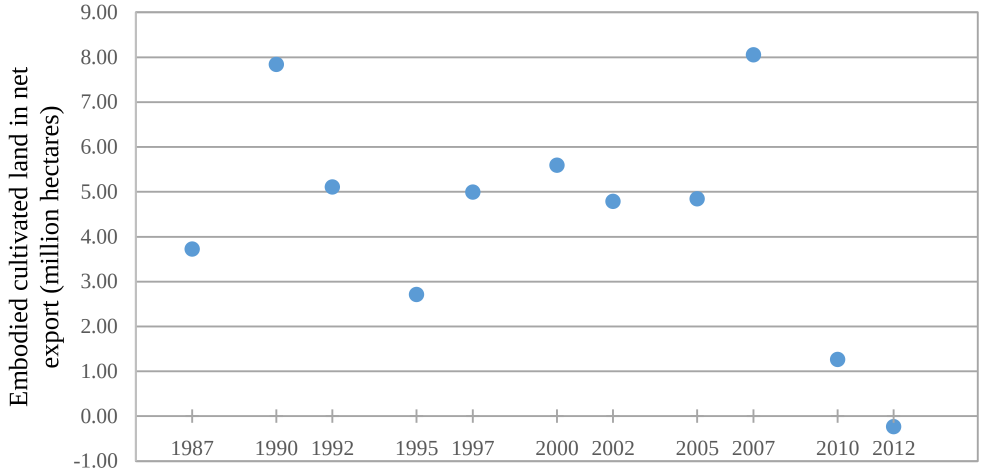


Figure 4.3 Embodied cultivated land in trade balance, 1987-2012

The embodied cultivated land in trade balance of three major industries shows different trends as shown in Figure 4.4. Primary industry changes from a net exporter to a net importer during 1987-2012 due to food demand growth, domestic and foreign price variance of agricultural product, which make China meet the challenge of agricultural production scarcity and food safety. The embodied cultivated land in net export of the secondary industry increases sharply since 2002, when China entered World Trade Organization (WTO) and became the "world factory" contributed by the fast-growing manufacturing industry. The tertiary industry keeps a trade balance during the concerned years. To sum up, ECLB's inflection points of the three industries arrives at 1990 and 2002, corresponding with some significant trade policies, such as China's market economy system reform and China's entering WTO.

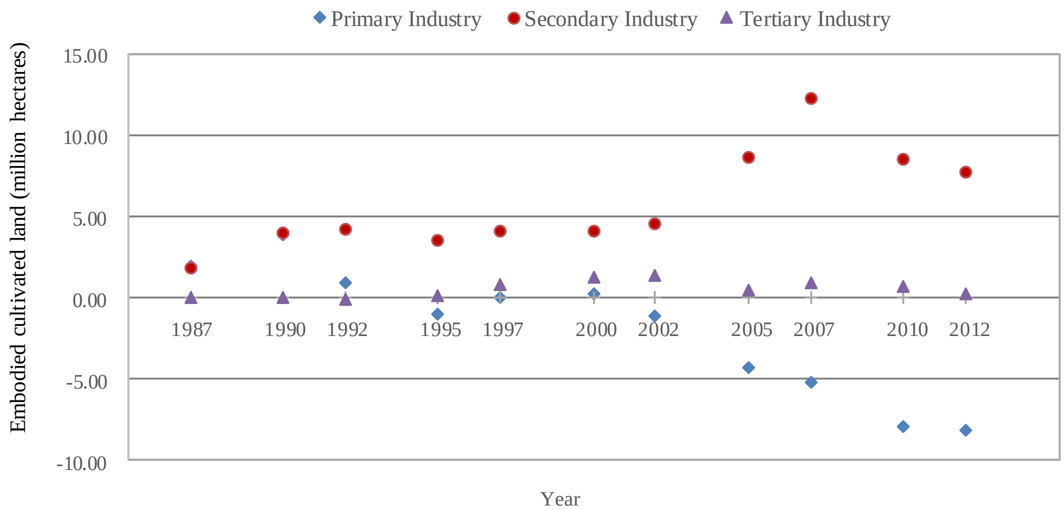


Figure 4.4 Embodied cultivated land in trade balance by three major industries, 1987-2012

4.2.1.3 Production- versus consumption-based embodied cultivated land use

Shown in Figure 4.5 is the comparison of production- and consumption-based embodied cultivated land during 1987-2012. The total cultivated land area in China from the perspective of production sees a modest decrease from 95.89 million hectares in 1987 to 94.97 million hectares in 1995, dropping by 0.12%. The cultivated land has a great increase of 18.39% in the next two years, which might be largely contributed by the change of land statistic system (Zhu, 2007). The next decade experiences a moderate downward trend from 129.90 million hectares to 121.74 million hectares. Under the stringent cultivated land protection policies made in the 11th Five-Year Plan to retain at least 120 million hectares of cultivated land, Cui and Kattumuri (2011) believe that most of the cultivated land loss during recent years can be attributed to ecological restoration and urban expansion. For example, 58.7% of the abandoned cultivated land lost used for ecological restoration between 1997 and 2008 (Comin, 2010). On the other hand, China has entered a period of accelerating urbanization, leading to the changes of industrial structure and corresponding land use pattern, which means the construction land is also taking up a lot of cultivated land (Chen, 2007).

The consumption-based embodied cultivated land shows a similar changing trend: it decreases from 91.51 million hectares in 1987 to 90.53 million hectares in 1992, then slightly increases to 92.26 million hectares in 1995 and sharply increases to 125.28 million hectares in 1997. After that, it gradually decreases to 103.60 million hectares in 2007 with the descent rate of 1.73% per year, then it sharply increases to 132.96 million hectares in 2012. However, the cultivated land embodied in consumption is always smaller than the direct cultivated land use within China's territory in 1987-2010, and the difference is expanding. This result shows that China has paid a high cultivated land resource cost to satisfy consumption outside its territory. Therefore, corresponding trade policies avoiding the virtual cultivated land resources leakage are required in China. Meanwhile, from the perspective of production principle, China should make great efforts to develop high-tech agriculture and adjust the industrial structure to improve cultivated land use efficiency. Only by the criterion of responsibilities shared both as the producer and the consumer, the cultivated land in China can be protected and exploited to the greatest extent.

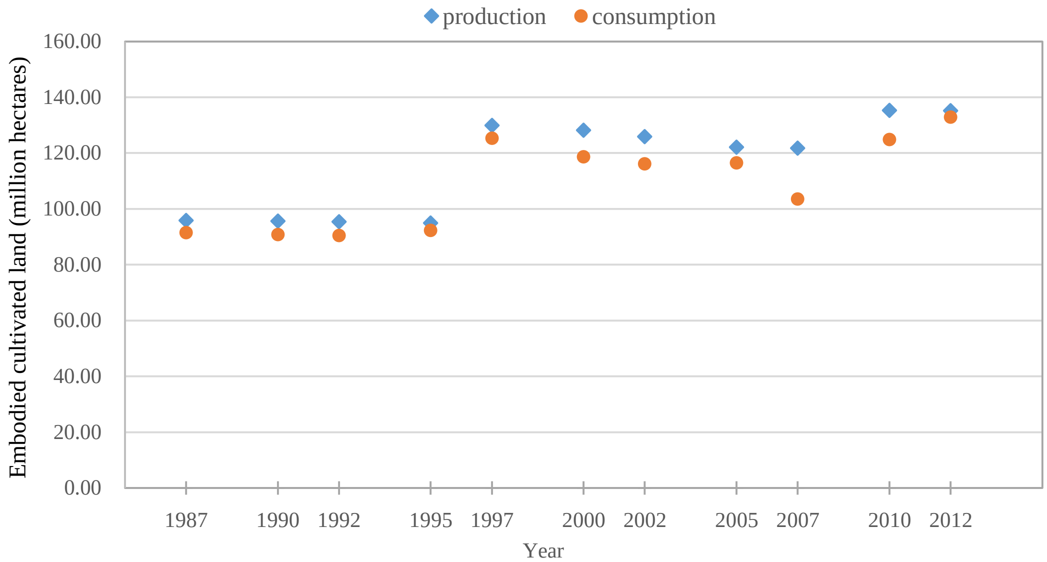


Figure 4.5 Production- versus consumption-based embodied cultivated land use, 1987-2012

From the perspective of production, cultivated land resources are all occupied by the agricultural sector. While from the perspective of consumption, cultivated land resources are assigned to all the economic sectors. For the three major industries as shown in Figure 4.6, primary industry utilizes the largest proportion of ECLC during 1987-2002, but ECLC by the secondary industry surpasses the primary industry since 2005 with China's fast process of industrialization and urbanization. The tertiary industry's ECLC increases in fluctuation and it has the potential to surpass the primary and secondary industries. It seems 2010 is an inflection point, ECLC by the primary industry began to increase but the secondary industry decreased. It was probably because the policy of "industry supporting agriculture in return" takes place. The above results imply the consumption of secondary and tertiary industries will have a greater influence on the cultivated land use in China due to the upgrading of the domestic industrial structure.

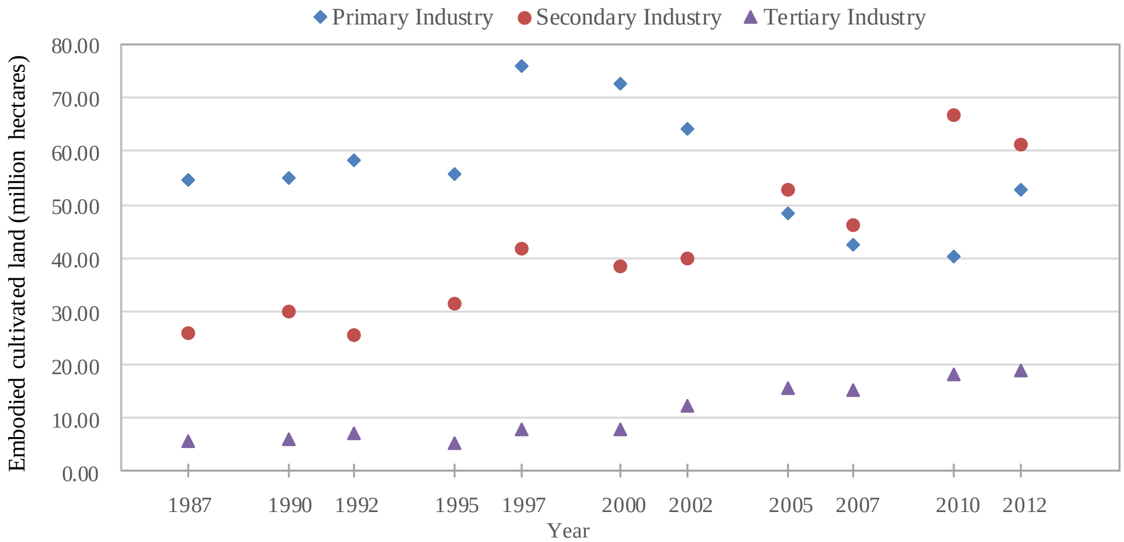


Figure 4.6 Consumption-based embodied cultivated land use by three major industries, 1987-2012

Demographic pressure and increasing competition for land in China are likely to increase vulnerability to food security. Cultivated land area coupled with agricultural products should be of concern when facing a severe food security situation. Figure 4.7 compares the output of major agricultural products and the responding cultivated land area to illustrate the linkage of agricultural products and cultivated land resources. China's cultivated land area has a general trend of fluctuations during 1987-1997, then it levels off in the next ten years. However, the output of major agricultural products increases steadily during 1987-2007, mainly driven by the significant increasing trend of fruits products. China has been the largest fruits production country with the yield rising from 16.68 million tons in 1987 to 181.36 million tons in 2007. As the most important agricultural crops, cereal crops, including rice, wheat and maize, have a relatively steady yield. Grassini et al. (2013) estimated that about 30% of the global cereal crops have reached their maximum possible crop yield potential. The production proportion of cereal crops drops from 39.29% to 23.34% during 1987-2007 followed by the growth of other agricultural production.

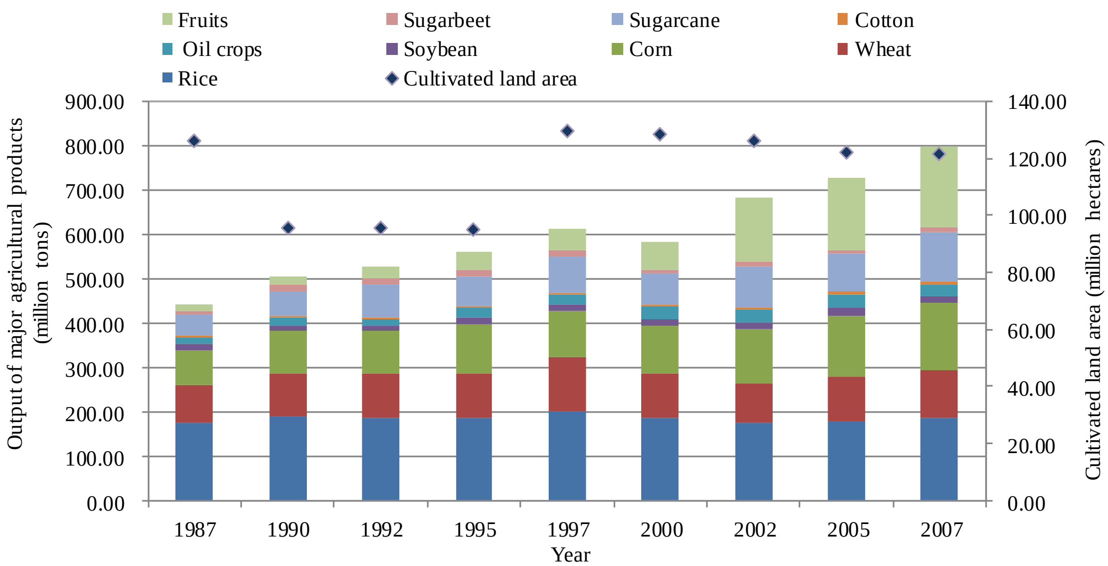


Figure 4.7 Output of major agricultural products and cultivated land area change, 1987-2012

4.2.2 Industrial analysis

4.2.2.1 Intensity

The embodied cultivated land intensities of the 42 sectors for China 2012 are presented in Figure 4.8. Sector 1 (Agriculture) has the highest intensity of 1.89 hectares/thousand Yuan, followed by Sectors 6 (Food Processing), 7 (Textile Industry) and 31 (Hotels, Catering Service) with intensities of 0.91, 0.62 and 0.50 hectares/thousand Yuan, respectively. All these four sectors are closely related to necessaries of daily life for residences, i.e., food and clothing, the production of which are highly associated with farm crops. In terms of more aggregated economic level, the average intensity of primary industries (1.89 hectares/thousand Yuan) is 9 times higher than that of secondary industries (0.21 hectares/thousand Yuan) and 21 times higher than that of tertiary industries (0.09 hectares/thousand Yuan). The huge industrial difference shows that industrial structure adjustment has great influence on cultivated land management in China.

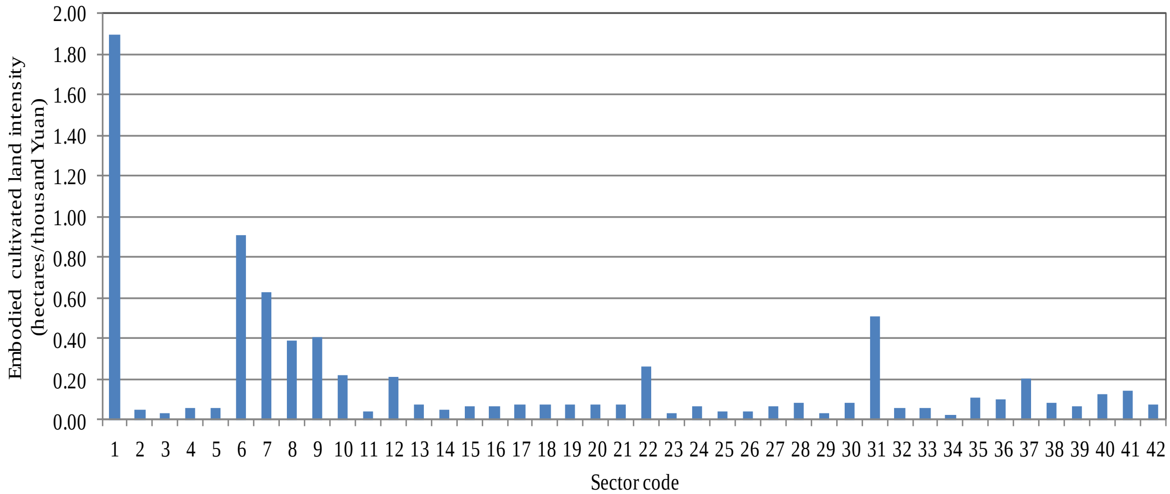


Figure 4.8 Embodied cultivated land intensity by sector in 2012

4.2.2.2 Trade

The distribution of embodied cultivated land in trade of 42 sectors for China 2012 is presented in Figure 4.9. For ECLI, the largest importing sector in China is Sector 1 (Agriculture, 9.68 million hectares), followed by Sectors 6 (Food Processing, 3.08 million hectares), 12 (Chemical Products, 2.58 million hectares) and 20 (Instruments, Meters, 1.72 million hectares). With respect to ECLE, Sectors 8 (Garments), 7 (Textile Industry) and 6 (Food Processing) rank the top three with the values of 4.22, 3.22 and 2.55 million hectares. In terms of sectoral trade balance, Sector 1 (Agriculture) is the largest net importer of embodied cultivated land in China, while Sector 8 (Garments) is the largest net exporter. Actually, China has entered an era of being a net importer of agricultural products, especially for the three major staple grain crops of wheat, rice and corn, and the import dependency has a remarkable rising trend in the past 10 years (Liu, 2013). Therefore, China should take responsibility for occupying foreign agriculture land through the growing agricultural product trade. In the past 20 years, China played a role of net exporter since it transfers too many cultivated-land-intensive products, e.g., textile products, to other countries, especially under the circumstance that cultivated land resources are so scarce in this country. It's important to establish strict export policies for these cultivated-land-intensive products. But China became a net importer of cultivated land with total ECLI and ECLE of 23.14 and 23.38 million hectares in 2012. This is because the policy of "industry supports agriculture in return" has worked. The factor of "China became a big net exporter of agricultural products" plays a leading position to make China be a net importer of cultivated land.

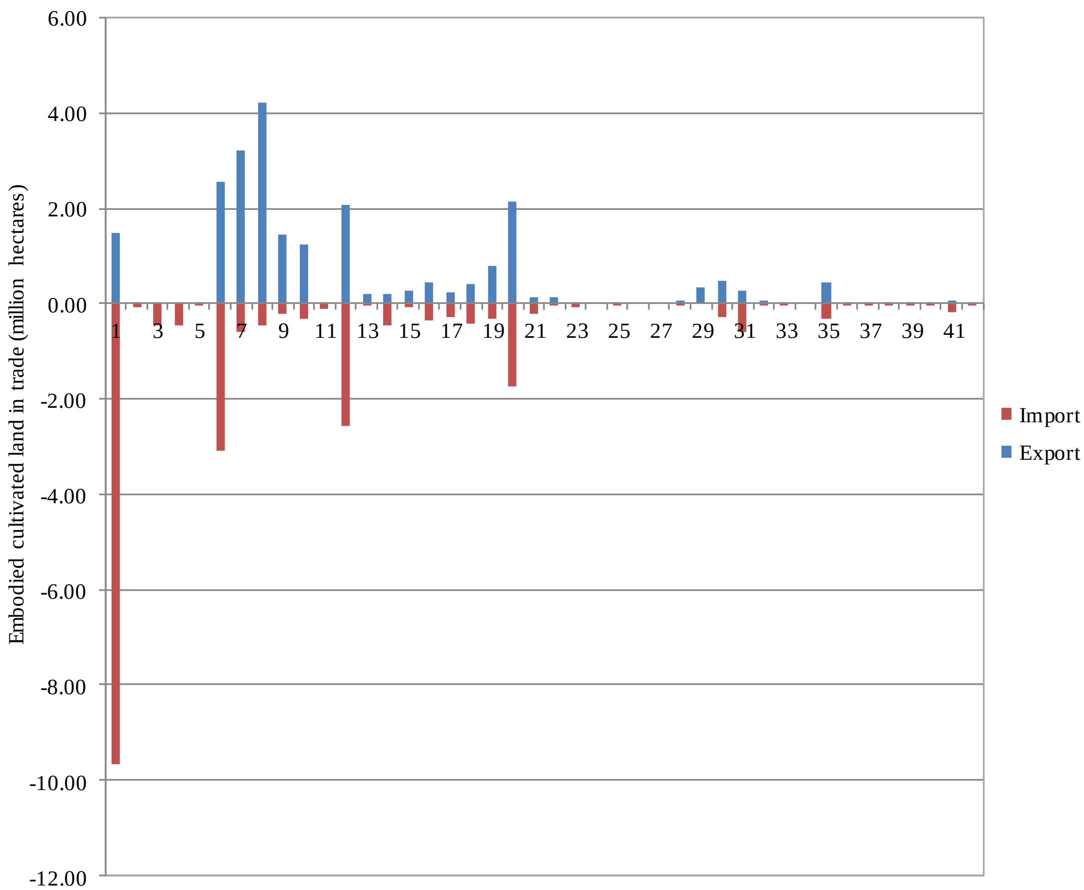


Figure 4.9 Embodied cultivated land in consumption by sector in 2012

4.2.2.3 Consumption

Shown in Figure 4.10 is ECLC of 42 sectors for China 2012. Sectors 1 (Agriculture) and 6 (Food Processing) embody the first and second largest volumes of cultivated land with 52.74 and 35.86 million hectares, mainly attributed to household consumption to meet the increasing food demand. Sector 28 (Construction) provides the third largest embodied cultivated land of 10.67 million hectares due to its significant fixed capital investment, even though the sector has a very lower embodied cultivated land intensity of 0.08 hectares/thousand Yuan. Sector 31 (Hotels, Catering Service) also accounts for considerable ELC, which is mainly contributed by urban household consumption of food in restaurants.

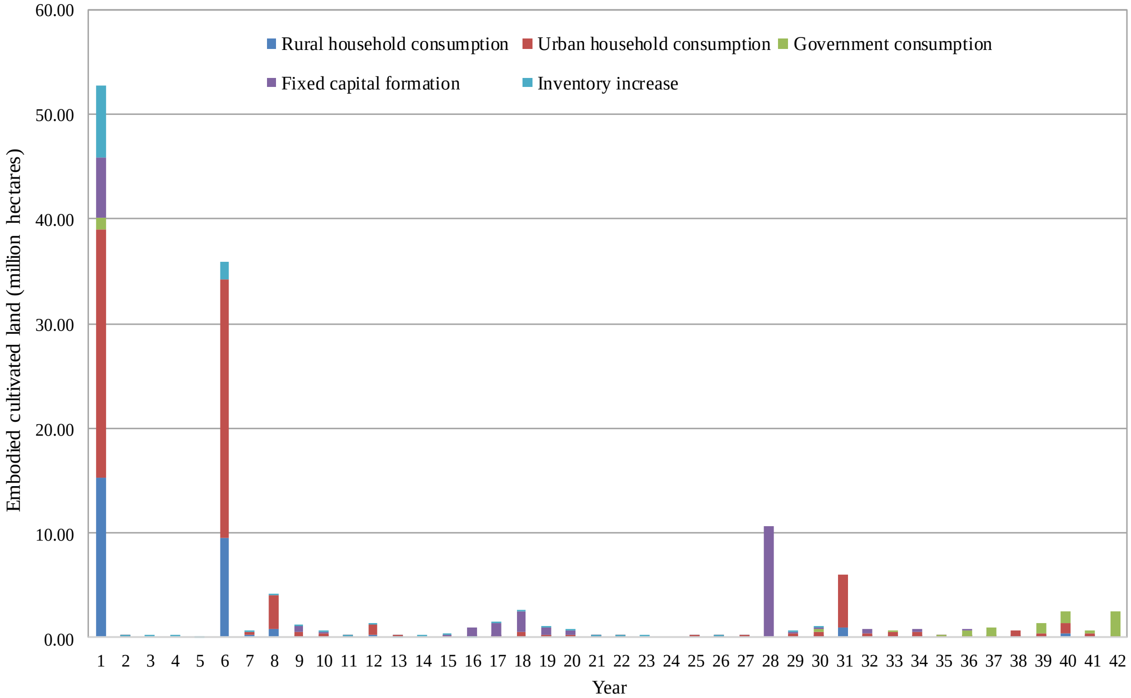


Figure 4.10 Embodied cultivated land in consumption by sector in 2012

4.3 Forest land

4.3.1 Time series analysis

4.3.1.1 Temporal change in efficiency

Analogous to cultivated land, forest land use efficiency is a measure of the overall forest land cost per economic output. This measure can be expressed as embodied forest land intensity. Figure 4.11 compares the embodied forest land intensities in 2000–2012. The embodied intensities within the 12 years exhibit a downward trend, which declines from 6.10 hectares/thousand Yuan to 0.47 hectares/thousand Yuan. The exponential trend line is simulated with a high goodness of fit as represented by a high R^2 value of 0.9963. However, the average annual decrement rate decreases from 0.94 to 0.14 hectares/thousand Yuan. Thus, the potential of increasing efficiency by protecting forest land is limited in the future. The Chinese government is challenged to develop an integrated forest land use management mode combined with the application of modern agricultural technology and economic structural adjustment.

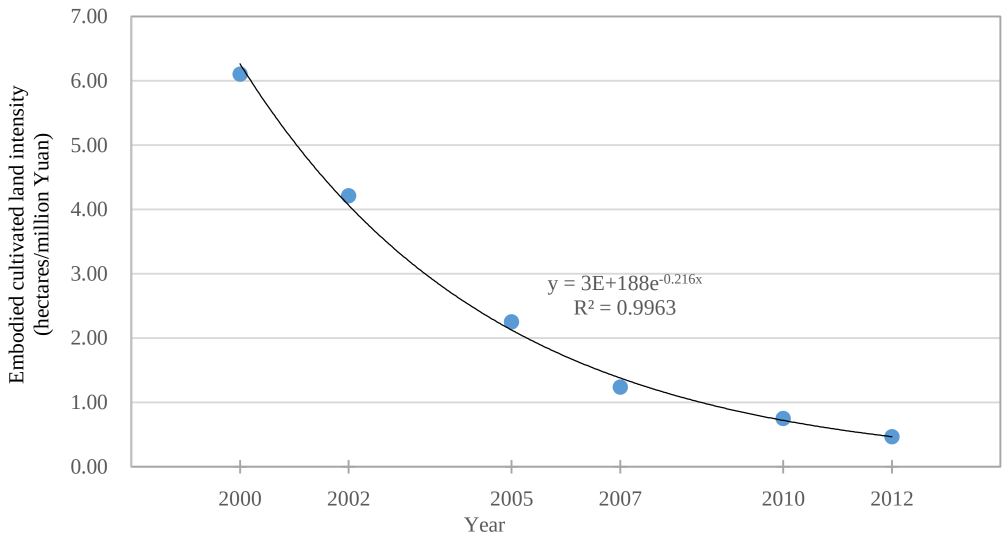


Figure 4.11 Embodied forest land intensity, 2000-2012

Industrial structure analysis is identified as an important aspect of IOA. The industrial embodied forest land intensity changes in China in 2000–2012 are shown in Figure 4.12. The intra-industry comparison indicates that the embodied forest land intensity of the primary industry declines substantially from 33.57 hectares/million Yuan to 3.44 hectares/million Yuan. This significant reduction can be attributed to the improvement of the efficiency of forest land use. By contrast, the embodied intensities of the secondary and tertiary industries are significantly small and decrease slightly from 3.29 hectares/million Yuan to 0.34 hectares/million Yuan and from 1.99 hectares/million Yuan to 0.17 hectares/million Yuan, respectively. The inter-industry comparison shows that the three major industries significantly differ in 2000. The intensity of the primary industry is 10.22 and 16.86 times higher than the levels of the secondary and tertiary industries, respectively.

However, the industrial difference in embodied forest land intensity decreases over the years because the intensity of the primary industry is substantially reduced with technical advancements. However, the reduction potential of secondary and tertiary industries is limited.

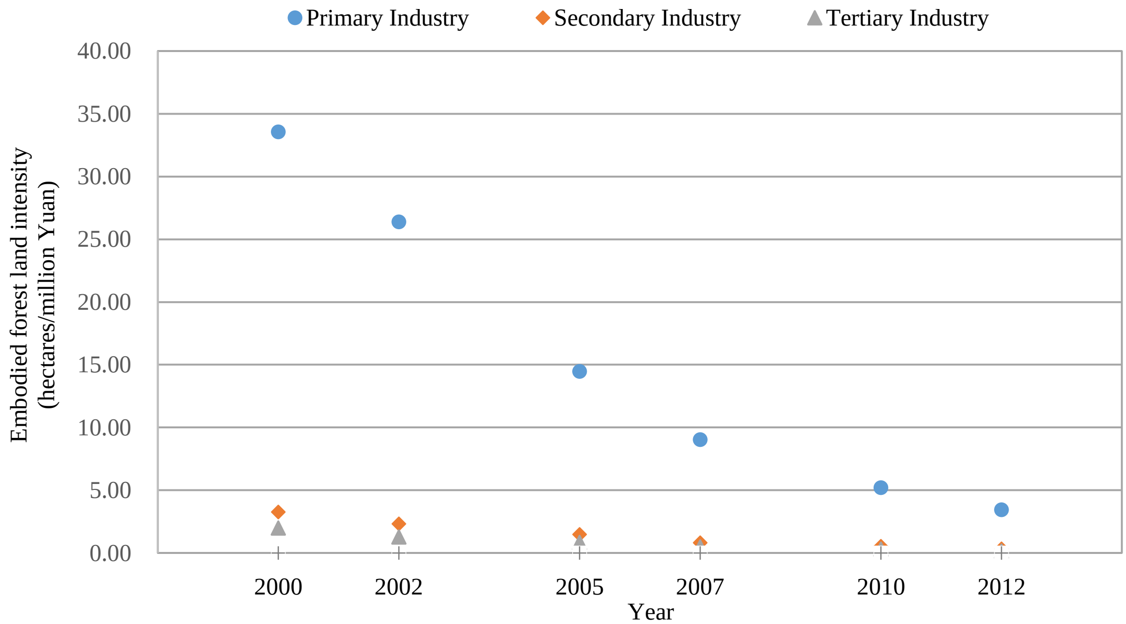


Figure 4.12 Embodied forest land intensity by three major industries, 2000-2012

4.3.1.2 Temporal change in trade pattern

From the perspective of trade balance, China is consistently a net exporter of forest land in 2000–2010 (see Figure 4.13), thus demonstrating that China is a forest land supplier for the globalized economy. China's EFLB varies significantly in 2000–2010, and the largest EFLB of 15.55 million hectares is obtained in 2007. The fluctuation is attributed to the evolutions of China's international trade structure. A trade balance position was achieved in 2012 because the import of timber products increased during this period. This condition is beneficial for China because the production of timber products seriously threatens the environment.

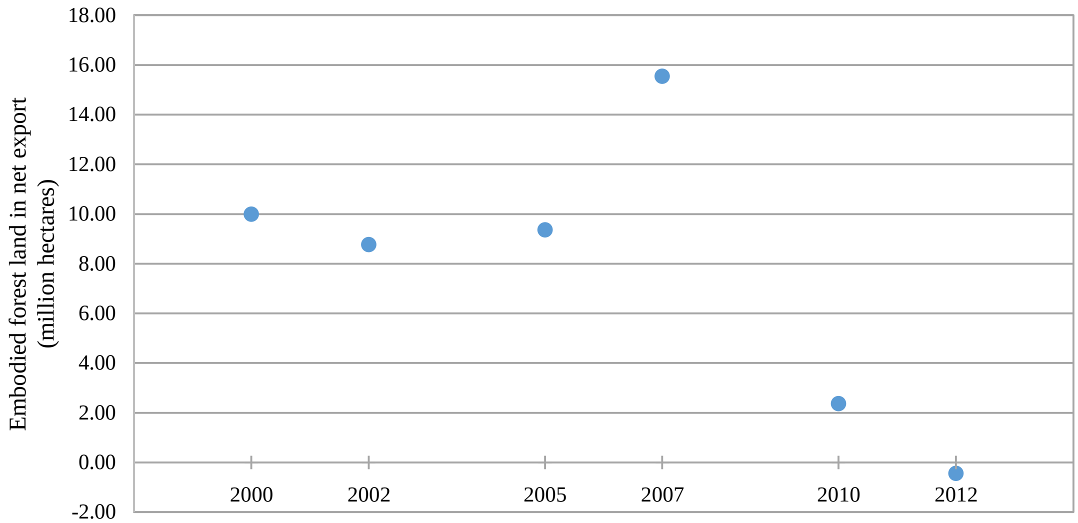


Figure 4.13 Embodied forest land in trade balance, 2000-2012

The embodied forest land in trade balance of the three major industries shows a significant difference as presented in Figure 4.14. The primary industry transforms from a net exporter to a net importer in 2000–2012 because of the increase in timber demand, which is attributed to rapid urbanization and growth of the construction industry. The embodied forest land in the net export of the secondary industry increases sharply from 2002 to 2007 and rapidly decreases from 2007 because of China's high demand for timber and paper products, which are mainly imported from Brazil, Chile, Russia, Canada, the United States, and Indonesia. The tertiary industry maintains a trade balance during the period, thus indicating a relatively low demand for timber and paper products. The international trading structure adjustment of China's forest and paper-related industries receives a favorable response because this effort promotes China's ecological protection.

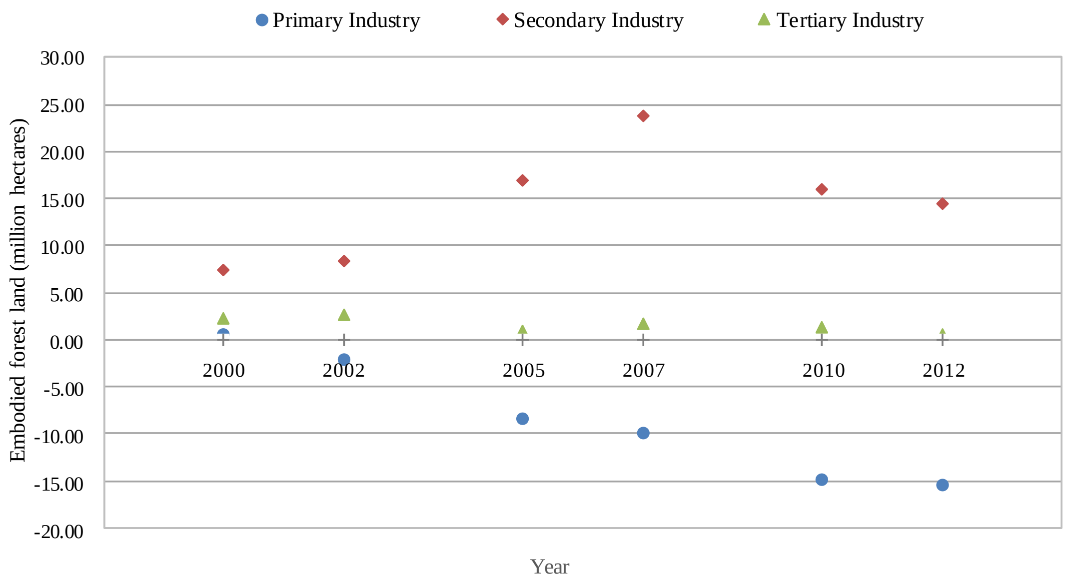


Figure 4.14 Embodied forest land in trade balance by three major industries, 2000-2012

4.3.1.3 Production- based versus consumption-based embodied forest land use

The comparison of production-based and consumption-based embodied forest land in 2000–2012 is shown in Figure 4.15. The total forest land area in China from the perspective of production slightly increases from 229.19 million hectares in 2000 to 253.40 million hectares in 2012 or by 9.55%. China's forest area ranks fifth in the world after Russia, Brazil, Canada, and the United States. However, many problems, i.e., low quality and unbalanced distribution, threaten China's forest resources.

The changes in consumption-based embodied forest land exhibits a similar trend. It slightly increases from 212.19 million hectares in 2000 to 249.27 million hectares in 2012. The forest land embodied in consumption is always smaller than the direct forest land use within China's territory in 2000–2010. However, the difference between these two indicators is close to zero in 2012. This result indicates that China previously paid a high forest land resource cost to satisfy consumption outside its territory. However, the importation of timber products continually increases with the creation of import partnerships with Russia, Brazil, and other regions. Thus, China nearly reached the balance of production and consumption in 2012.

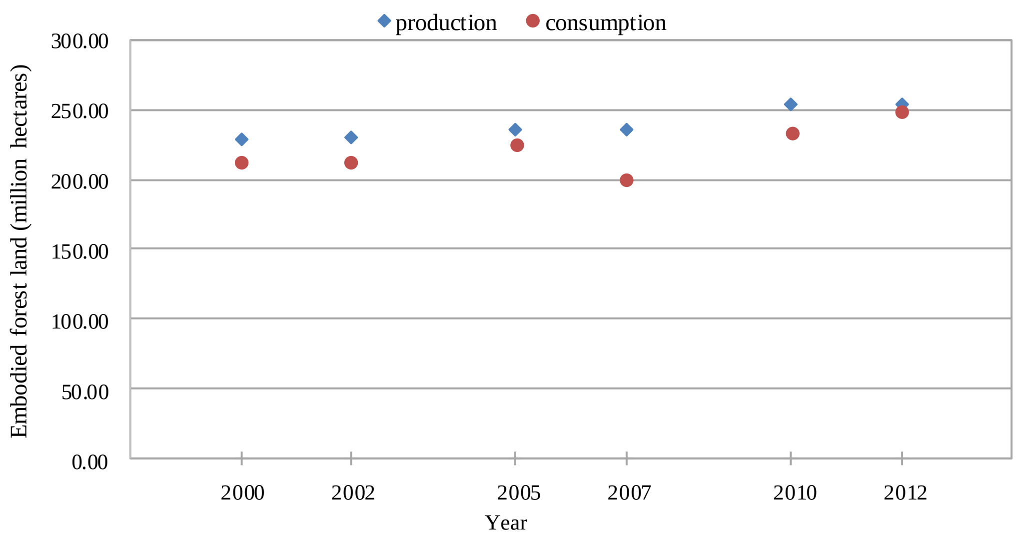


Figure 4.15 Production-based versus consumption-based embodied forest land use, 2000-2012

Similar to cultivated land, forest land resources are all occupied by the agricultural sector from the perspective of production. However, from the perspective of consumption, forest land resources are assigned to all economic sectors. Figure 4.16 shows that the primary industry utilizes the largest proportion of EFLC in 2000–2002. However, EFLC by the secondary industry surpasses that of the primary industry in 2005 because of China's rapid industrialization and urbanization. In 2012, the secondary industry begins to decrease, and the primary industry starts to increase. This change may be attributed to the shift toward agricultural development. The EFLC of the tertiary industry fluctuates, but a gap exists between the tertiary industry and the primary and secondary industries.

Figure 4.16 Consumption-based embodied forest land use by three major industries, 2000-2012

4.3.2 Industrial analysis

4.3.2.1 Intensity

The embodied forest land intensities of the 42 sectors in China in 2012 are presented in Figure 4.17. Sector 1 (Agriculture) has the highest intensity at 3.55 hectares/thousand Yuan, followed by Sectors 6 (Food Processing), 7 (Textile Industry), and 31 (Hotels and Catering Service) with intensities of 1.71, 1.17, and 0.95 hectares/thousand Yuan, respectively. These four sectors are closely related to the basic needs of individuals and consume substantial amounts of forest-related products. At the aggregated economic level, the average intensity of the primary industries (3.55 hectares/thousand Yuan) is 10 times higher than that of the secondary industries (0.35 hectares/thousand Yuan) and 21 times higher than that of the tertiary industries (0.17 hectares/thousand Yuan). The significant industrial difference indicates that industrial and consumption structure adjustment substantially affects forest land management in China.

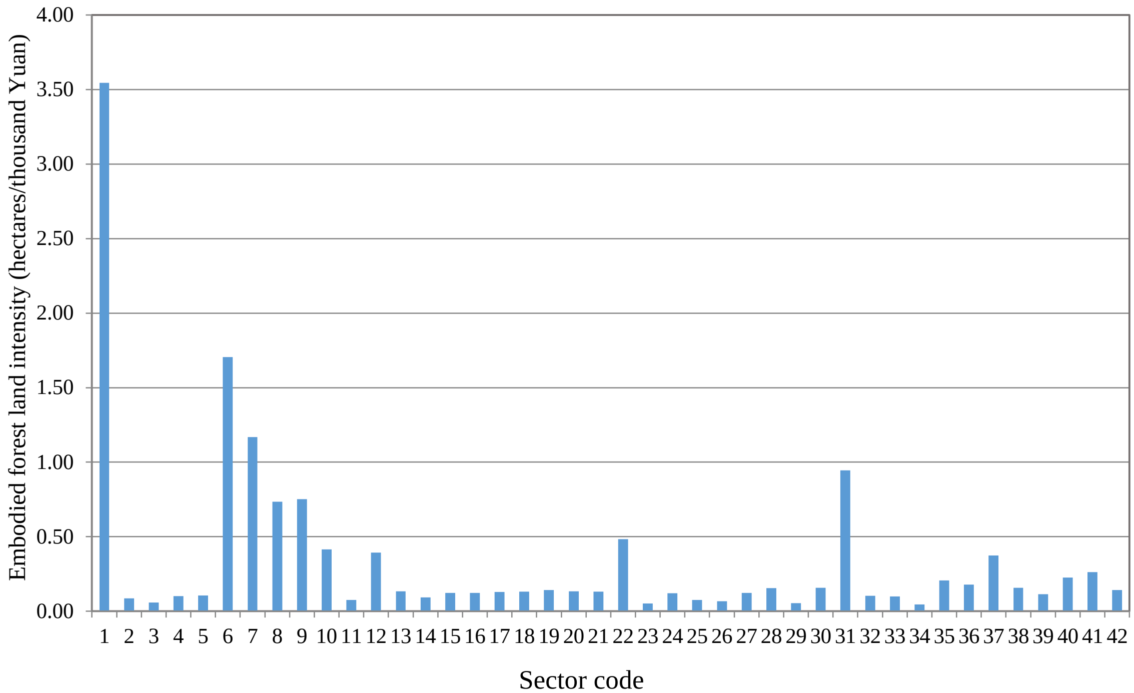


Figure 4.17 Embodied forest land use intensity by sector in 2012

4.3.2.2 Trade

The distribution of embodied forest land in terms of trade in the 42 sectors in China in 2012 is presented in Figure 4.18. For EFLI, the largest importing sector in China is Sector 1 (Agriculture, 18.15 million hectares), followed by Sector 6 (Food Processing, 5.77 million hectares) and Sectors 12 (Chemical Products, 4.83 million hectares) and 20 (Instruments, Meters, 3.22 million hectares). With respect to EFLE, Sectors 8 (Garments), 7 (Textile Industry), and 6 (Food Processing) are the top three with values of 7.90, 6.04, and 4.78 million hectares. In terms of sectoral trade balance, Sector 1 (Agriculture) is the largest net importer of embodied forest land in China with a value of 15.38 million hectares, and Sector 8 (Garments) is the largest net exporter with a value of 7.09 million hectares. China is currently a net importer of forest products and should take responsibility for occupying foreign forest land. In the past 10 years, China has always functioned as a net exporter because it transfers excessive amounts of forest-land-intensive products (e.g., paper products) to other countries despite its forest land resources per capita being scarce in this country. Establishing strict trading policies is important to prevent the further exportation of forest products. China became a net importer of forest land with a total EFLI and EFLE of 43.39 million hectares and 43.83 million hectares, respectively, in 2012. This finding shows that China has enacted sustainable and green international trading policies for forest, timber, and paper products.

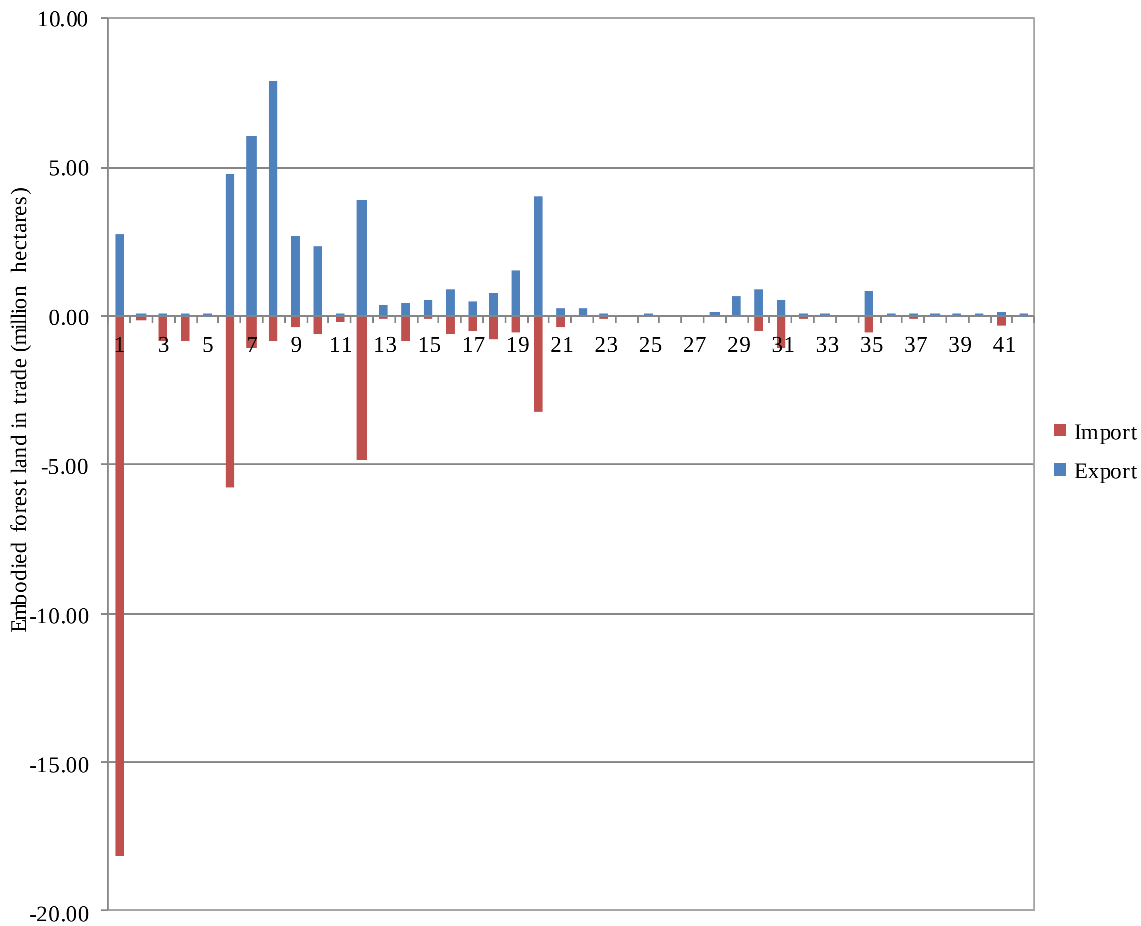


Figure 4.18 Embodied forest land in trade by sector in 2012

4.3.2.3 Consumption

The EFLC of the 42 sectors in China in 2012 is described in Figure 4.19. Sectors 1 (Agriculture) and 6 (Food Processing) contribute the first and second largest forest land areas with 98.87 million hectares and 67.24 million hectares, respectively. These large areas are mainly attributed to household consumption to meet the increasing food demand as forest land can also provide non-timber products, such as nuts, berries, mushrooms, medical plants, and animals. Sector 28 (Construction) contributes the third largest embodied forest land with 20.00 million hectares because of its significant fixed capital investment although the sector has a low embodied forest land intensity at 0.16 hectares/thousand Yuan. Sector 31 (Hotels, Catering Service) also accounts for a considerable ELC with a value of 11.07 million hectares, which is mainly contributed by urban household consumption of timber products and non-timber food products in restaurants.

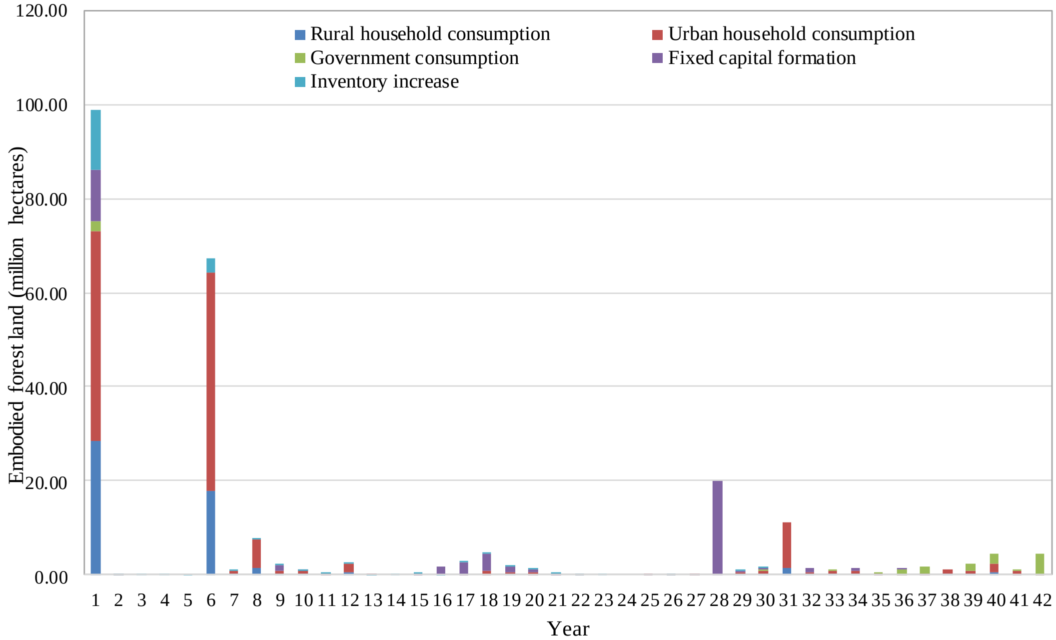


Figure 4.19 Embodied forest land in consumption by sector in 2012

4.4 Pasture land

4.4.1 Time series analysis

4.4.1.1 Temporal change in efficiency

Analogous to that of cultivated and forest land, pasture land use efficiency is a measure of the overall pasture land cost per economic output. Pasture land use efficiency can be expressed as embodied pasture land intensity. Figure 4.20 compares the embodied pasture land intensities in 2000–2012. The embodied intensities within the 12-year period generally show a downward trend, which declines from 7.03 hectares/thousand Yuan to 0.41 hectares/thousand Yuan. The exponential trend line is simulated with a high goodness of fit as represented by a high R^2 value of 0.9969. However, the average annual decrement rate declines from 1.10 hectares/thousand Yuan to 0.12 hectares/thousand Yuan. Thus, the potential of increasing efficiency by protecting pasture land is moderately limited in the future. Therefore, the Chinese government is challenged to develop an integrated and systematical pasture land use management mode combined with high-technology innovations and trade and consumption structure upgrade.

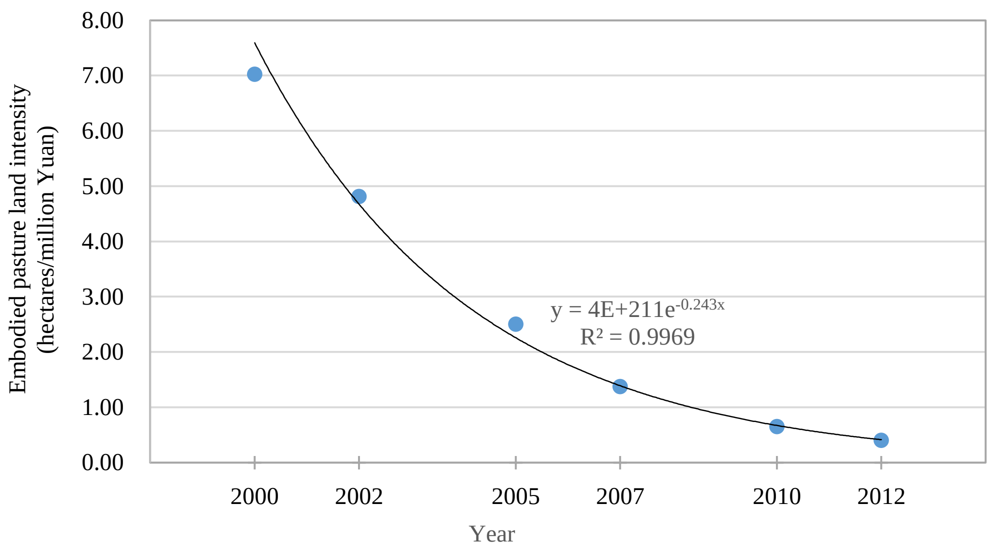


Figure 4.20 Embodied pasture land intensity, 2000-2012

Similar to the industrial analysis of cultivated and forest land, industrial structure analysis is an important aspect of IOA. The industrial embodied pasture land intensity changes in China in 2000–2012 are illustrated in Figure 4.21. The intra-industry comparison indicates that the embodied pasture land intensity of the primary industry declines substantially from 38.64 hectares/million Yuan to 2.98 hectares/million Yuan. This reduction can be attributed to the improved efficiency of pasture land use of the livestock industry. The embodied intensities of the secondary and tertiary industries are significantly low and decrease slightly from 3.78 hectares/million Yuan to 0.30 hectares/million Yuan and from 2.29 hectares/million Yuan to 0.14 hectares/million Yuan, respectively. The inter-industry comparison shows that the three major industries significantly differ in 2000. This variance decreases in the following years because of the technical innovations adopted by the livestock industry. These technologies substantially improve the efficiency of the pasture land use of the livestock industry. However, the reduction of the secondary and tertiary industries is limited because the efficiency values of the secondary and tertiary industries are extremely lower than that of the primary industry.

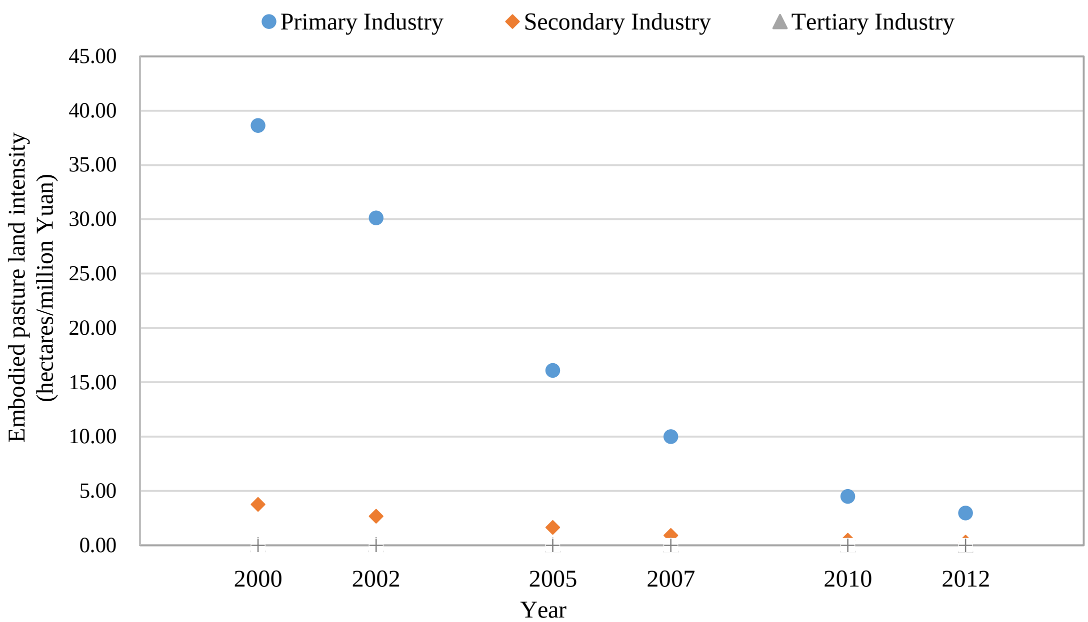


Figure 4.21 Embodied pasture land intensity by three major industries, 2000-2012

4.4.1.2 Temporal change in trade pattern

From the perspective of trade balance, China is consistently a net exporter of pasture land in 2000–2010 (see Figure 4.22), thus demonstrating that China is a pasture land supplier for the globalized economy. China's EPLB significantly varies in 2000–2010, and the largest EPLB of 17.24 million hectares is obtained in 2007. The fluctuation is due to the evolutions of China's international trade structure of dairy products contributed by urbanization, rising incomes, and westernization of diets in China. Nevertheless, this instability reached a trade balance position in 2012 as the import of dairy products had been increasing at an annual increasing rate of 42% since 2009.

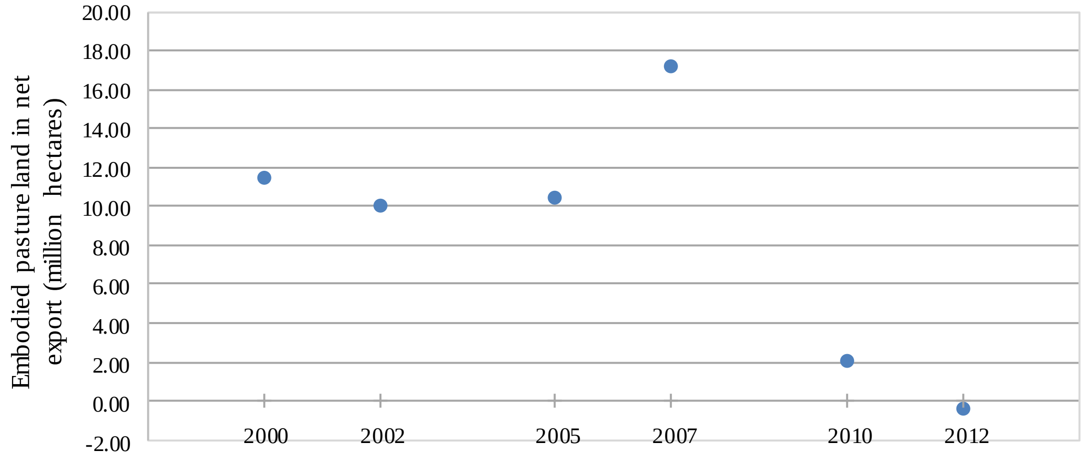


Figure 4.22 Embodied pasture land in trade balance, 2000-2012

The embodied pasture land in the trade balance of three major industries demonstrates a great difference as shown in Figure 4.23. The changing trend of embodied pasture land in trade by three major industries is similar to that of forest land: the primary industry changes from a net exporter to a net importer in 2000–2012 because of the high demand for dairy products brought about by rapid urbanization, rising incomes, and westernization of diets. Embodied pasture land in the net export of secondary industry sharply increases from 2002 to 2007, and it significantly decreases after 2007. This phenomenon can be attributed to the fast industrialization of China and a significant number of exports of manufactured goods, but the environment-friendly manufactured products are currently undergoing an encouraging reduction of the secondary industry's net export. The tertiary industry maintains a trade balance during the concerned years, and this balance is attributed to its property of not being a pasture resource-intensive industry.

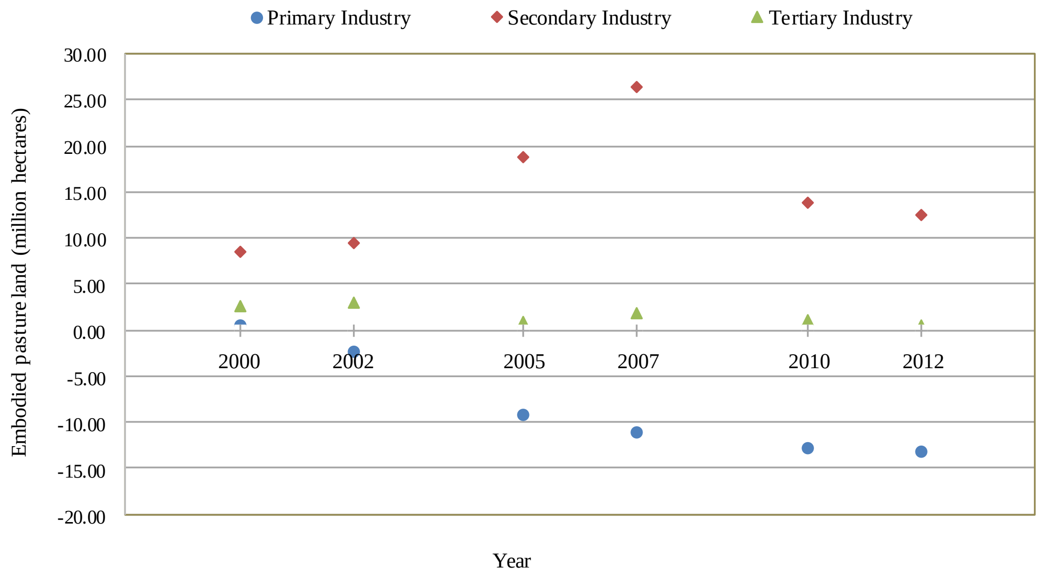


Figure 4.23 Embodied pasture land in trade balance by three major industries, 2000-2012

4.4.1.3 Production-based versus consumption-based embodied pasture land use

The comparison of production- and consumption-based embodied pasture land during 2000-2012 is presented in Figure 4.24. The total pasture land area in China sees a decrease from 263.85 million hectares in 2000 to 219.57 million hectares in 2012, decreasing by 16.78%. China's pasture area is the driver to make China the largest producer of sheep and the fourth largest producer of cattle. The Chinese government has formulated a variety of programs to prevent grass degradation.

The consumption-based embodied pasture land shows a fluctuated changing trend: it slightly increases from 244.27 million hectares in 2000 to 262.15 million hectares in 2005, then it sharply decreases to 202.81 million hectares in 2010, and finally it slightly increases to 215.99 million hectares in 2012. The change is mainly attributed to the structure adjustment of consumption and trading of dairy products. The pasture land embodied in consumption is basically smaller than the direct pasture land use within China's territory in 2000-2012, but the trade balance could be observed in 2005 and 2012. This result shows that China has paid a high pasture land resource cost to satisfy consumption outside its territory previously. However, with China's great efforts in protecting environment and ecology, the situation of sacrificing resources will be alleviated significantly.

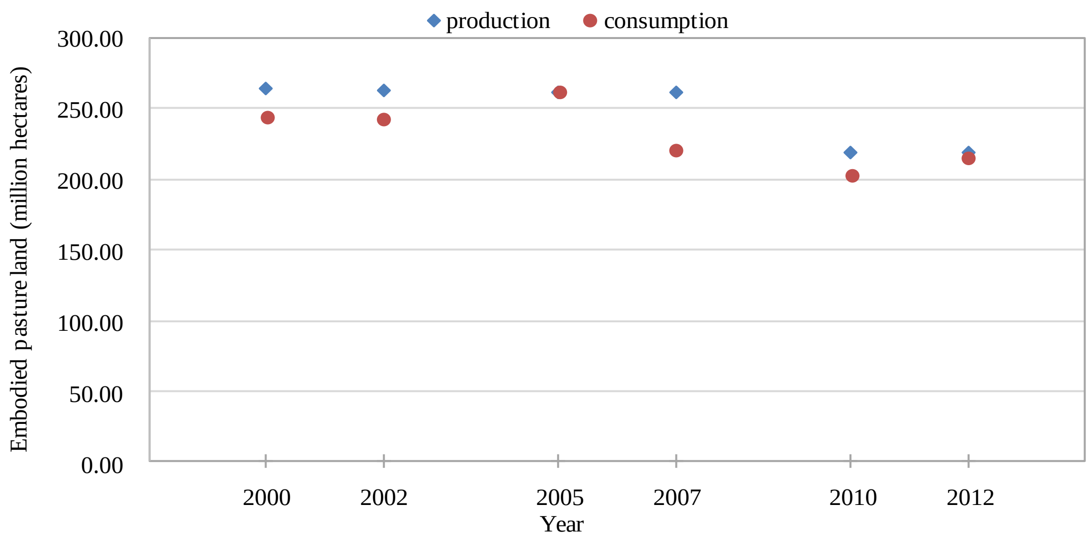


Figure 4.24 Production-based versus consumption-based embodied pasture land use, 2000-2012

Similar to cultivated and forest land, pasture land resources are all occupied by the agricultural sector from the perspective of production. From the perspective of consumption (see Figure 4.25), pasture land resources are assigned to all economic sectors. For the three major industries, the primary industry utilizes the largest proportion of EPLC in 2000–2002, but EPLC by the secondary industry surpasses the primary industry in 2005 because of China's rapid industrialization and urbanization processes. Beginning 2010, the secondary industry begins to decrease and the primary industry starts to increase. This phenomenon may be attributed to the increasing dairy product demands caused by the rising incomes and westernization of diets. The tertiary industry's EPLC increases in fluctuation, but a gap still exists in the tertiary industry with primary and secondary industries.

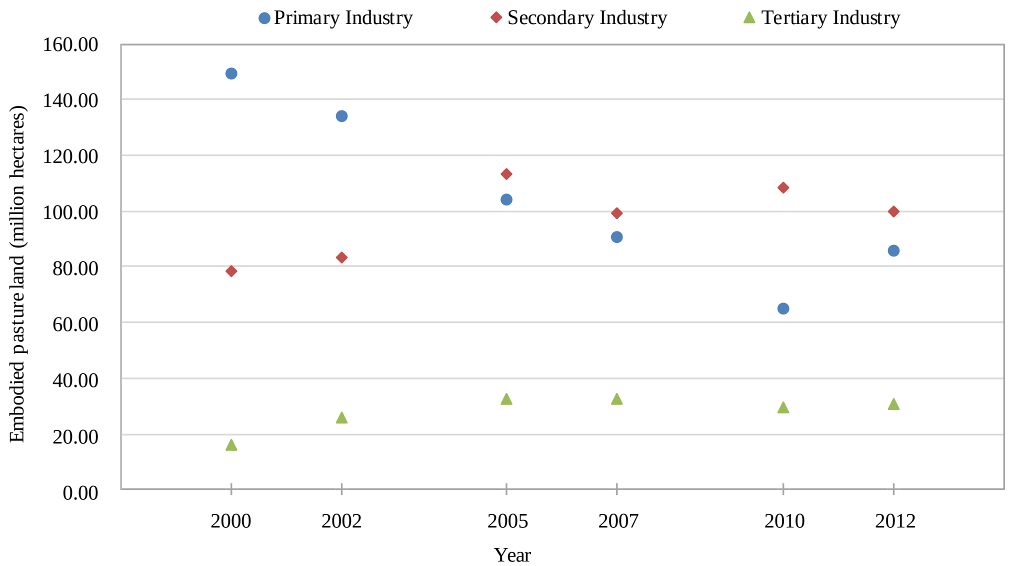


Figure 4.25 Consumption-based embodied pasture land use by three major industries, 2000-2012

4.4.2 Industrial analysis

4.4.2.1 Intensity

Figure 4.26 presents the embodied pasture land intensities of the 42 sectors in China in 2012. Sector 1 (Agriculture) has the highest intensity of 3.07 hectares/thousand Yuan, followed by Sectors 6 (Food Processing), 7 (Textile Industry), and 31 (Hotels, Catering Service) with intensities of 1.48, 1.01, and 0.82 hectares/thousand Yuan, respectively. All these four sectors are closely related to the necessities for daily living and are highly correlated with dairy products. At the aggregated economic level, the average intensity of primary industries (3.07 hectares/thousand Yuan) is 10 times higher than that of secondary industries (0.31 hectares/thousand Yuan) and 21 times higher than that of tertiary industries (0.15 hectares/thousand Yuan). The huge industrial difference shows that the industrial and consumption structure adjustments significantly influence pasture land management in China.

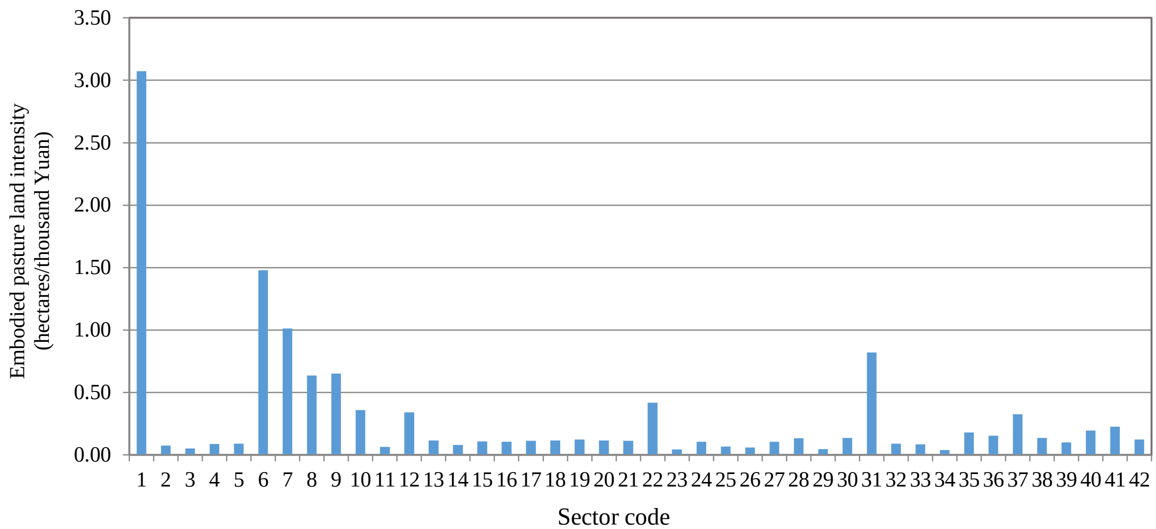


Figure 4.26 Embodied pasture land intensity by sector in 2012

4.4.2.2 Trade

Figure 4.27 presents the embodied pasture land distribution in trade of the 42 sectors in China in 2012. For EPLI, the largest importing sector in China is Sector 1 (Agriculture, 15.73 million hectares), followed by Sectors 6 (Food Processing, 5.00 million hectares), 12 (Chemical Products, 4.18 million hectares), and 20 (Instruments, Meters, 2.79 million hectares). For EPLE, Sectors 8 (Garments), 7 (Textile Industry), and 6 (Food Processing) are the top three with values of 6.85, 5.24, and 4.14 million hectares, respectively. In sectoral trade balance, Sector 1 (Agriculture) is the largest net importer of embodied pasture land in China with a value of 15.73 million hectares, and Sector 8 (Garments) is the largest net exporter with a value of 6.14 million hectares. In the past decade (2000–2010), China constantly played the role of net exporters because it transferred many pasture land-intensive products (e.g., dairy products) to other countries. However, China became a net importer of pasture land with a total EPLI and EPLE of 37.59 and 37.98 million hectares, respectively, in 2012. China has actually entered the era of being a net importer of pasture products and should take responsibility for occupying pasture land in foreign regions.

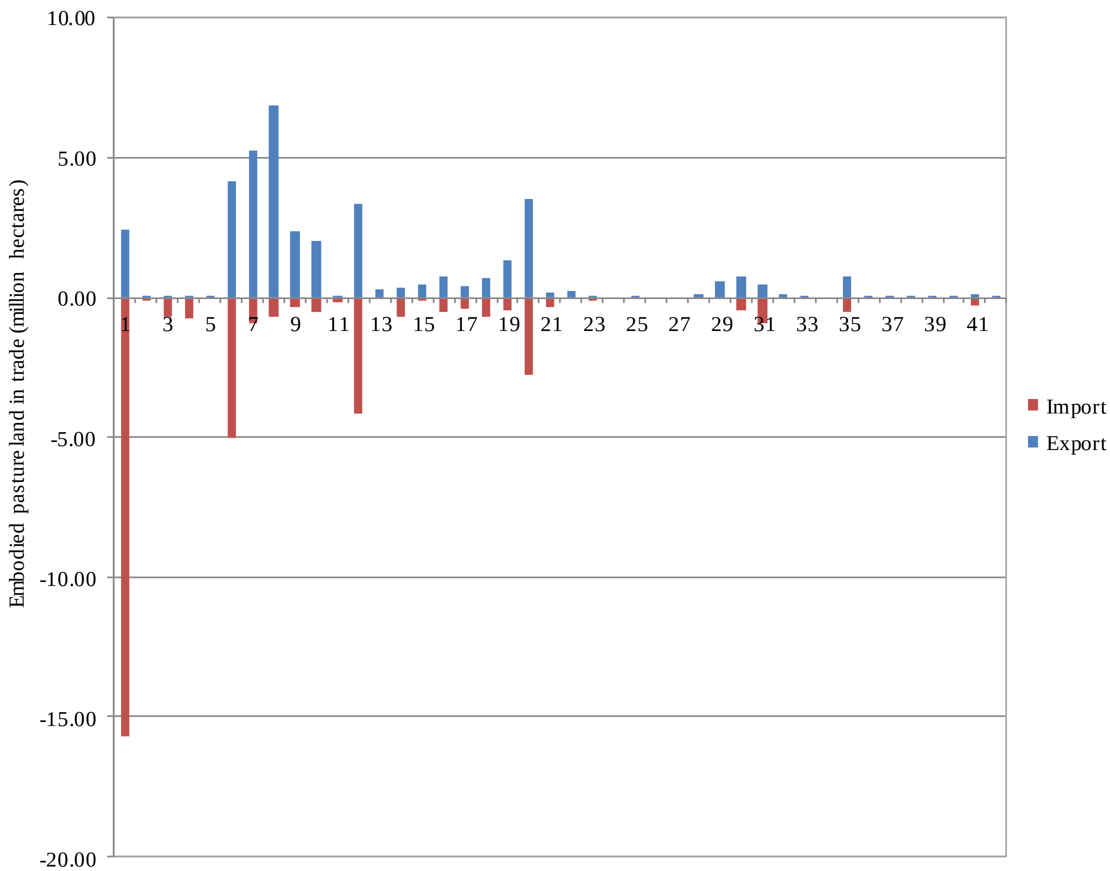


Figure 4.27 Embodied pasture land in trade by sector in 2012

4.4.2.3 Consumption

EPLC of the 42 sectors of China in 2012 is presented in Figure 4.28. Sectors 1 (Agriculture) and 6 (Food Processing) embody the first and second largest volumes of pasture land with 85.67 and 58.26 million hectares, respectively. These volumes are mainly attributed to household consumption to meet the increasing food demand given that pasture land can also support the production of dairy products. Sector 28 (Construction) has the third largest embodied pasture land of 17.33 million hectares caused by its significant fixed capital investment, which consumes many resources despite this sector's low embodied pasture land intensity of 0.13 hectares/thousand Yuan. Sector 31 (Hotels, Catering Service) also accounts for the considerable ELC with a value of 9.59 million hectares, which is mainly contributed by the urban household consumption of dairy products in restaurants.

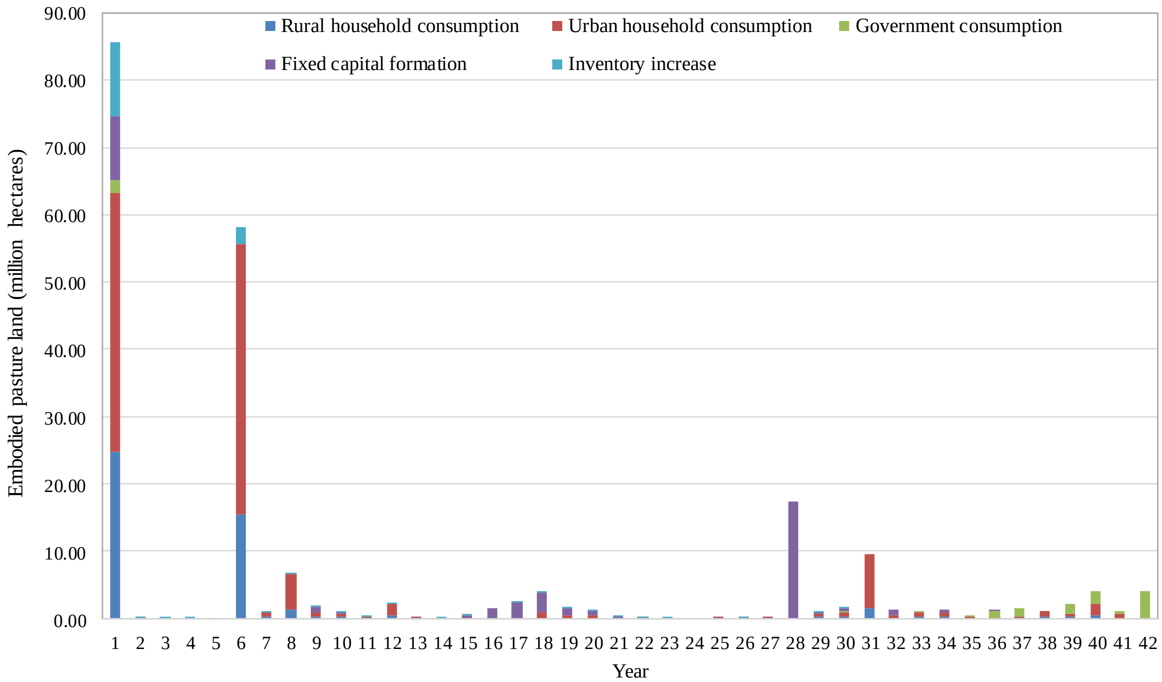


Figure 4.28 Embodied pasture land in consumption by sector in 2012

4.5 Construction land

4.5.1 Time series analysis

4.5.1.1 Temporal change in efficiency

Construction land use efficiency is a measure of the overall construction land cost per economic output, and it is expressed as embodied construction land intensity. Figure 4.29 compares the embodied construction land intensities in 2000–2012. According to the general trend, the embodied intensities for these 12 years show a downward trend, declining from 1.07 hectares/thousand Yuan to 0.048 hectares/thousand Yuan. The exponential trend line is simulated with a high goodness of fit as represented by a high R^2 value of 0.9968. However, the average annual decrement rate declines from 0.25 hectares/thousand Yuan to 0.012 hectares/thousand Yuan. This finding suggests that increasing efficiency by protecting construction land will be increasingly difficult in the future. Therefore, the Chinese government is challenged to develop an integrated construction land use management mode that considers both technical and commercial factors.

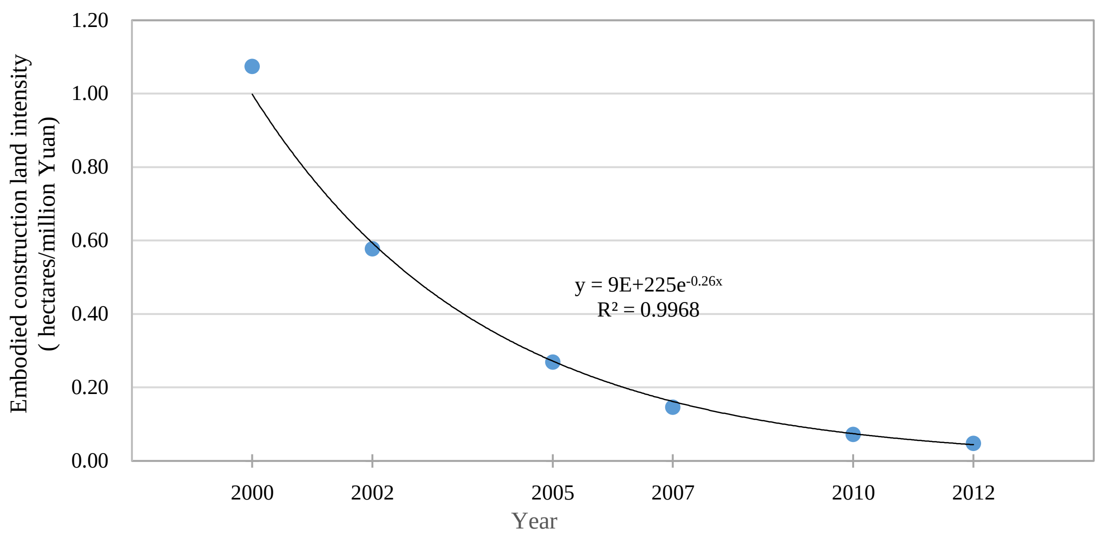


Figure 4.29 Embodied construction land intensity, 2000-2012

Industrial structure analysis is identified as an important aspect of IOA. Accordingly, the industrial embodied construction land intensity changes in China in 2000–2012 are shown in Figure 4.30. Unlike cultivated, forest, and pasture land, the embodied construction land intensity of the three major industries shows a trend toward the same difference: embodied construction land intensity of the primary industry significantly declines from 1.14

hectares/million Yuan to 0.06 hectares/million Yuan, and the embodied intensities of the secondary and tertiary industries also significantly drop from 1.09 hectares/million Yuan to 0.05 hectares/million Yuan and from 0.99 hectares/million Yuan to 0.04 hectares/million Yuan, respectively. These reductions can be attributed to technology development and commercial structure optimization.

In the inter-industry comparison, the construction land intensity of the primary industry is larger than that of the secondary industry in 2000 since several water conservancy facilities require much land to build over that period. However, since 2002, the land intensity of the secondary industry has surpassed that of the primary industry with the industrialization process. After 2005, the land intensities of the primary and secondary industries are nearly the same because of the "industry-replenishing agriculture" policy. The construction land intensity of the tertiary industry is generally lower than that of the primary and secondary industries because of its characteristic of having a non-resource intensive industry. Another significant observation is that the construction land intensities of these three major industries are close to the same value.

Figure 4.30 Embodied construction land intensity by three major industries, 2000-2012

4.5.1.2 Temporal change in trade pattern

From the perspective of trade balance, China is consistently a net exporter of construction land in 2000–2010 (see Figure 4.31). Therefore, China is a construction land supplier for the globalized economy. China's ECoLB significantly varies in 2000–2010. The largest ECoLB of 2.7 million hectares is obtained in 2007. The fluctuation is due to the evolutions of China's international trade structure. The changing trend of China's ECoLB is more relevant to China's trade structure than ECLB, EFLB, and EPLB. This finding can be explained by the similarity of the construction land use efficiency of various types of industries.

China is experiencing an urbanization process. Mega-events strategies, namely, international projects cooperated with other countries, have restructured the urban space by means of economic restructuring and population decentralization (Chan and Li, 2016). This will significantly change the construction land use pattern, and transfer virtual land resources simultaneously. The study on the effects of mega-events in China (such as some mega-projects in the silk road economic belt) on global resource displacement is very meaningful in the future to achieve China's sustainable development.

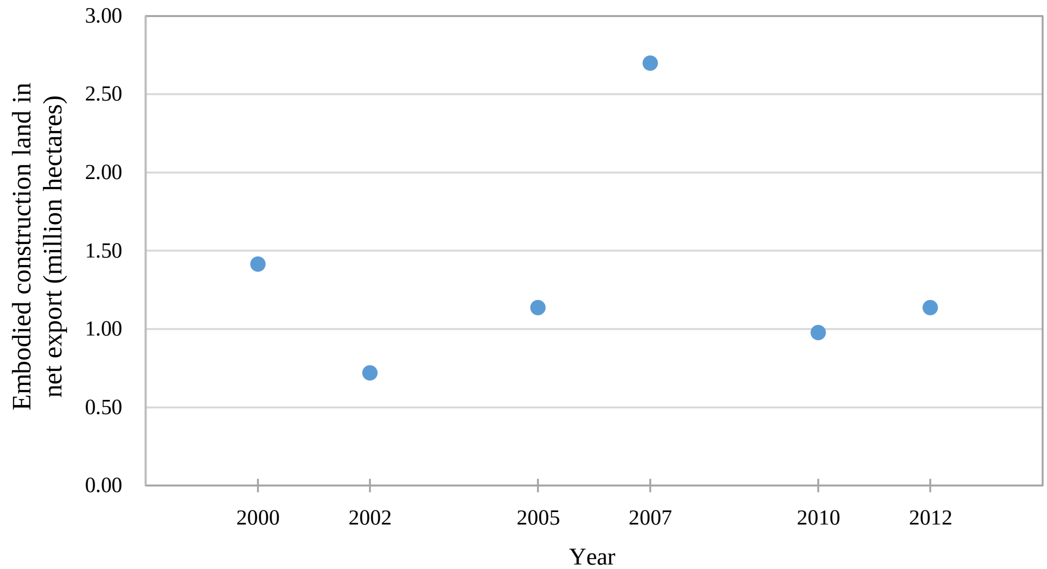


Figure 4.31 Embodied construction land in trade balance, 2000-2012

The embodied construction land in trade balance of the three major industries demonstrates a great difference (see Figure 4.32). The primary industry changes from a net exporter to a net importer in 2000–2012 because of the high demand for food products caused by rapid urbanization and improved standard of living. Embodied construction land in the net export of the secondary industry sharply increase from 2002 to 2007 and then decreases after 2007. This phenomenon is attributed to the fast industrialization of China and the significant number of exports of manufactured goods in 2002–2007. The exports of construction land resources through the secondary industry decrease, thus indicating that the "green industrial policy" are taking effect in the recent period. The tertiary industry consistently shows to be a net exporter during the concerned years, and this finding is attributed to China's growing service industries.

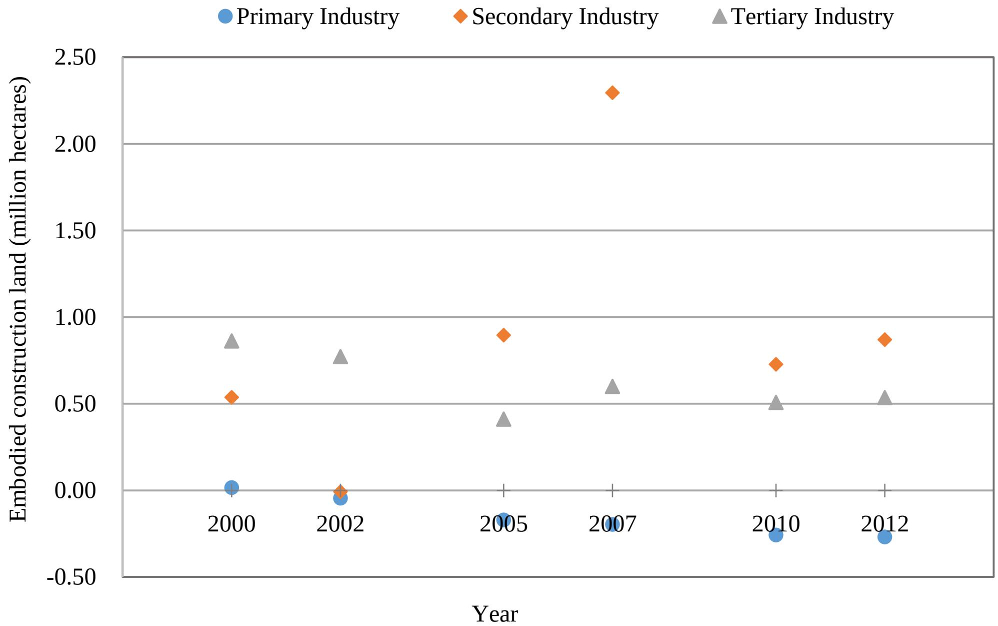


Figure 4.32 Embodied construction land in trade balance by three major industries, 2000-2012

4.5.1.3 Production-based versus consumption-based embodied cultivated land use

In the past 10 years, China's construction land use gradually increased with only a slight change. Figure 4.33 shows the annual increased construction land use in 1999–2013 at a range of 82.6–615.2 thousand hectares. The increased construction land in China mainly comes from cultivated land. The proportion of conversion from cultivated land to construction land at a range of 56.55–40.64% is illustrated in Figure 4.33. It first decreases from 51.33% to 42.85% with a certain fluctuation in 1999–2007 and then levels at approximately 40% in 2007–2013. In the past decade (2000–2010), the changing rate of the construction land area in China is the largest at 11.17% compared with other regions.

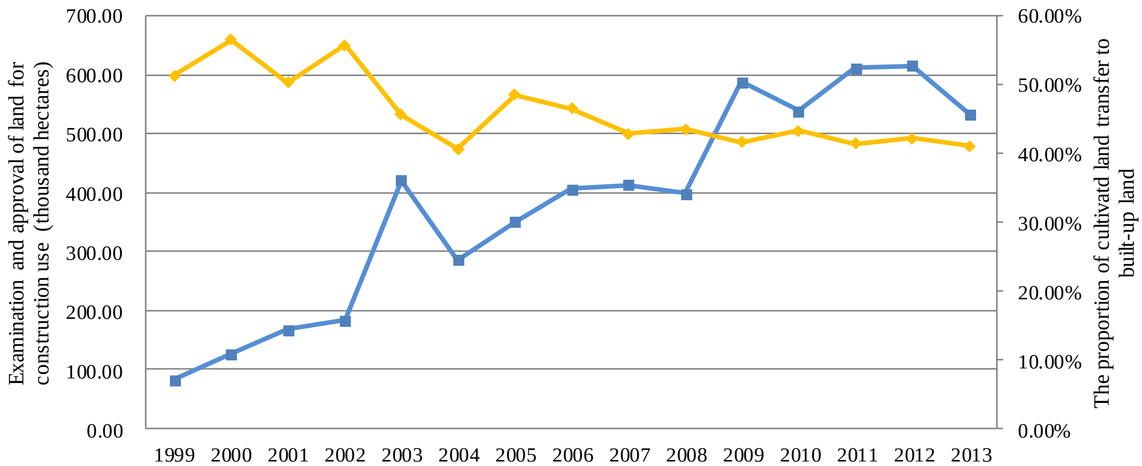


Figure 4.33 Annual increased construction land use

Note: The blue line depicts the annual increased construction land examined and approved by the government. The yellow line denotes the proportion of conversion from cultivated land to construction land.

The comparison of production- and consumption-based embodied construction land in 2000–2012 is presented in Figure 4.34. The total construction land area in China decreases from 31.13 million hectares in 2000 to 24.08 million hectares in 2005, and then it increases to 25.55 million hectares in 2012. The supply for construction land should be increased in the coming decades to meet the increasing demand under the backdrop of rapid urbanization. However, several limitations hinder the large expansion of construction land, such as environmental, political, and legal factors.

The consumption-based embodied construction land shows a similar fluctuating changing trend to the production-based construction land: the former slightly decreases from 29.72 million hectares in 2000 to 23.05 million hectares in 2005 and then increases to 202.81 million hectares is observed in 2010; and finally, a slight increase to 24.39 million hectares in 2012. The change is mainly attributed to the consumption and trading structure adjustment. The construction land embodied in consumption is slightly smaller than the actual construction land area in 2000–2012. The trade balance of construction land has been fundamentally maintained.

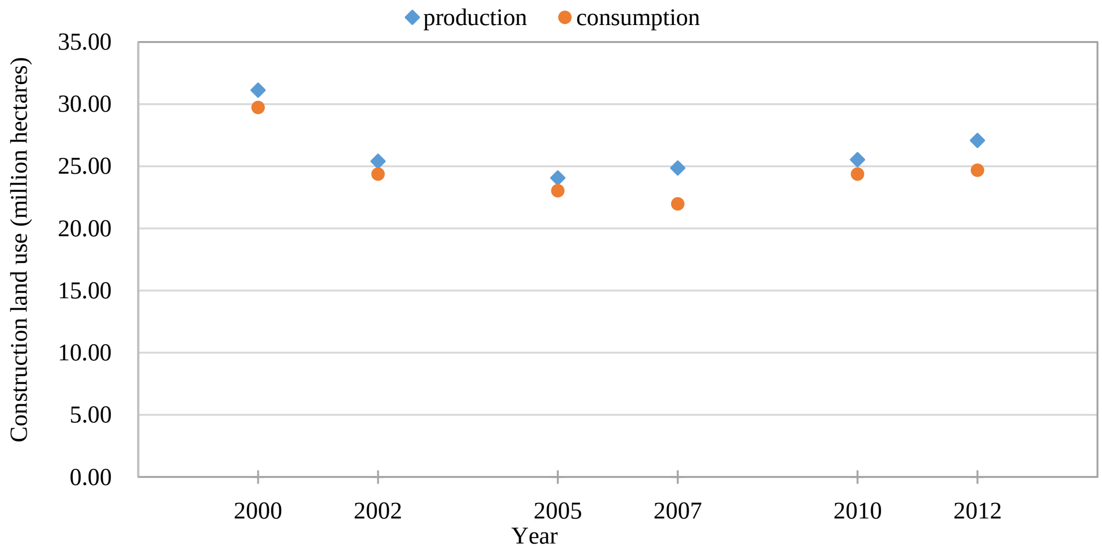


Figure 4.34 Production-based versus consumption-based construction land use, 2000-2012

Different from cultivated, forest and pasture land, construction land resources are occupied by all kinds of industries from both production and consumption perspectives. For the three major industries as shown in Figure 4.35, secondary industry utilizes the largest proportion of ECoLC during the concerned period with the values of 18.63 million hectares in 2000 and then gradually reduced to 14.10 million hectares in 2012. ECoLC of tertiary industry takes the second place with 6.68 million hectares' construction land in 2000, then it increases to 8.84 million hectares, due to a great flourish of the service industry in this emerging economy. Compared with the above two industries, the primary industry's ECoLC remains a low value, and it also experiences a decrease from 2000 with 4.40 million hectares to 2012 with the value of 1.73 million hectares.

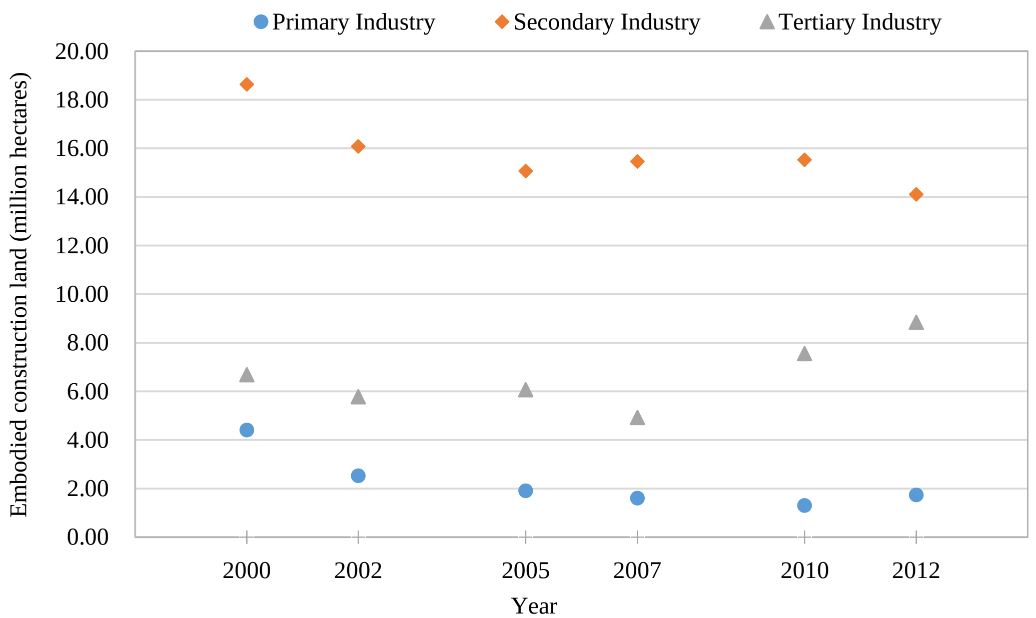


Figure 4.35 Consumption-based embodied construction land use by three major industries, 2000-2012

4.5.2 Industrial analysis

4.5.2.1 Intensity

The embodied construction land intensities of 42 sectors in China in 2012 are presented in Figure 4.36. The intensities of all the sectors move toward a leveling trend. Sector 30 (Transport and Storage) has the highest intensity of 0.09 hectare/thousand Yuan given that transportation facilities have high land occupation characteristics. At the aggregated economic level, the average intensity of the primary industries (0.06 hectare/thousand Yuan) is 1.26 times higher than that of the secondary industries (0.05 hectare/thousand Yuan) and 1.32 times higher than that of the tertiary industries (0.05 hectare/thousand Yuan), and the average intensity of all the sectors is 0.05 hectare/thousand Yuan. The indicator to measure the construction land occupation of all types of industry per economic output has no significant difference.

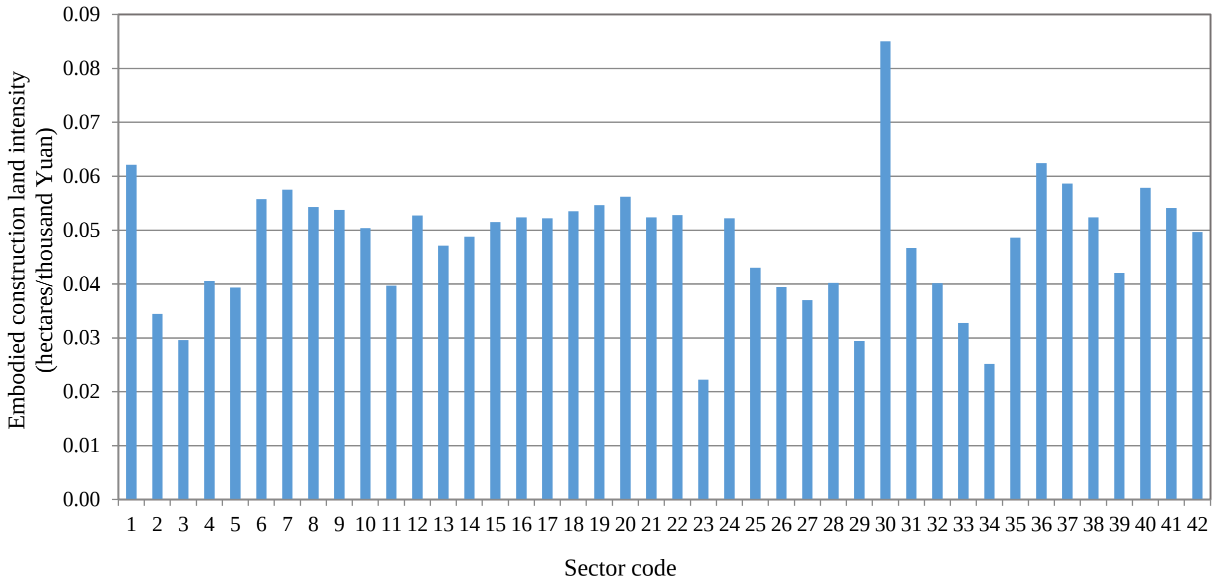


Figure 4.36 Embodied construction land intensity by sector in 2012

4.5.2.2 Trade

The distribution of embodied construction land in trade of the 42 sectors in China in 2012 is presented in Figure 4.37. For ECoLI, the largest importing sector in China is Sector 20 (Telecommunications Equipment, 1.35 million hectares), followed by Sectors 6 (Food Processing, 5.00 million hectares), 12 (Chemical Products, 0.65 million hectares), and 14 (Smelting and Pressing of Metal, 0.44 million hectares). With respect to ECoLE, Sectors 20 (Telecommunications Equipment), 19 (Electric Equipment), and 8 (Garments) are the top three with values of 1.69, 0.59, and 0.06 million hectares, respectively. In terms of sectoral trade balance, Sector 3 (Petroleum Extraction) is the largest net importer of embodied construction land in China with a value of 0.42 million hectares, and Sector 8 (Garments) is the largest net exporter with a value of 0.52 million hectares. The trade structure of construction land is significantly influenced by the import and export of monetary flows as the construction land efficiency nearly has the same magnitude.

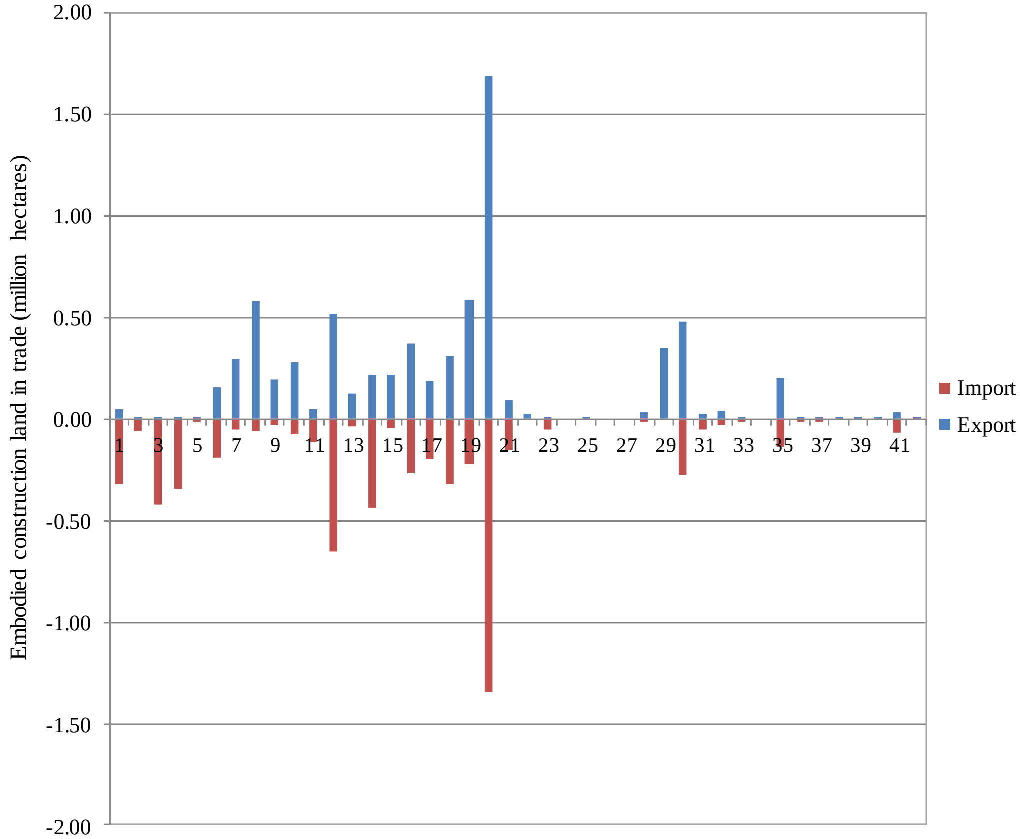


Figure 4.37 Embodied construction land in trade by sector in 2012

4.5.2.3 Consumption

ECoLC of the 42 sectors in China in 2012 is described in Figure 4.38. Sectors 28 (Construction) and 6 (Food Processing) embody the first and second largest volumes of construction land with 5.19 and 2.20 million hectares, respectively. These large volumes are mainly attributed to the improved household living standards, especially housing and food. Sector 18 (Transportation Equipment) provides the third largest embodied construction land of 1.83 million hectares caused by the increasing demand for private cars. This finding shows that the sectors closely related to people's lives require additional construction land to enhance their living standards.

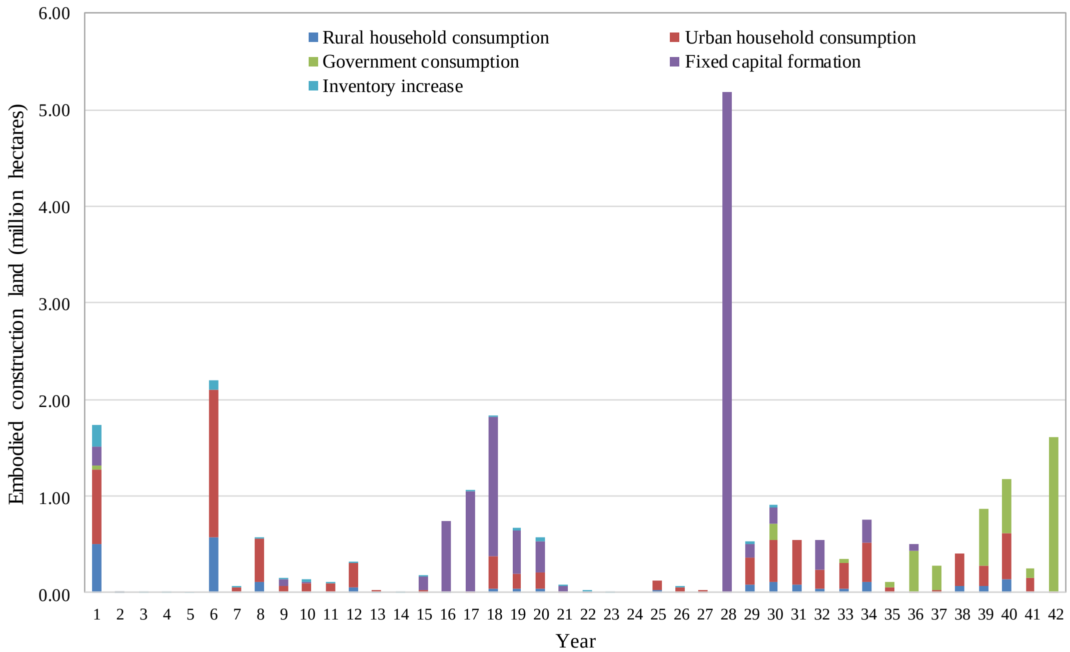


Figure 4.38 Embodied construction land in consumption by sector in 2012

4.6 Discussions and policy implications

The evolution of China's land use policies is closely related to the economic and social changes, and it has shown different features in different periods. Before the reform and opening up of China, the land use policy was subordinate to the planned economy policy. The land tenure system was established to separate ownership and use right in the 1980s (Wang et al., 2012). Associated with the land tenure system, a series of laws and regulations were promulgated, like Agriculture Law, Land Management Law, Water and Soil Conservation Law, and Equilibrium of Requisition-Compensation of Cultivated Land. (Yang and Li, 2000). Then, the 11th Five-year Plan set a goal that "the total area of cultivated land in China stays above the 'red line' of 120 million hectares," which is the bottom-line area of cultivated land in China (Cui and Kattumuri, 2011). Furthermore, the marketization of land resources has been initiated on the basis of the "double maintenance policy-making strategy" to maintain economic development and land resource conservation

(Wang et al., 2012). To fully realize land marketization and balance the demand and supply of land effectively, understanding the economic driving forces of land use is necessary.

In recent years, the issue of land conservation in China has become important because of the increasing food demand, the expansion of biofuel production, and especially the rapid urbanization (Fan et al., 2013; Qiang et al., 2013). For example, the urban areas of China increased by almost 25% in the 1990s, and this increase resulted in a massive cultivated land loss (Jiang et al., 2013). Acknowledging the scarcity of land in China, studies on how land in China is distributed to meet the requirements of consumption and trade activities based on IOA are relatively few. Under these circumstances, an IO modelling is carried out in China to conduct a temporal simulation of ELP, ELC, ELI, and ELE in 1987–2012 to identify the factors influencing China's embodied land resource utilization. Furthermore, the four types of land use embodied in domestic consumption and international trade in 2012 with sectoral details are calculated and analyzed. The results are as follows:

(1) Temporal analysis on China's embodied land use.

China's embodied cultivated, forest, pasture, and construction land intensities in 1987–2012 or 2000–2012 show a downward trend, declining from 0.34 to 0.02, 0.61 to 0.05, 0.70 to 0.04, and 0.11 to 0.005 hectares/thousand Yuan. This result demonstrates China's effort in improving various land use efficiencies and effectiveness.

China is consistently a net exporter of cultivated, forest, pasture, and construction land in 2000–2010. The variation laws of the three agricultural land patterns are similar: embodied land in trade balance varies significantly during the concerned period, and the largest values are all obtained in 2007. The range of fluctuation of embodied cultivated, forest, and pasture land is 8.06–-0.23, 15.55–-0.44, and 10.41–-0.38 million hectares, respectively. The fluctuation is closely related to the evolution of China's international agricultural trade structure. The variation range of embodied construction land in trade balance is relatively smaller than that of agricultural land at 2.70–0.98 million hectares.

The change in consumption-based embodied land use is not highly significant. The variation ranges of consumption-based embodied cultivated, forest, pasture, and construction land are 103.6–132.96, 199.87–249.27, 202.81–262.15, and 21.98–29.72 million hectares, respectively. However, the embodied consumption in four land use types has a large difference. Consumption-based forest and pasture land are approximately 10 times larger than construction land, and consumption-based cultivated land is approximately 5 times larger than construction land. This finding demonstrates the significance of land devoted to various agricultural activities.

(2) Sectoral analysis on China's embodied land use.

In these three types of agricultural land, Sector 1 (Agriculture) has the highest intensity, and the other sectors closely related to the necessities for daily living, such as Sectors 6 (Food Processing), 7 (Textile Industry), and 31 (Hotels, Catering Service), have high intensities. Regarding construction land, the intensities of all the sectors move toward a leveling trend given that various economic activities are all embedded in construction land.

In the three agricultural land categories, Sector 1 (Agriculture) is the largest net importer of embodied cultivated, forest, and pasture land in China with values of 8.20, 15.38, and 15.73 million hectares, respectively, and Sector 8 (Garments) is the largest net exporter of embodied cultivated, forest, and pasture land in China with values of 3.78, 7.09, and 6.14

million hectares, respectively. Although a structural similarity of the embodied cultivated, forest, and pasture land in trade by sector is observed, considerable differences still exist in terms of magnitude. Embodied forest and pasture land in both importers and exporters by sector are double the embodied cultivated land. In construction land, Sector 3 (Petroleum Extraction) is the largest net importer of embodied construction land in China with a value of 0.42 million hectares, and Sector 8 (Garments) is the largest net exporter with a value of 0.52 million hectares.

From an industrial perspective, the basic necessities of clothing, food, shelter, and transportation consume a large number of land resources. Specifically, Sectors 1 (Agriculture), 6 (Food Processing), and 28 (Construction) embody the largest volumes of cultivated, forest, and pasture land at 52.74, 35.86, and 10.67 million hectares, 98.87, 67.24, and 20.00 million hectares, and 85.67, 58.26, and 17.33 million hectares, respectively. Sectors 28 (Construction), 6 (Food Processing), and 18 (Transportation Equipment) consume the largest construction land at 5.19, 2.20, and 1.83 million hectares, respectively.

According to the industrial analysis of embodied land in this study, establishing the shared criterion in all the industries for land conservation is necessary and important. Land-intensive industries are obligated to improve land utilization efficiency using technical development and resource reallocation. For example, agricultural mechanization and automation are highly instrumental in effectively using cultivated land in Sector 1 (Agriculture). However, industries with low land intensity can contribute significantly to consumption and trade activities. Many export products from high-tech and service industries occupying less land resources can help to restrict the outflow of land resources from China.

To provide a consistent data supporting basis for policy making, regularly establishing the historical land database through an effective accounting mechanism is important. According to the results of this study, China has paid a high land resource cost to satisfy consumption outside its territory even though the downward trend of embodied intensities for the 20 years confirms the country's effort and effectiveness to improve land use efficiency. Encouragingly, China places high priority on trade structural change (i.e., increasing export of manufactured, high-tech products such as electronic devices (with low cultivated land intensity) to replace the traditional, low-end products such as textile (with high cultivated land intensity), which is beneficial to balance the economic and environmental benefits and avoid land loss.

Our attempt to evaluate China's land use in 1987–2012 has several limitations. First, this study attempts to analyze China's four types of land use resources. However, cultivated, forest, and pasture land are aggregated into only one sector (Agriculture Sector) and are not separated into different sectors based on the cultivated, forest, and pasture land use types because of the data availability. Therefore, the embodied land intensities of different products are equal because they are derived from the same industrial sector. However, to conduct an effective examination of China's land protection policies, an in-depth understanding of cultivated, forest, and pasture land use types for different agricultural, forestry, and animal husbandry products in China is required. Second, as in conventional IO studies, imported commodities are assumed to have the same embodied land intensities as domestic ones because of the limitation of import intensity data although the imported commodities show a substantial difference from the domestic ones (Weber et al., 2008). Third, different sector classifications from different original input–output data sources are used in this study, and these differences impede a detailed sectoral comparison. Sector consistency is required if a comparative study will be conducted (Su et al., 2010). However, a corresponding error can be generated because of the different sector classifications in China's original IO tables. This research focuses on the comparison of China's overall cultivated land change regardless of the level of sector classification. Therefore, this study does not consider the sector classification difference and sector aggregation or disaggregation. If the sector aggregation or disaggregation is considered in this study, an additional sector aggregation or disaggregation error must also be analyzed. Fourth, China's land statistics system was set up in 1987. Since then, the statistical procedures have experienced the following three stages: before 1996, information was collected from a year-round survey from Jan 1 to Dec 31; in 1996–2006, the survey was adjusted to cover only Mar 1 to Oct 31 of a year; since 2007, the survey has been reverted to the initial year-round standard (Jiang, 2013; Wang et al., 2012). The change in land data collection procedures negatively affects data quality and consistency, thus increasing the difficulty in conducting a time-serial study. However, given that land use pattern is comparatively stable in a year on the national scale, the data discrepancy introduced from collection procedure changes is considered acceptable for this study. Finally, this study applies national GDP deflators to adjust price change instead of using other price indicators. Price change during the research period noticeably varies from sector to sector. Thus, more detailed sectoral price level indicators can portray this variation more precisely than before. However, the sectoral level price indicator is unavailable in this study because of data limitation.

4.7 Chapter summary

The issue of land conservation in China is important given the increasing food demand, rapid urbanization, and enhancement of biofuel production. Despite the scarcity of land resources in China, relatively few studies have investigated how land in China is distributed to meet the requirements of domestic consumption and international trade from the historical view based on long time-serial IOA analysis. Under these circumstances, this chapter identifies the underlying economic influence factors at the level of embodied land resource utilization. Historical changing pattern is analyzed through the long time-serial simulation of ELP, ELC, ELI, and ELE in 1987–2012. Furthermore, the embodied land in domestic consumption and international trade balance in 2012 is analyzed with high sectoral resolution. The calculated results are a solid reference to re-recognize the characteristics of embodied land requirements of the Chinese economy, and they provide a detailed database for the guidance of sustainable land use management.

Chapter 5 Spatial Nexus: Land Occupation of the Chinese Economy over Space

5.1 Introduction

This chapter identifies the spatial nexuses of China's four land use types, namely, cultivated, forest, pasture, and construction land. Spatial nexus is to identify the characteristics of interregional virtual land flows combined with geographical properties. Currently, the ever-closer economic relationship among various industries in different regions through interregional trade exacerbates the pressure on the spatial displacement of resources. Therefore, identifying the issues of spatial transfer of land use pressure and the spatial distribution patterns of land footprint in the whole supply chain is important. Specifically, China's actual land cover distribution patterns, regional land footprint distribution patterns, and regional spatial transfer of virtual land use in 2010 are described in detail in this chapter. Results in this chapter are calculated based on the most recent available data, including cultivated, forest, pasture, and construction land data in 2010, and MRIO data in 2010.

5.2 Cultivated land

5.2.1 Actual cultivated land cover distribution

In 2010, China has 135.27 million hectares of cultivated land, accounting for 19.81% of the total national land area. The average per capita cultivated land area in China is 0.10 hectare/capita. As shown in Figure 5.1, thirteen provinces are identified with cultivated land areas that are over 5 million hectares, namely, Heilongjiang, Inner Mongolia, Henan, Shandong, Jilin, Sichuan, Hebei, Yunnan, Anhui, Gansu, Hubei, Xinjiang, and Liaoning. The total share of cultivated land use of these 13 regions is 69.84%. Most of these regions have a higher level of per capita cultivated land area. The three largest regions are Heilongjiang, Inner Mongolia, and Jilin with values of 0.41, 0.37, and 0.26 hectares per capita, respectively. By contrast, some developed regions, such as Shanghai, Beijing, Guangdong, Tianjin, and Fujian, among others, have few cultivated land resources even though they need to feed a large population. This finding reflects the imbalance in the spatial distribution of cultivated land supply and demand.

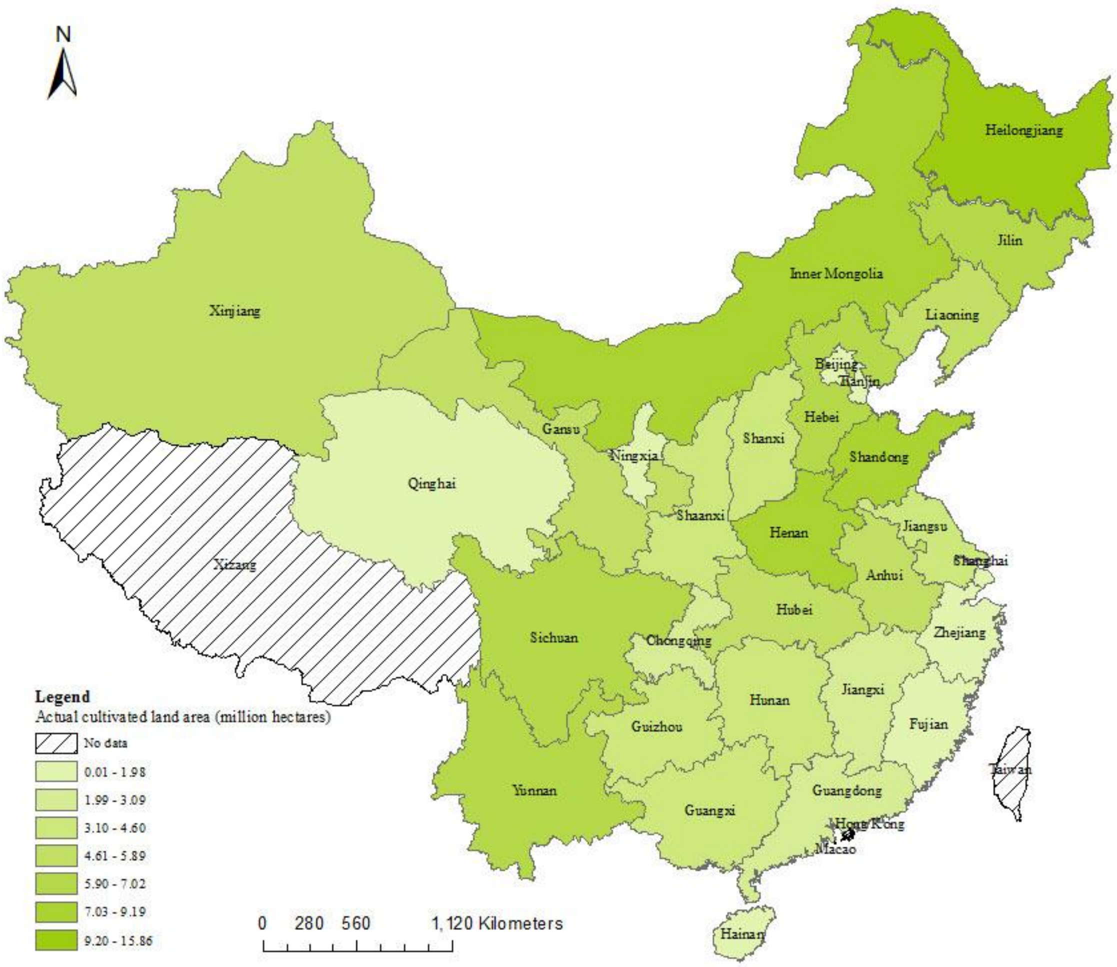


Figure 5.1 Proportion of cultivated land among the provinces of China

5.2.2 Regional virtual cultivated land footprint distribution

Regional cultivated land use intensity is shown in Figure 5.2. China's average embodied cultivated land intensity is 2.67 hectares/million Yuan. A total of 14 regions are below average, and 16 regions are above average. Moreover, the embodied cultivated land intensity is negatively correlated with the regional economic level. The top five regions with the highest intensities are Heilongjiang, Gansu, Guizhou, Yunnan, and Xinjiang with values of 9.20, 7.07, 6.93, 6.00, and 5.50 hectares/million Yuan, respectively. The regions with the lowest intensities are Tianjin, Zhejiang, Guangdong, Beijing, and Shanghai with values of 1.15, 1.07, 0.90, 0.86 and 0.57 hectares/million Yuan, respectively.

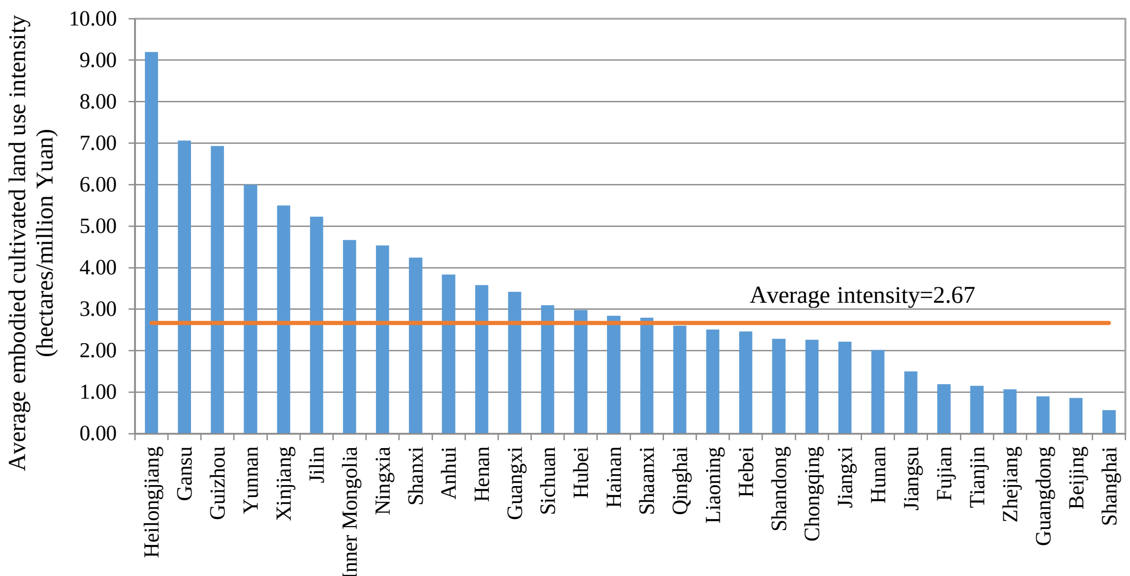


Figure 5.2 Regional embodied cultivated land intensity

Figure 5.3 shows China's ECLC with a total value of 116.46 million hectares. From the regional perspective, Shandong, Heilongjiang, Henan, Jiangsu and Inner Mongolia have the largest values of 7.89, 7.48, 6.76, 5.55 and 5.47 million hectares, respectively, as they have sufficient cultivated land resources or the highest household consumption ability.

Hainan, Ningxia, Qinghai, Fujian, and Tianjin have the smallest values of 0.63, 0.71, 0.87, 1.85, and 1.96 million hectares, respectively. The few actual cultivated land resources or the lowest consumption ability of these regions is attributed to their low population and less developed economy.

As shown in Figure 5.3, the imbalance of cultivated land supply and demand is revealed, by comparing the regional distribution of actual and embodied cultivated land resources. For most regions with poor cultivated land resources but with a developed economy, such as Shanghai, Tianjin, and Beijing, they have low actual cultivated land use but consume a large number of cultivated land resources because of their high economic levels. Regions with abundant cultivated land resources but undeveloped economies, such as Inner Mongolia, Heilongjiang, and Hebei, have high values of actual cultivated land resources, but their embodied cultivated land uses are low.

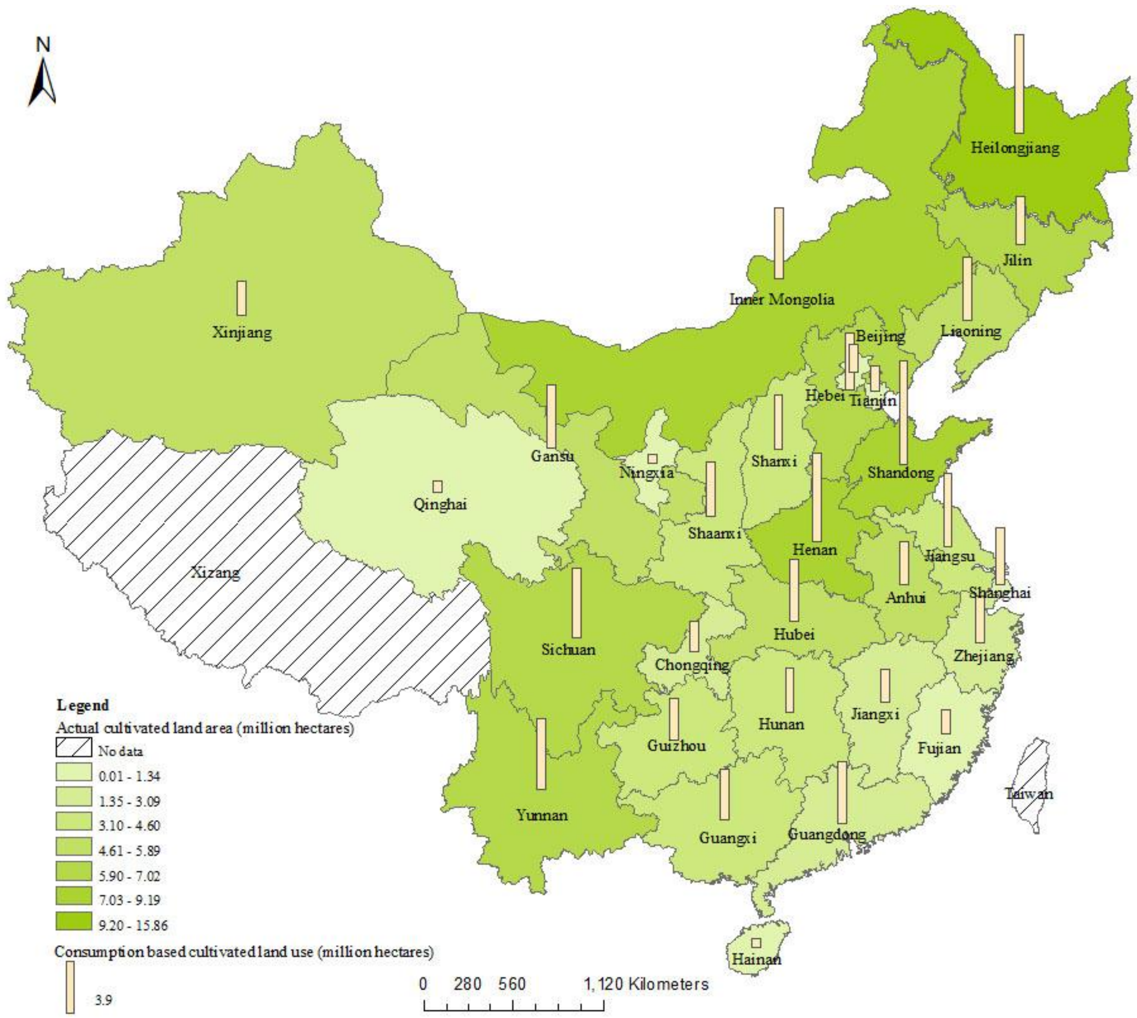


Figure 5.3 Cultivated land use embodied in the final consumption

5.2.3 Regional transfer of virtual cultivated land use

Figure 5.4 shows China's cultivated land embodied in trade balance. Trade leads to the transfer of virtual land. To clearly compare the regional resource transfer, regions with positive values are defined as the cultivated land resource suppliers, and regions with negative values are considered as the land resources receivers. Shanghai, Guangdong, Jiangsu, Zhejiang, Shandong, Beijing, Tianjin, Liaoning, Fujian, Shanxi, Shaanxi, Qinghai, and Chongqing play the roles of receivers of cultivated land resources with net import values of 4.66, 3.85, 3.22, 2.91, 2.65, 2.20, 1.79, 0.97, 0.91, 0.47, 0.39, 0.30, and 0.04

million hectares, respectively. Heilongjiang, Inner Mongolia, Jilin, Xinjiang, Anhui, Hebei, Guizhou, Sichuan, Yunnan, Henan, Gansu, Hunan, Ningxia, Jiangxi, Guangxi, and Hebei are the suppliers of cultivated land resources with net export values of 6.93, 2.93, 2.67, 1.84, 1.83, 1.71, 1.51, 1.05, 0.75, 0.74, 0.58, 0.49, 0.45, 0.43, 0.23, 0.19, and 0.04 million hectares, respectively.

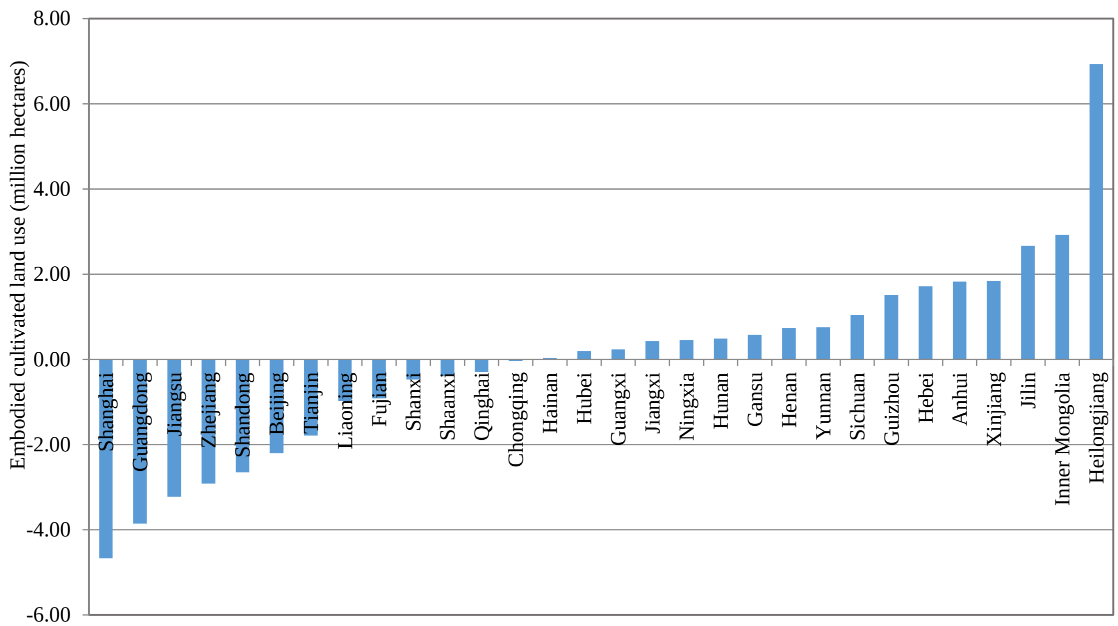


Figure 5.4 Cultivated land embodied in trade balance

Figure 5.5 shows the major embodied cultivated land flows in interregional trade with values exceeding 0.35 million hectares. Two main trends can be seen from the main flowing directions: cultivated land resources mainly flow from Xinjiang, Heilongjiang, Jilin, and Inner Mongolia to Shandong, Jiangsu, Shanghai and Zhejiang; and also flow from some southern provinces to Guangdong.

The GDP of the Yangtze River Delta, as China's largest economic circle, accounts for 20% of the total. Its total import and export volumes rank first in China. Facing the trend of globalization, resource allocation is profoundly affected by economic flows. The

Yangtze River Delta, the most developed region in China, mainly receives huge cultivated land flows from its neighboring provinces, such as Henan, Anhui and Jiangxi. Topping the GDP ranking in China among the provincial regions, Guangdong also attracts huge embodied land flows from Guangxi, Hunan, and Yunnan. As the third largest economy in China, Shandong Province absorb large numbers of cultivated land resources from some resource-intensive provinces, such as Xinjiang, Inner Mongolia, and Heilongjiang. The main characteristics of Shandong, Jiangsu, Shanghai and Guangdong are their highly developed commodity economies and abundant cultivated land resources. Despite their high-quality substantial land resources, these three economic regions still require a certain amount of cultivated land resources from neighboring regions to relieve the resource pressure caused by their rapid economic development and population increase.

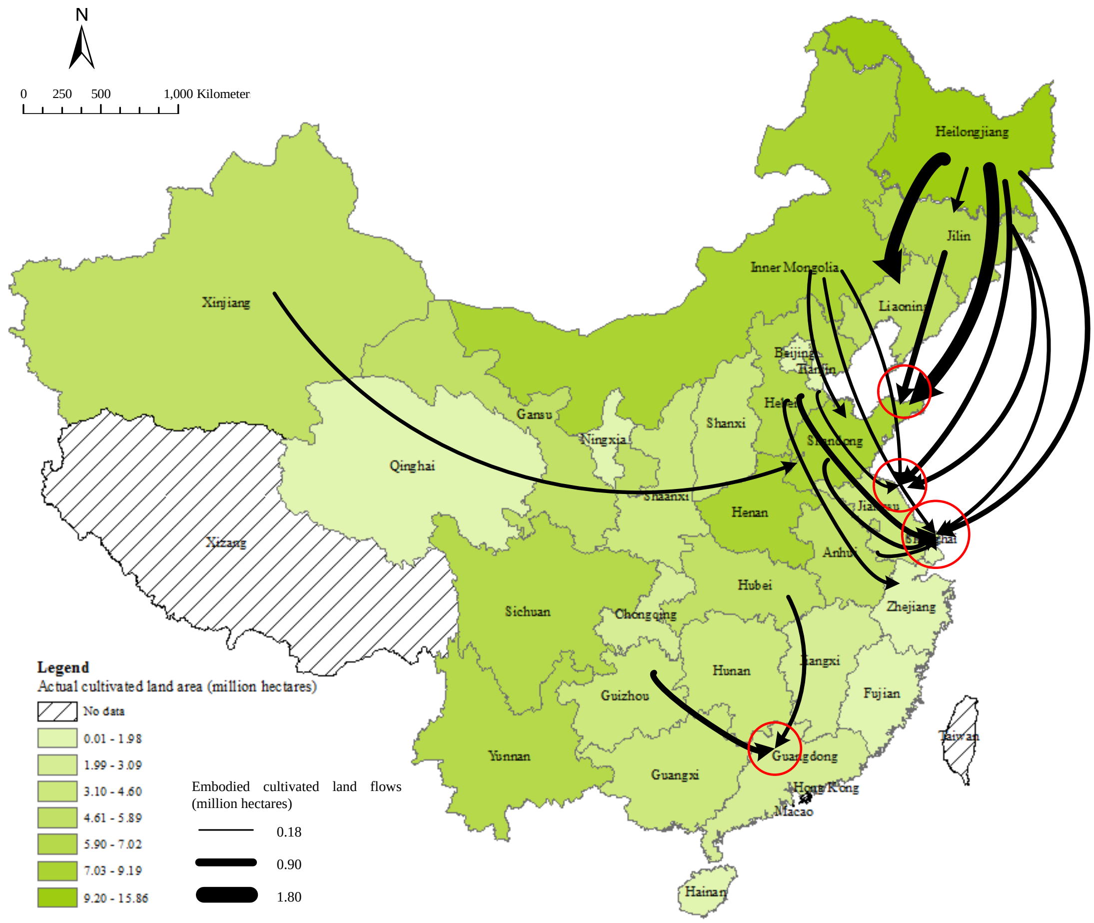


Figure 5.5 Major embodied cultivated land flows in interregional trade

Note: The direction of the arrow represents the embodied land flow direction and the width of the arrow shows the size of the embodied land flow.

5.3 Forest land

5.3.1 Actual forest land cover distribution

In 2010, China has 253.77 million hectares of forest land, accounting for 37.16% of the total national land areas. As shown in Figure 5.6, Inner Mongolia, Yunnan, Sichuan, Heilongjiang, Guangxi, Hunan, Shaanxi, Jiangxi, and Guangdong have forest land areas of above 10 million hectares. The share of forest areas of these nine provinces accounts for 62.14% of the total. Most of these regions are inland and undeveloped regions except for

Guangdong Province. By contrast, the provinces with few forest land resources are developed regions, such as Shanghai, Tianjin, Jiangsu, and Beijing.

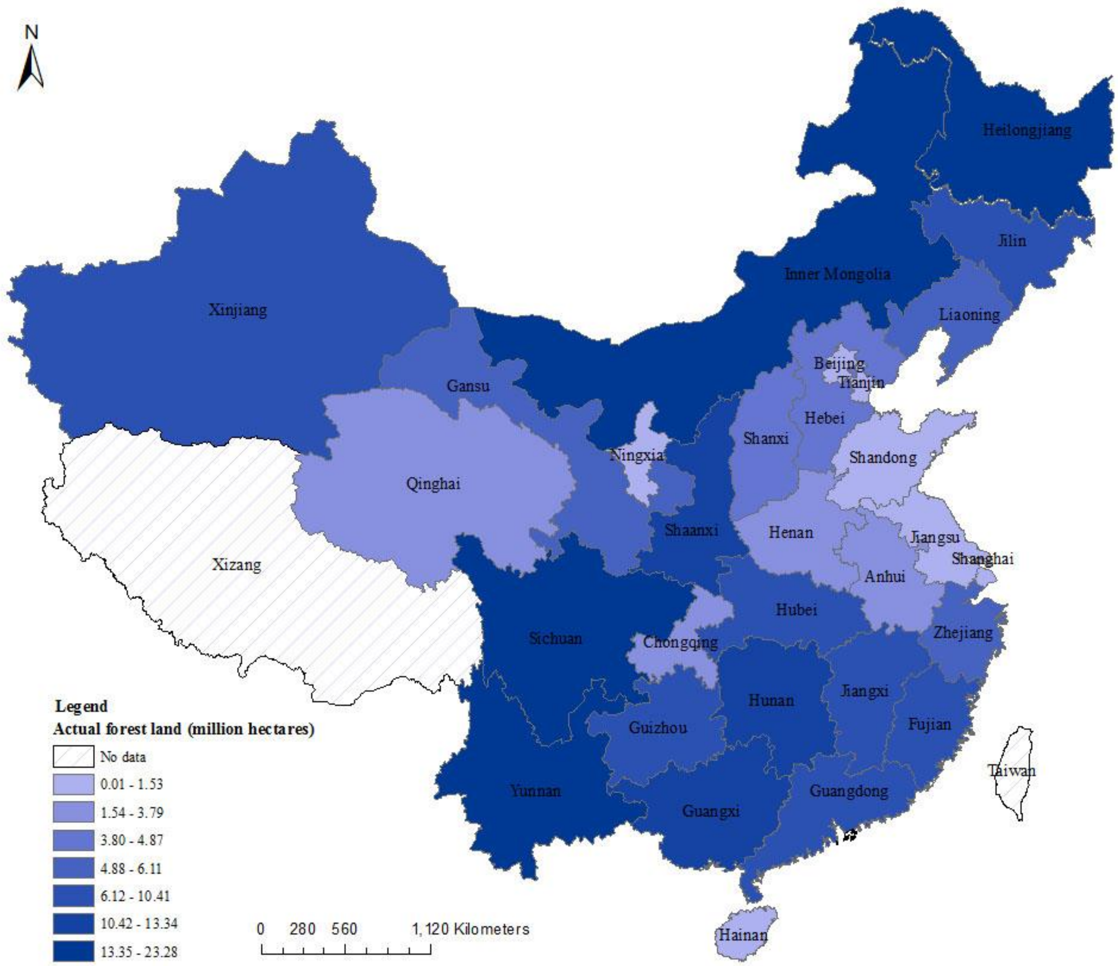


Figure 5.6 Proportion of forest land among the provinces in China

5.3.2 Regional virtual forest land footprint distribution

China's regional forest land use intensity is illustrated in Figure 5.7. China's average embodied forest land intensity is 4.48 hectares/million Yuan. A total of 17 regions are below the national average, and 13 regions are above average. Similar to cultivated land use, forest land shows the following pattern: embodied forest land intensity is negatively correlated with the regional economic level. The top five regions with the highest intensities are Yunnan, Heilongjiang, Qinghai, Inner Mongolia, and Guizhou with values of 22.14, 16.82, 16.04, 14.81, and 14.05 hectares/million Yuan, respectively. The regions with the lowest intensities are Shanghai, Jiangsu, Tianjin, Guangdong, and Beijing with values of 0.86, 1.03, 1.68, 1.76 and 1.81 hectares/million Yuan, respectively.

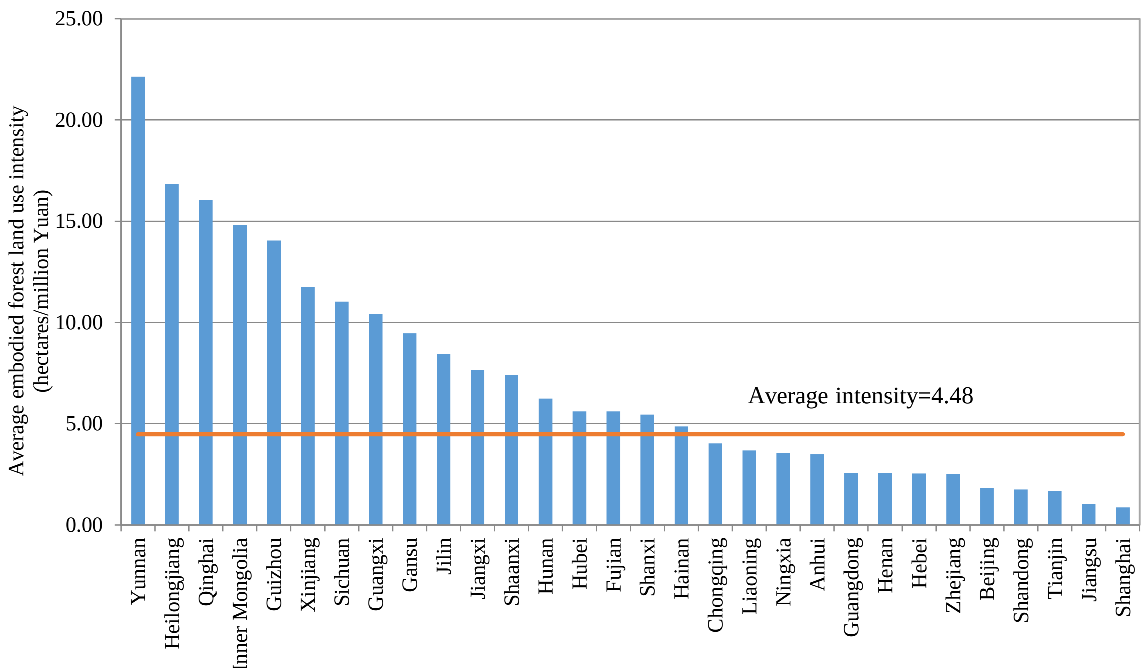


Figure 5.7 Regional embodied forest land intensity

Figure 5.8 shows EFLC with a total value of 209.27 million hectares. From the regional perspective, Yunnan, Sichuan, Inner Mongolia, Guangdong, and Guangxi consume the largest forest land resources, with values of 18.44, 16.01, 12.79, 12.56 and 10.33 million hectares, respectively. These figures reflect their sufficient forest land resources or high household consumption ability. Ningxia, Hainan, Tianjin, Beijing, and Anhui have the smallest values of 0.60, 1.08, 2.84, 3.38, and 3.45 million hectares, respectively. These figures reflect their few actual forest land resources or their low consumption ability.

The imbalance of forest land supply and demand is revealed by comparing the regional distribution of actual and embodied forest land resources. Most regions with poor forest land resources but developed economies, such as Shanghai, Tianjin, Jiangsu, and Beijing, have low actual forest land use but consume a large number of forest land resources because of their high economic levels. Most regions with abundant forest land resources but undeveloped economies, such as Inner Mongolia, Heilongjiang, and Xinjiang, have high values of actual forest land resources, but their embodied forest land uses are low.

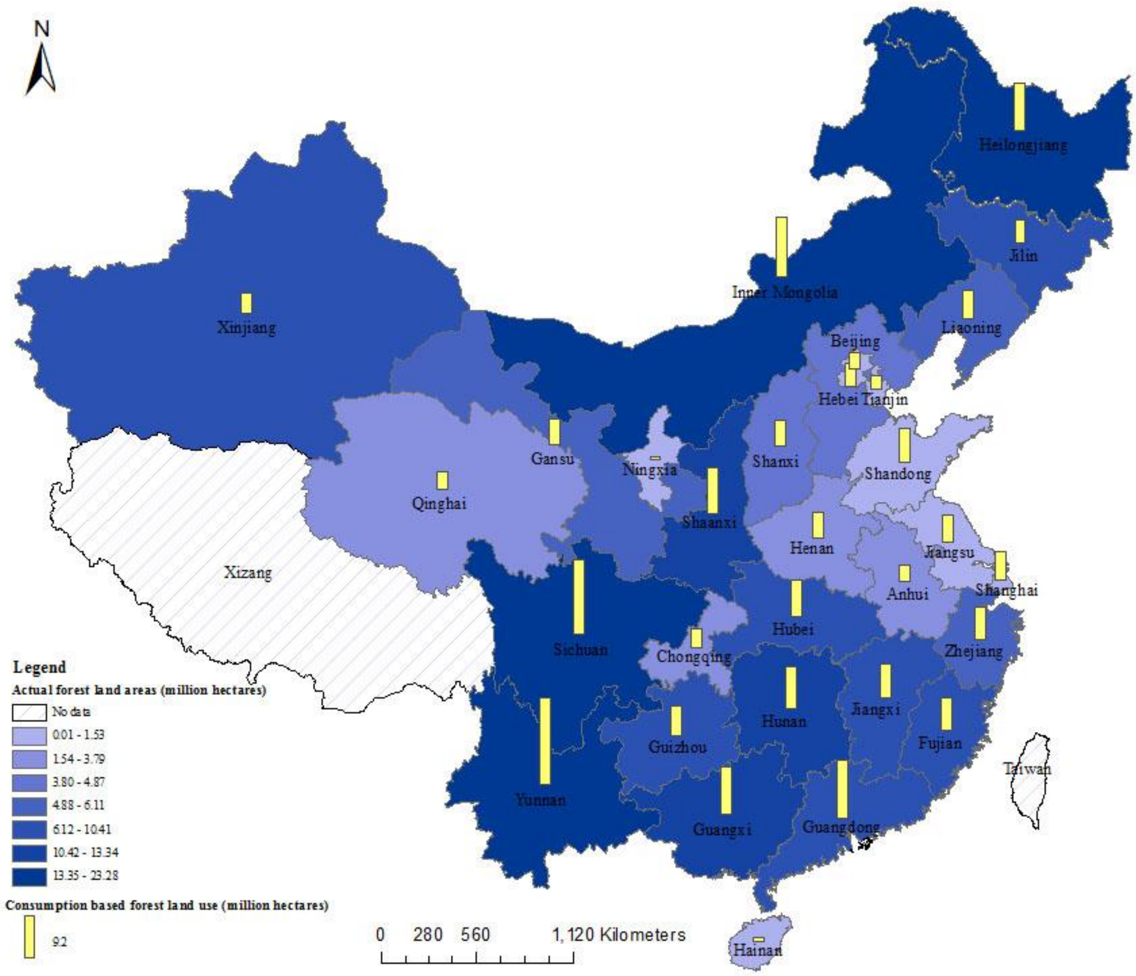


Figure 5.8 Forest land use embodied in final consumption

5.3.3 Regional transfer of virtual forest land use

Figure 5.9 shows China's forest land embodied in trade balance. Similar to cultivated land use, regions with positive values are defined as the forest land resource suppliers, and regions with negative values are considered as the land resources receivers. There are 15 regions as importers and 15 regions as exporters. Jiangsu, Shandong, Shanghai, Guangdong, Zhejiang, Beijing, Tianjin, Henan, Liaoning, Shanxi, Hebei, Chongqing, Anhui, Qinghai, and Fujian play the roles of receivers of forest land resources. Heilongjiang, Inner Mongolia, Sichuan, Yunnan, Xinjiang, Jilin, Guizhou, Jiangxi, Shaanxi, Gansu, Ningxia, Hubei and Hainan are the suppliers of forest land resources.

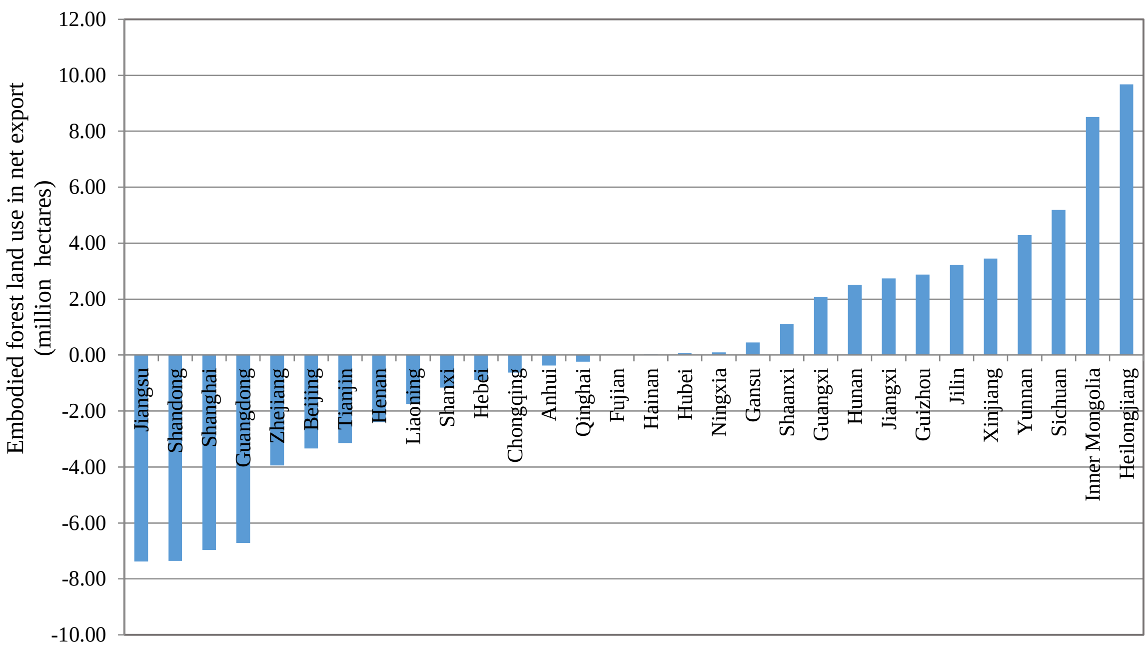


Figure 5.9 Forest land embodied in trade balance

Figure 5.10 shows the major embodied forest land flows in interregional trade with values exceeding 0.69 million hectares. Considering the characteristic similarities between cultivated land and forest land, the following two similar trends can be observed from the main flowing directions: forest land resources flow from Heilongjiang, Inner Mongolia, Ningxia, and Sichuan to Shandong, Jiangsu, and Shanghai, and flow from Yunnan, Guangxi, Guizhou, Hunan, Hubei, and Jiangxi, to Guangdong Province. The largest interregional forest land trading flow is from Heilongjiang to Shandong with a value of 2.10 million hectares.

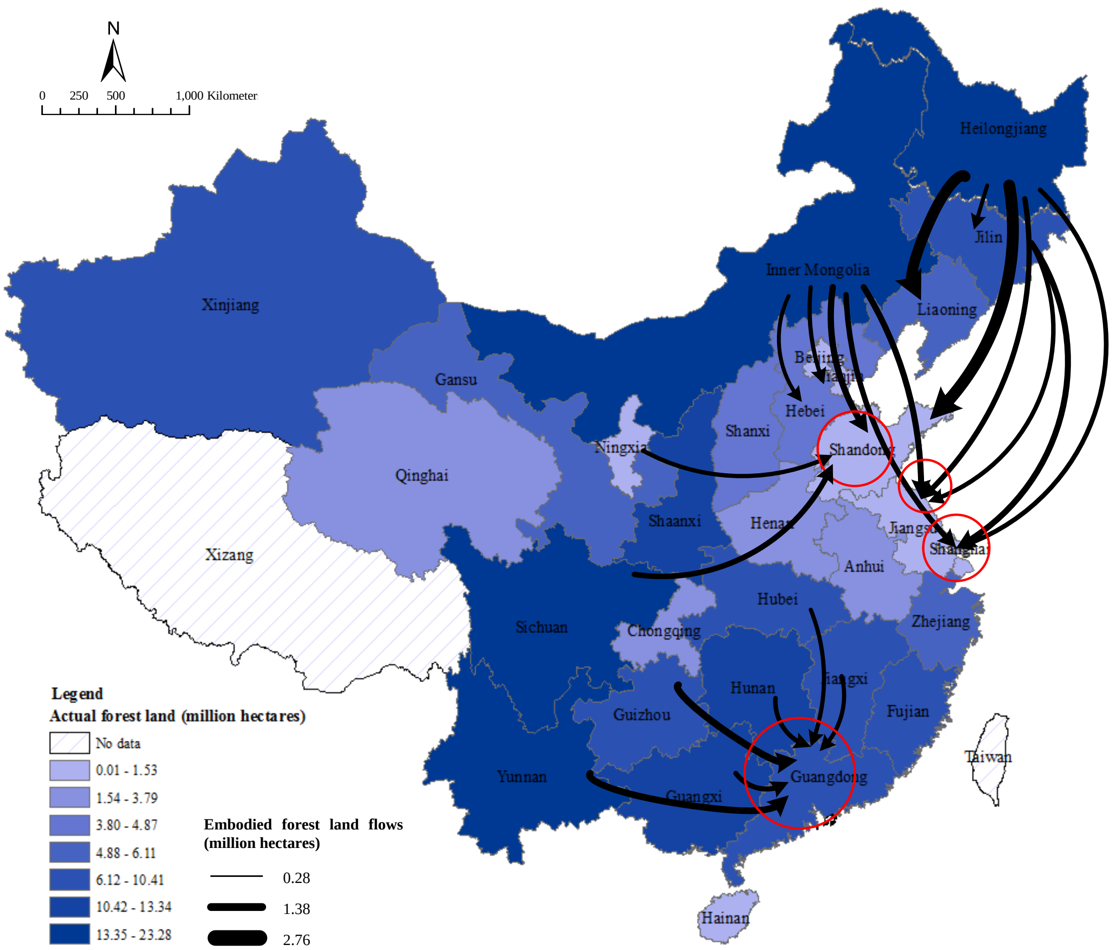


Figure 5.10 Major embodied forest land flows in interregional trade

Note: The direction of the arrow represents the embodied land flow direction and the width of the arrow shows the size of the embodied land flow.

5.4 Pasture land

5.4.1 Actual pasture land cover distribution

In 2010, China has 219.67 million hectares of pasture land, accounting for 32.16% of the total national land areas. The spatial distribution of China's pasture land is uneven compared with that of cultivated and forest land resources. As shown in Figure 5.11, eight provinces, namely, Inner Mongolia, Qinghai, Xinjiang, Sichuan, Gansu, Shaanxi, Ningxia, and Heilongjiang, have pasture land areas of above 1 million hectares. Most notable among these provinces are Inner Mongolia with a 33.32% share of the national total pasture land, Qinghai with a 27.41% share, and Xinjiang with a 24.04% share. These figures suggest that 84.77% of total pasture land resources are distributed among Inner Mongolia, Qinghai, and Xinjiang.

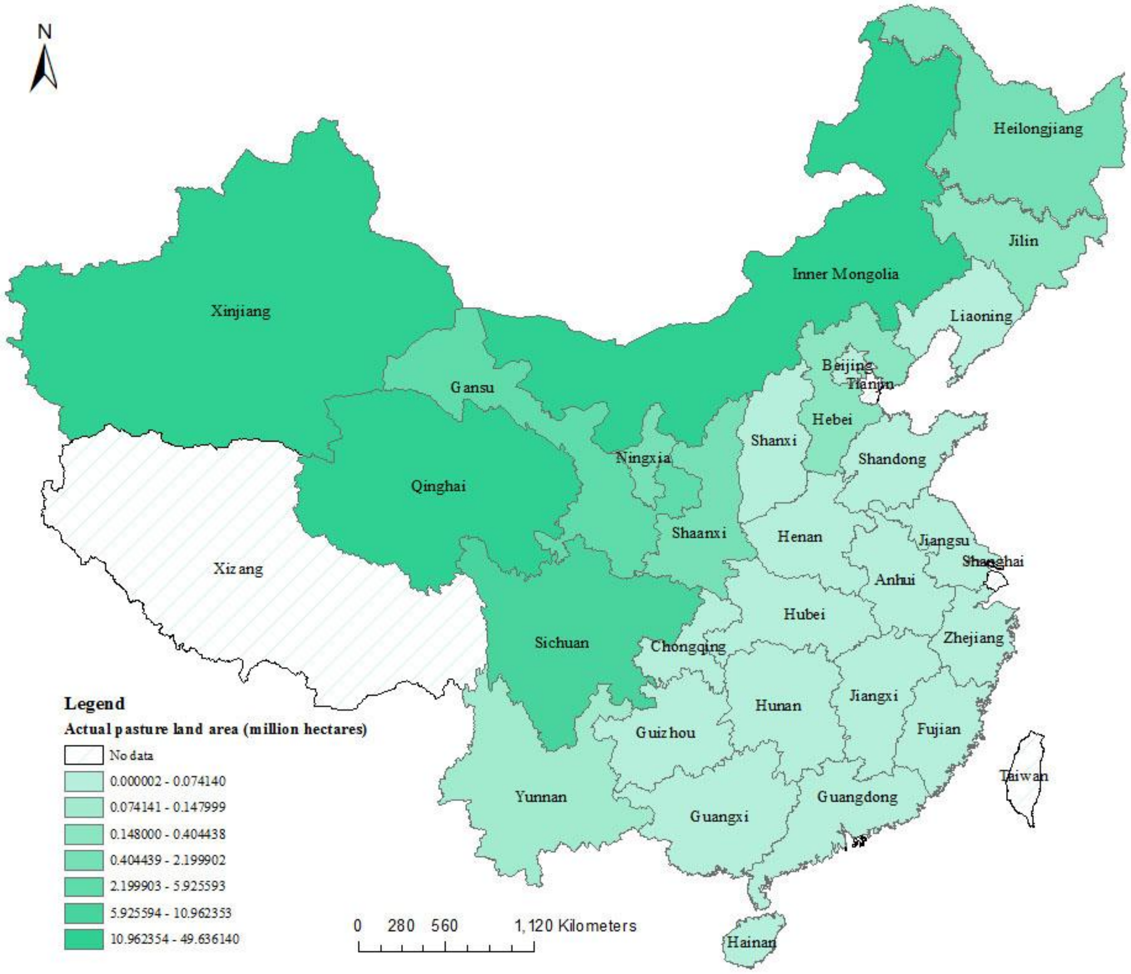


Figure 5.11 The proportion of pasture land among provinces of China

5.4.2 Regional virtual pasture land footprint distribution

China's regional pasture land use intensity is described in Figure 5.12. China's average embodied pasture land intensity is 2.49 hectares/million Yuan. A total of 24 regions are below the national average, and six regions are above average. Compared with cultivated land and forest use, embodied pasture land intensity has its own characteristic features. Qinghai has the highest embodied intensity with a value of 181.08 hectares/million Yuan, which is 72.86 times higher than the average. Xinjiang and Inner Mongolia have the second and third largest embodied intensities, which are 18.01 and 12.44 times higher than the average, respectively. This finding can be explained by the fact that most pasture land resources are occupied by these three provinces.

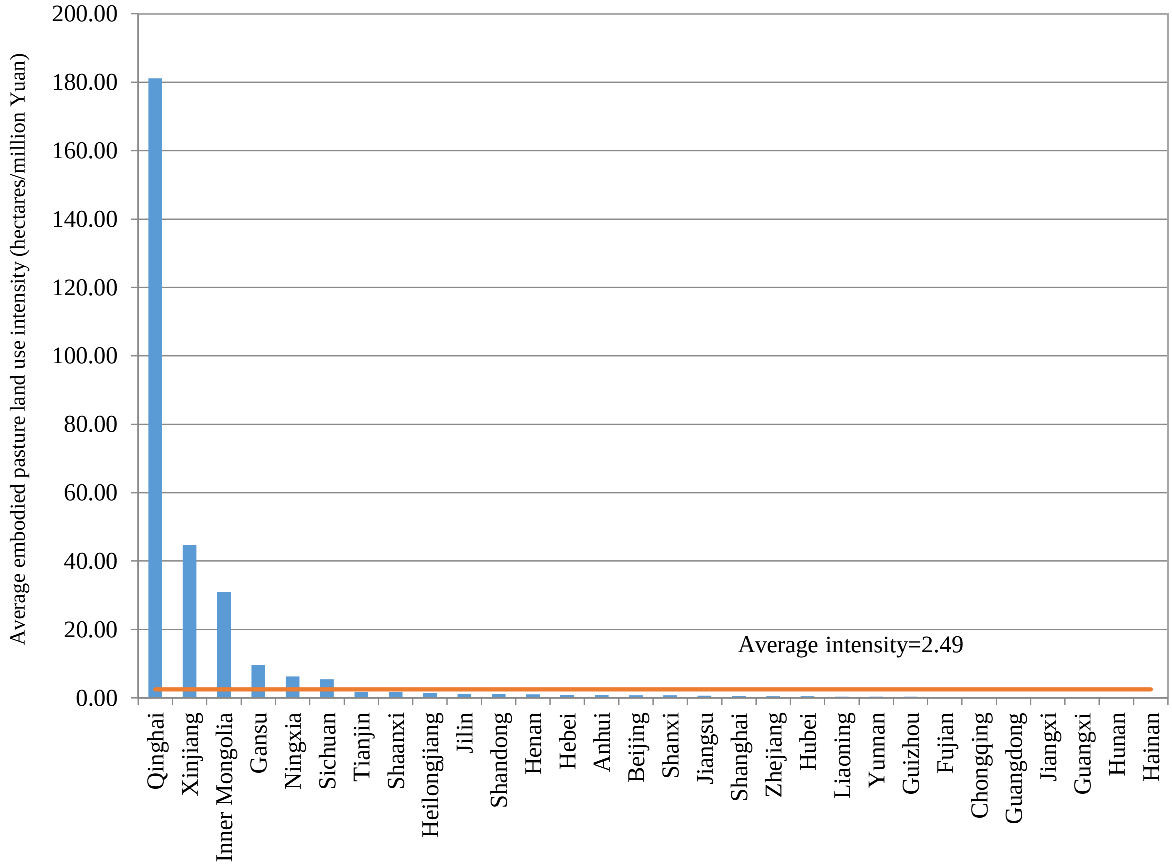


Figure 5.12 Regional embodied pasture land intensity

Figure 5.13 shows EPLC with a total value of 132.78 million hectares. From the regional perspective, Qinghai, Inner Mongolia, and Xinjiang are the three largest consumers of pasture land resources with values of 37.88, 24.69 and 15.02 million hectares that account for 28.57%, 18.59%, and 11.31%, respectively, of the total. These figures reflect their sufficient pasture land resources, i.e., 84.77% of pasture land resources are distributed among Inner Mongolia, Qinghai, and Xinjiang. The economy of these three regions is highly dependent on their pasture land resources. Their pasture land use efficiency per unit of economic output is relatively low.

The imbalance of pasture land supply and demand is also revealed by comparing the regional distribution of actual and embodied pasture land resources. Regions with rich pasture land resources, such as Qinghai, Inner Mongolia, and Xinjiang, consume a huge amount of resources by themselves but also export their own resources to other regions. Given that most regions in China have poor pasture land resources, they must absorb resources to meet their own consumption.

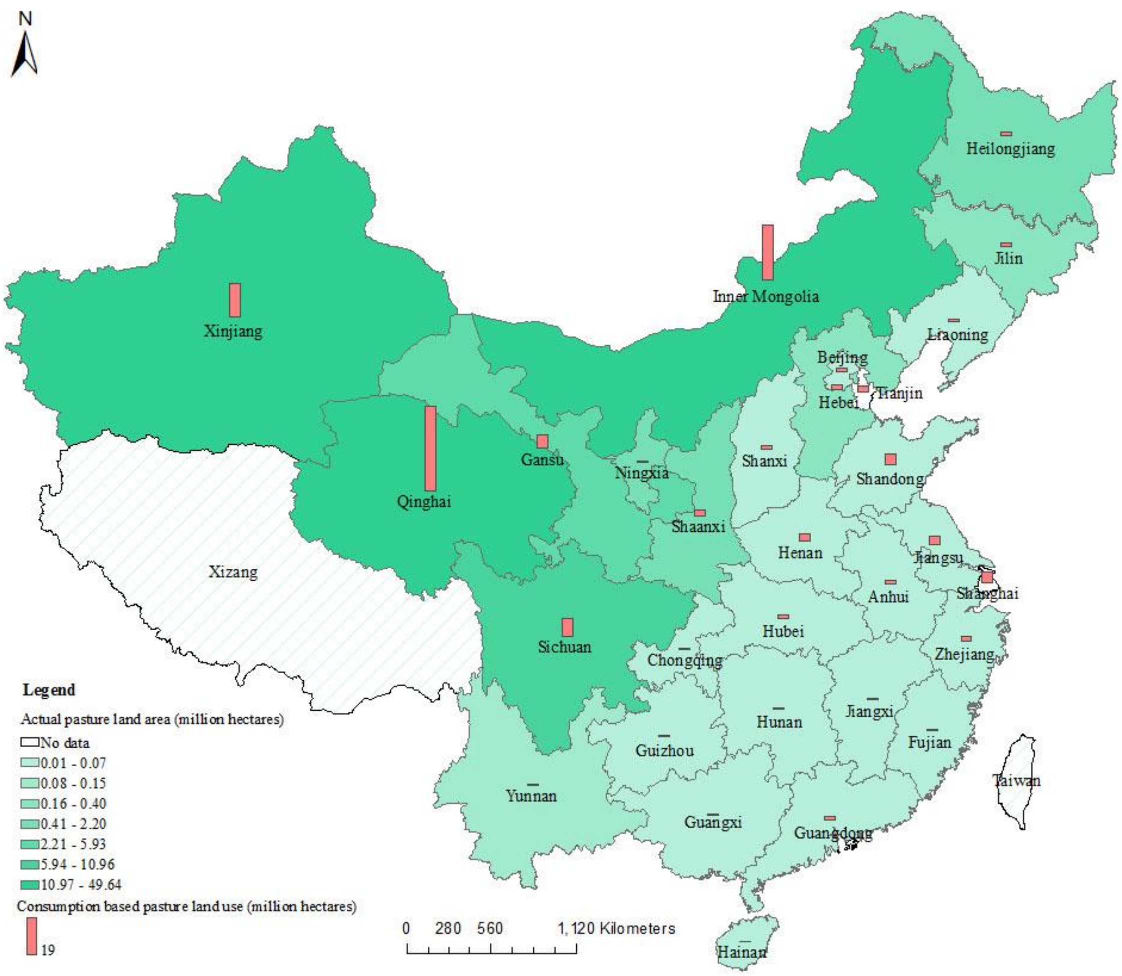


Figure 5.13 Pasture land use embodied in the final consumption

5.4.3 Regional transfer of virtual pasture land use

As presented in Figure 5.14, China is a net importer of pasture land. A total of 24 regions defined as pasture land resource suppliers have positive values, and only six regions defined as land resource receivers have negative values. Only the pasture land-intensive regions of Inner Mongolia, Xinjiang, Sichuan, Qinghai, Gansu, and Ningxia play the roles of suppliers of pasture land resources with net export values of 20.79, 16.55, 2.74, 2.44, 0.49, and 0.48 million hectares, respectively. All the remaining regions receive pasture land resources from these six regions through commodity trading.

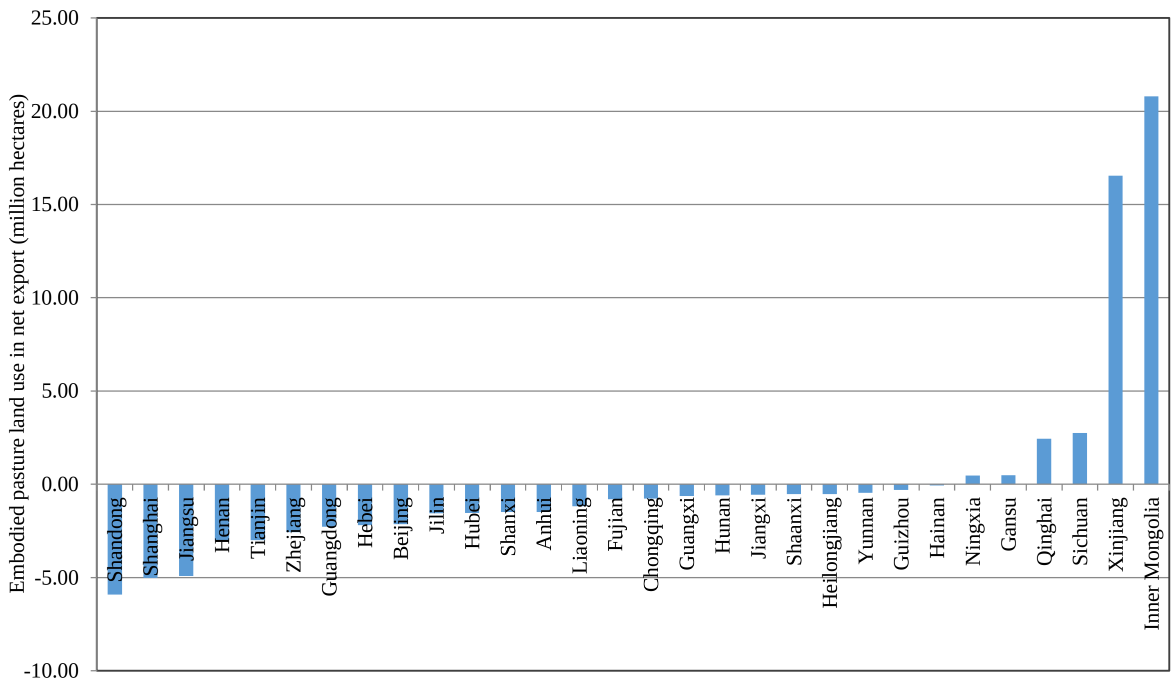


Figure 5.14 Pasture land embodied in trade balance

Figure 5.15 shows the major embodied pasture land flows in interregional trade with values exceeding 0.64 million hectares. These flows mainly come from two regions, namely, Xinjiang and Inner Mongolia. The largest interregional pasture land trading flow comes from Xinjiang to Shandong with a value of 3.06 million hectares. Compared with those of cultivated and forest land, the starting points of embodied pasture land flows are mainly concentrated in the pasture land-intensive regions of Xinjiang, and Inner Mongolia.

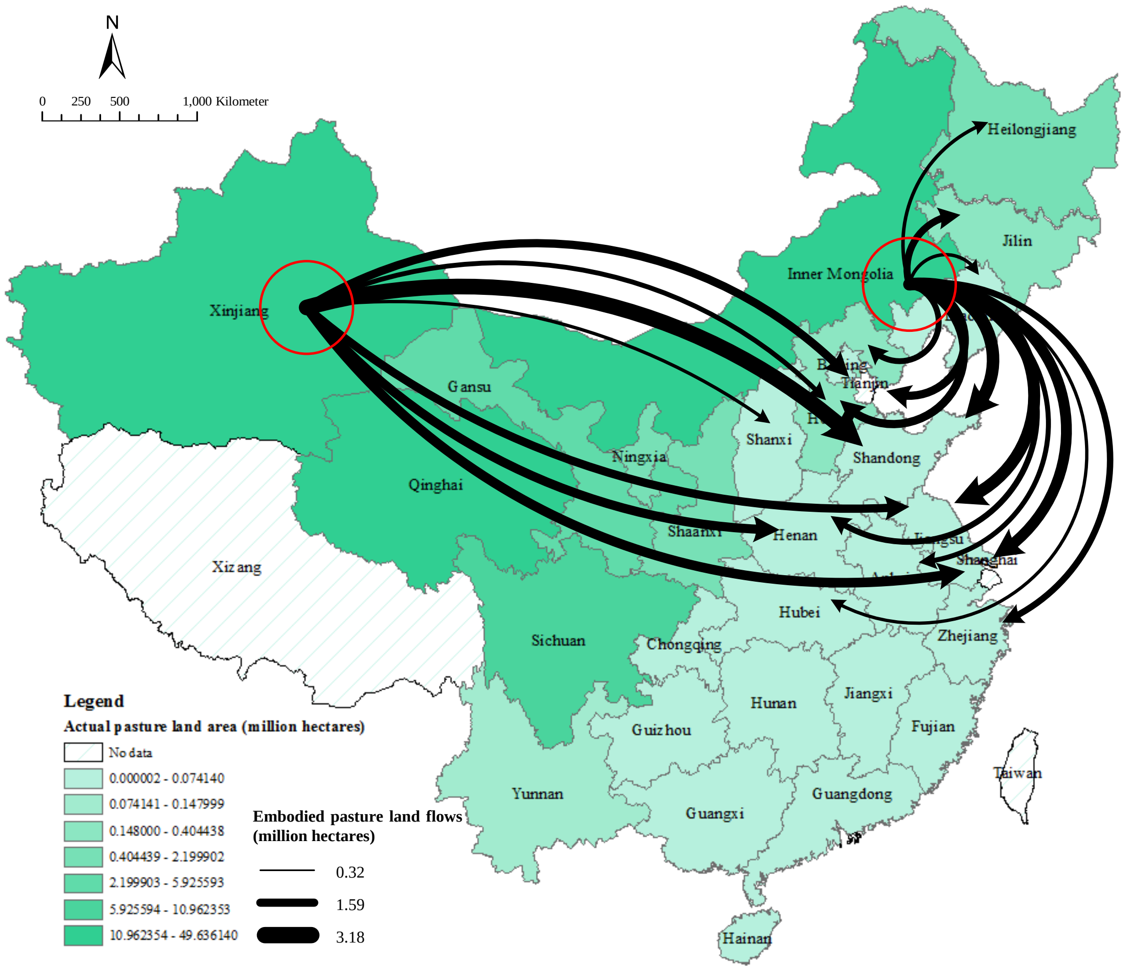


Figure 5.15 Major embodied pasture land flows in interregional trade

Note: The direction of arrow represents the embodied land flow direction and the width of arrow shows the size of the embodied land flow.

5.5 Construction land

5.5.1 Actual construction land cover distribution

In 2010, China has 35.68 million hectares of construction land, accounting for 5.22% of the total national land areas. As shown in Figure 5.16, Shandong, Henan, Jiangsu, Guangdong, Anhui, Hebei, Sichuan, Hunan, Hubei, Inner Mongolia, and Jiangxi have construction land use areas of over one million hectares. China's average per capita construction land use is 0.02 hectares/capita. Regions above the national average tend to be the undeveloped regions, such as Ningxia, Inner Mongolia, Qinghai, and Xinjiang, among others. The regions under the national average are mostly provinces with fast economic development and dense population.

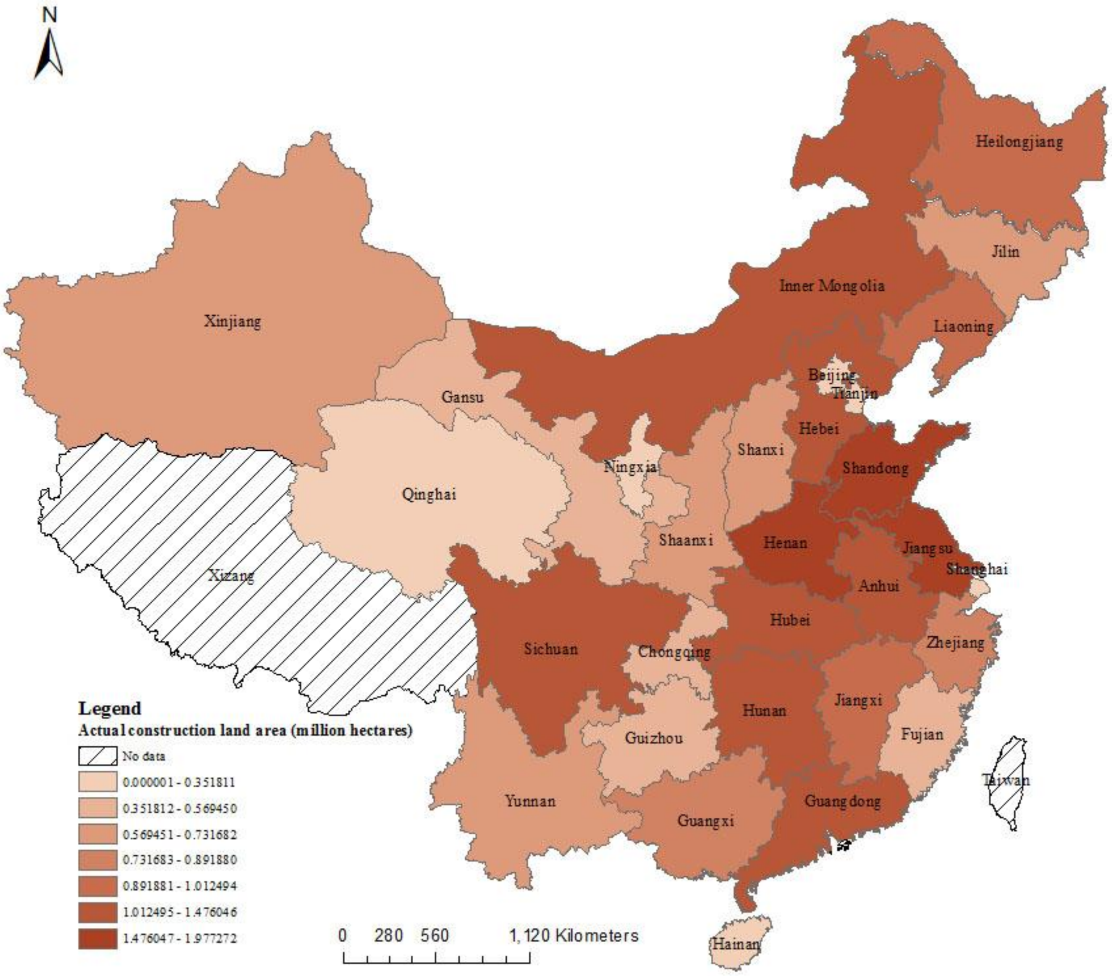


Figure 5.16 Proportion of construction land among the provinces in China

5.5.2 Regional virtual construction land footprint distribution

As shown in Figure 5.17, China's regional construction land use intensity shows the regional distribution. The national average embodied construction land intensity is 0.51 hectares/million Yuan. Only nine regions are below the national average, and 21 regions are above average. Moreover, intensity is negatively correlated with economic development. The top five regions with the highest intensities are Qinghai, Ningxia, Xinjiang, Gansu, and Inner Mongolia with values of 1.58, 1.48, 1.08, 1.02, and 0.86 hectares/million Yuan, respectively. The regions with the lowest intensities are Shanghai, Beijing, Tianjin, Zhejiang, and Guangdong with values of 0.21, 0.23, 0.32, 0.33, and 0.33 hectares/million Yuan, respectively.

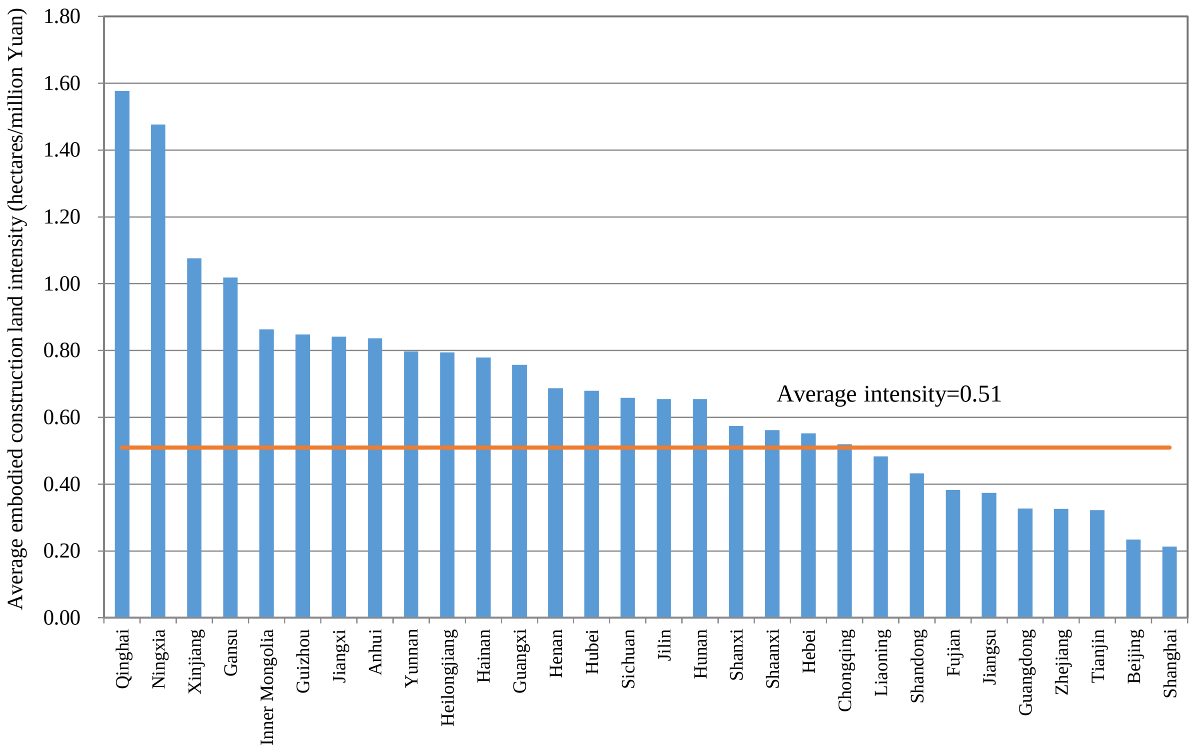


Figure 5.17 Regional embodied construction land intensity

Figure 5.18 shows ECoLC with a total value of 21.55 million hectares. From the regional perspective, Henan, Shandong, Jiangsu, Guangdong, and Sichuan have the largest values of 1.48, 1.44, 1.32, 1.24 and 1.08 million hectares, respectively, because of their sufficient construction land resources or high household consumption ability. Hainan, Qinghai, Ningxia, Beijing, and Guizhou have the smallest values of 0.15, 0.21, 0.29, 0.35, and 0.36 million hectares, respectively. Their few actual construction land resources or low consumption ability is attributed to their low population and less developed economy.

A positive correlation between actual and embodied construction land use is shown in Figure 5.18. For example, Shandong, Henan, Guangdong, Jiangsu, and Sichuan all have high values of actual and embodied construction land uses. Tianjin, Guizhou, Qinghai, Hainan, and Ningxia all have low actual and embodied construction land uses. The embodied construction land use means the total construction land resource consumption generated by the goods or services consumption within the targeted region. The regional distribution of the actual and embodied construction land use has a high consistency. Compared with other types of land use, such as cultivated, forest, and pasture land, the construction land use planning roughly achieves the supply–demand balance. The consistency can prove the rational allocation of construction land resources.

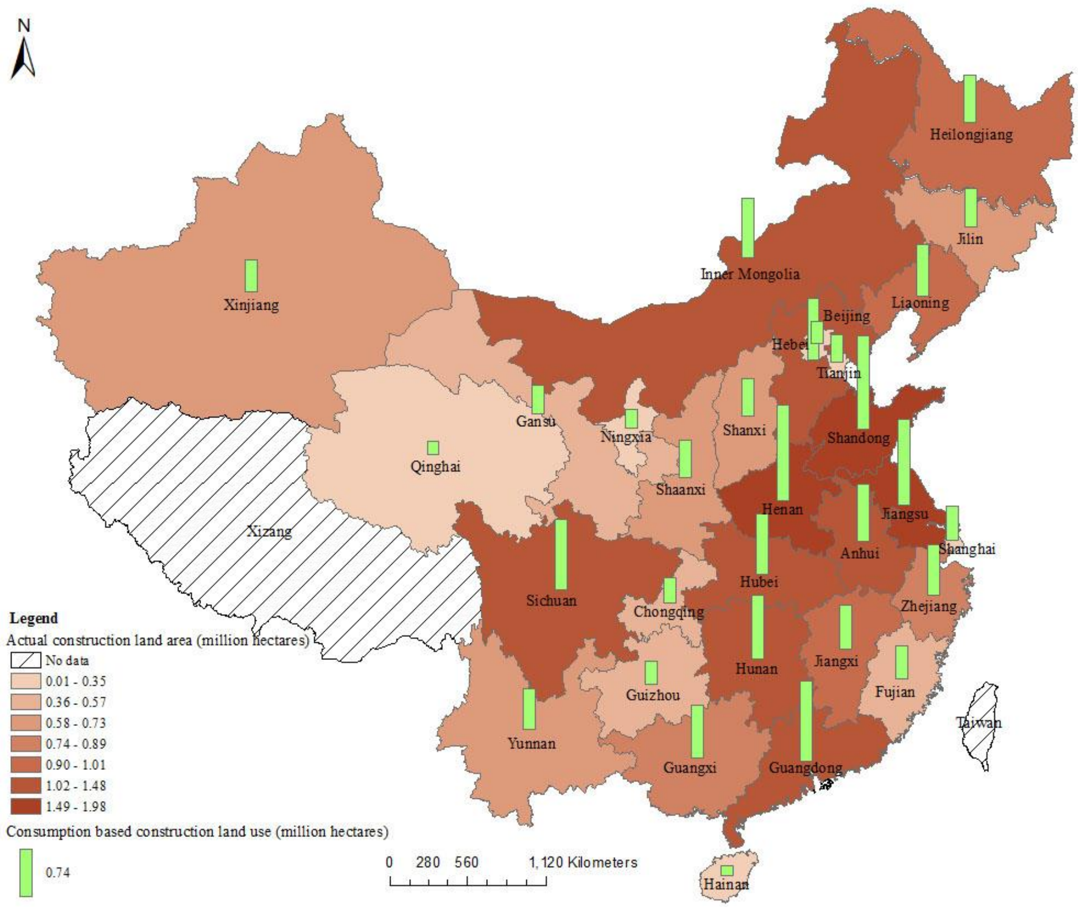


Figure 5.18 Construction land use embodied in the final consumption

5.5.3 Regional transfer of virtual construction land use

Figure 5.19 shows China's construction land embodied in trade balance. To create a clear comparison of the regional resource transfer, regions with positive values are defined as construction land resource suppliers, and regions with negative values are defined as land resource receivers. Guangdong, Shanghai, Zhejiang, Beijing, Jiangsu, Tianjin, Fujian, Yunnan, and Liaoning play the roles of construction land resource receivers. Other provinces are the suppliers of construction land resources. The developed regions in China have established the earliest platforms of trade-driven economy since the reform and opening up. To promote further development, these regions occupy substantial construction land resources of other regions outside of their boundaries through commodity trading resource. We observe that Hebei Province, which is located on China's east coast and has rich land resources, exports substantial land resources to other developed regions, such as Beijing (0.06 million hectares), Tianjin (0.05 million hectares), Shanghai (0.05 million hectares), Jiangsu (0.07 million hectares), and Zhejiang (0.06 million hectares). This finding can be attributed to the irrational industrial structure adjustment, such as the heavy industrial development in Hebei Province.

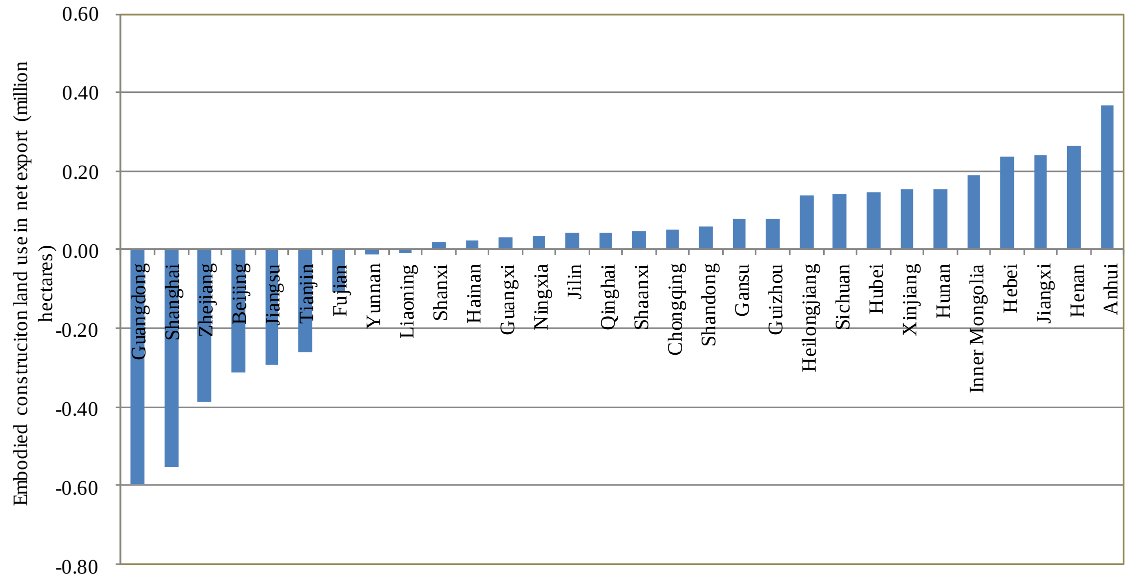


Figure 5.19 Construction land embodied in trade balance

Figure 5.20 shows the major embodied construction land flows in interregional trade with values exceeding 0.04 million hectares. Three economic regions of China with the most active trade activities attract a great deal of embodied land flows mainly derived from nearby provinces.

The GDP of the Yangtze River Delta is China's largest economic circle. Its total import and export volumes rank first in this country. Resource allocation is profoundly affected by economic flows along with the challenges caused by globalization. As the most developed region in China, the Yangtze River Delta mainly receives huge construction land flows from its neighboring provinces, such as Henan, Anhui, and Jiangxi. Topping the GDP ranking in China among the provincial regions, Guangdong also attracts huge embodied land flows from Guangxi, Hunan, and Yunnan. As China's two municipalities and the core of the Beijing–Tianjin–Hebei regions, Beijing and Tianjin receive a large number of construction land flows from Hebei and Inner Mongolia. The main characteristics of these three regions lie in their highly developed commodity economies and abundant construction land resources. Despite having substantial high-quality land resources, the three economic regions still occupy a certain amount of virtual land resources from neighboring regions to relieve the resource pressures caused by the rapid economic development.

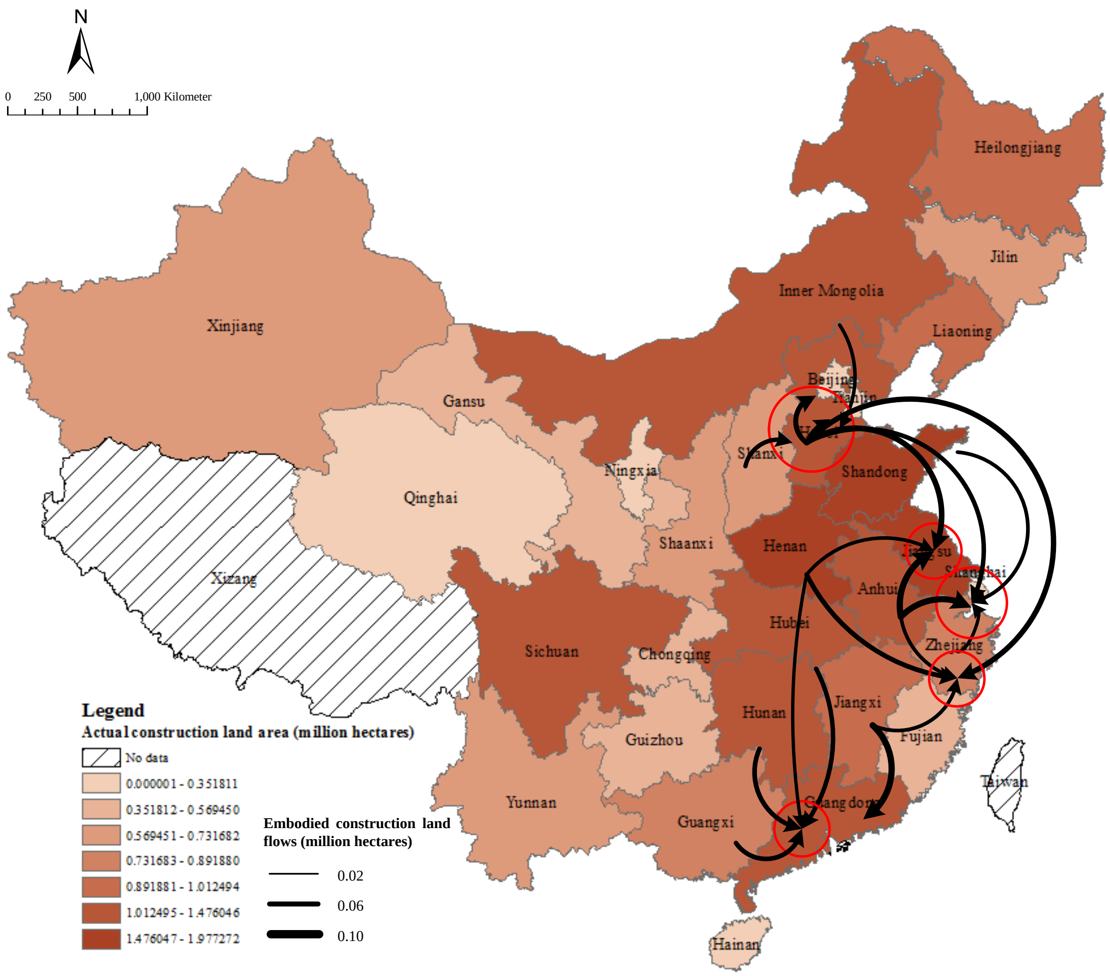


Figure 5.20 Major embodied construction land flows in interregional trade

Note: The direction of the arrow represents the embodied land flow direction and the width of the arrow shows the size of the embodied land flow.

5.6 Discussions and policy implications

This chapter initially considers the supply and demand of actual land use resources. The total share of 13 provinces with cultivated land areas of over 5 million hectares is 69.84%. This finding reflects the imbalance in the spatial distribution of the supply and demand of cultivated land. While for forest land resources, 9 provinces have forest land areas above 10 million hectares, and the share of forest areas of these 9 provinces accounts for 62.14% of the total. Provinces with few forest land resources are the developed regions, such as Shanghai, Tianjin, Jiangsu, and Beijing. The imbalance between supply and demand can also be observed by forest land. A total of 84.77% of pasture land resources are distributed among Inner Mongolia, Qinghai, and Xinjiang. Regions above China's average per capita construction land tend to be the undeveloped regions, such as Ningxia, Inner Mongolia, Qinghai, and Xinjiang. Regions under the national average are mostly provinces with fast economic development and a dense population.

The regional land footprint distributions are described in detail. Shandong, Heilongjiang, Henan, Jiangsu, and Inner Mongolia are the most important drivers of cultivated land consumption in China even though they have relatively few cultivated land resource endowments. Conversely, Hainan, Ningxia, Qinghai, Fujian, and Tianjin have minimum values. Yunnan, Sichuan, Inner Mongolia, Guangdong, and Guangxi consume the largest forest land resources; by contrast, Ningxia, Hainan, Tianjin, Beijing, and Anhui have the smallest values. Qinghai, Inner Mongolia, and Xinjiang are the three largest consumers of pasture land resources, and the economies of these three regions are highly dependent on their pasture land resources. Unlike those of cultivated, forest, and pasture land, the regional distribution of actual and embodied construction land is mostly consistent. The consistency can prove the rational allocation of construction land resources to roughly achieve the supply–demand balance.

The regional transfer of virtual land flows is observed. Cultivated land resources flow from Xinjiang, Heilongjiang, Jilin, and Inner Mongolia to Shandong, Jiangsu, Shanghai, and Zhejiang provinces, and flow from southern provinces to Guangdong. Forest land resources flow from Heilongjiang, Inner Mongolia, Ningxia, and Sichuan to Shandong, Jiangsu, and Shanghai provinces, and flow from neighboring southern provinces, such as Yunnan, Guangxi, Guizhou, Hunan, Hubei, and Jiangxi to Guangdong. The largest interregional forest land trading flow is from Heilongjiang to Shandong with a value of 2.10 million hectares. Pasture land resource flows mainly come from two regions, namely, Xinjiang in West China and Inner Mongolia in North China. Compared with cultivated and forest land, the starting points of embodied pasture land flows are mainly concentrated in pasture land-intensive regions, such as Xinjiang, Inner Mongolia, and Qinghai. The three economic regions of China with the most active trade activities attract a great deal of embodied construction land flows mainly derived from the nearby provinces.

The interregional cooperation policies based on the regional advantages should be emphasized based on the spatial nexus. It is appropriate for all regional governments to join forces so that more sustainable and effective measures can be established. Regions play the roles of either receivers (net land resource importers) or suppliers (net land resource exporters) of land resources. Receivers, like Shanghai, Guangdong, and Shandong, are capable of providing more economic and technical supports for both their own and other regions' developments as highly developed economies. Suppliers, like Heilongjiang, Inner Mongolia, and Xinjiang should focus on the improvement of production technology and resource utilization efficiency.

5.7 Chapter summary

An unbalanced regional resource distribution is observed in China. Additional land resources are occupied by undeveloped regions, and the developed regions have few land resources. The growing regional trade also increases the interweaving economic linkages among industries. This finding exacerbates the pressure on the spatial displacement of resources. This chapter identifies the spatial nexuses of China's four land use types and tracks the resources to their origin or location where they are utilized through a complex economic network. Specifically, actual land cover distributions are described, the regional land footprint distributions are identified, and the regional transfers of virtual land use are analyzed. The calculated results are expected to facilitate the creation of integrated sustainable land use decisions through optimizing industrial and regional trade structures, and allocating regional responsibility.

Chapter 6 Resource Nexus: Farm Land and Water Occupation of the Chinese Economy

6.1 Introduction

The environmental indicators generally interact and complement each other. Thus, recognizing the complex linkages and feedback of various resource usages and environmental impacts is significant. The resource nexus provides an integrated view to gain a better understanding of resource-related questions, which are difficult to answer using traditional approaches. The nexus between "land" and other resource items, such as "water," "energy," "greenhouse gas emissions," "climate change," and so on, has attracted significant attention. This study uses "land and water" as an example because they are the most typical items to elaborate the issue of "resource nexus." In this chapter, nexus thinking is employed to address the co-benefits of farm land and water use, as the two basic elements of land and water most significantly affect worldwide agricultural production activities (Hanjra and Qureshi, 2010; Lambin and Meyfroidt, 2011).

Agricultural production is currently exerting great pressure on farm land and water use in China due to rising food demands, which is caused by population growth, changes in dietary habit, and enhanced biofuel production (Rulli et al., 2013). Per capita farm land in China is only about 0.08 hectares, while per capita freshwater availability is less than 2000 m^3/year (Yang et al., 2009). Due to this unfavorable situation, studies concerning China's land and water resources have proliferated (Hubacek and Sun, 2001; Wang et al., 2012; Zhang and Anadon, 2014; Zhang et al., 2011b; Zhao et al., 2009). However, there have been no studies focusing on the mismatch of farm land and water resources in China with the aim of developing sustainable agriculture production and minimizing environmental risks. In terms of farm water use, irrigation water can be withdrawn from two different sources, i.e., surface/ground water and rainwater, defined as "blue water" and "green water" respectively (Hoekstra and Mekonnen, 2012). And, although blue water resources have been comprehensively studied (Biewald et al., 2014; Dong et al., 2014; Hoekstra and Hung, 2005; Zhang and Anadon, 2014), green water resources have received little attention despite their importance (Rost et al., 2008). Notably, 60%-70% of food produced worldwide is entirely dependent on green water (Rost et al., 2008). To fill this gap in the literature, this study simultaneously analyzes China's farm land as well as green and blue water uses.

The geographic distribution of China's farm land and water resources are unbalanced (Zhang and Anadon, 2014). Meanwhile, the ever-closer economic relationship among various industries in different regions through interregional trade exacerbates the pressure on resource displacement. The farm land and water-intensive commodities/services are generally consumed in economically developed regions, but produced in resource-rich regions. The issue of resource pressure transfer, as well as the total direct and indirect resource consumption in the whole supply chain, i.e. the embodied resource utilization, have attracted much attention in the environmental accounting field (Costello et al., 2011; Hertwich and Peters, 2009; Kanemoto et al., 2012). IOA is a useful tool to comprehensively clarify the interweaving economic linkages among industries, which facilitates the tracking of resources to their origin or to where they are utilized through a complex economic network (Larsen and Hertwich, 2009; Peters et al., 2011; Skelton et al., 2011). To take account of regional characteristics as well as industrial impacts, MRIO has been used to present the interactions among various industries within several associated economic regions (Wiedmann, 2009). Many studies have applied MRIO to analyze onefold resource endowment or pollution emissions (Lenzen, 2009; Liang et al., 2007; Su and Ang, 2014; Zhang et al., 2013; Zhang and Anadon, 2014; Zhou and Imura, 2011). However, the environmental indicators usually interact and complement each other. The significance of uncovering the nexus of different environmental factors in a complex social economy has been stressed in many studies (Apergis and Payne, 2010; Casillas and Kammen, 2010; Chen and Chen, 2014; Villarroel Walker et al., 2014). To monitor different aspects of human impact on the ecosystem, some researchers accessed different kinds of resource endowments simultaneously using an extended MRIO model (Ewing et al., 2012; Fang et al., 2014; Galli et al., 2013; Galli et al., 2012). For example, Ewing et al. (2012) harmonized the ecological footprint and water footprint using an environmentally extended MRIO model. Galli et al. (2013) developed an environmentally-extended MRIO model to group the footprint family under a common framework and combine the indicators in the family. These studies have conducted substantial theoretical explanations for the connections and interactions among various environmental impacts based on the MRIO model. The extended MRIO model provides a way for analysis and comparison of various indicators using a consistent assessment framework, which facilitate the decision-makers' understanding of the environmental impacts by assessing the combination of different environmental indicators (Ewing et al., 2012). They are considered to be meaningful to guide the policymaking about environmental impact mitigation strategies. Yet few practical cases have been analyzed to assess the environmental impacts comprehensively using the extended MRIO model. Like, Kjartan et al. (2012) took European Union as a case to identify its three interconnected and mutually influenced environmental pressures, including carbon emissions, appropriation of productive land, and freshwater use, caused by consumption based on an MRIO model. The lack of such studies limits our overall understanding of the integrated environmental pressures within a specified region.

As a large agricultural country, China's unbalanced distribution of farm land and water resources has raised many debates on the sustainability of agricultural production and resources utilization. There therefore needs to be a discussion on how China could better allocate farm land and water resources to meet unbalanced food demands and satisfy regional economic growth needs. Given the gap in current knowledge, this chapter simultaneously assess the farm land and water uses in China based on recent available data with regional and sectoral details (30 sectors within 30 regions) based on an MRIO model. A set of indicators are also proposed to reveal the regional and sectoral farm land and water use intensity, as well as the impacts of consumption and trade on regional farm land and water use. In addition to allocation under the land/water-demand requirements, agricultural policies can also be formulated to improve resource end-use efficiency and optimize industrial structure and regional trade structure.

6.2 Data and method

Data collected in this chapter include economic data, farm land use data, and farm water use data. This chapter also adopted the MRIO table compiled by researchers from the Chinese Academy of Science and China's National Bureau of Statistics (Liu et al., 2012), which includes 30 provinces with 30 sectors and is based on 30 SRIO tables and the calculated interregional trade matrixes using the gravity model (Liu et al., 2012; Zhang et al., 2013).

The farm land use data for 30 regions in China is obtained from China Land and Resources Statistical Yearbook 2008 (MLR, 2008). Despite being a relatively small proportion of total available land, farm land is the main focus of research due to its important role in food production and thereby in survival of the human species (Gibbs et al., 2010; Qiang et al., 2013).

Crops can only directly use soil water, which is composed of blue water, i.e. the surface water and ground water used for farm land irrigation, and green water, i.e. the rainwater stored in the soil supplied to crops (Mekonnen and Hoekstra, 2011). These are the two forms of water either diverted or withdrawn. However, water use in this study refers to water consumption, meaning that the withdrawn water is incorporated by the crops. Therefore, the total farm water use in this study is defined as the total water consumption of blue and green water for crop production. To collect the required blue and green water data, China Environmental Statistical Yearbook (NBS and MEPC, 2008), the Yearbook of China Water Resources (Yang, 2008), China's Water Resources Bulletin (CMWR, 2007), and China's Agricultural Water Use Report (Li and Peng, 2009) are referenced. The detailed database of direct blue and green water used for farm land in 30 regions across mainland China is obtained from China's Agricultural Water Use Report (Li and Peng, 2009). The water resources statistics in China can be classified as agricultural water, industrial water, household and service water, and eco-environment water. Agricultural water use accounted for 61.86% of China's total water use (NBS and MEPC, 2008), while 90~95% of agricultural water was used for farm land irrigation (Li and Peng, 2009), These proportions provide a basis for blue water estimation, while green water use is based on regional precipitation in farm land areas and the water seepage into groundwater (Li and Peng, 2009). Although the estimation procedures are crude, they provide the most detailed temporal and spatial farm water resource data that distinguishes between blue and green water.

The mismatch between regional farm land and water use is shown in Table 6.1. The national total farm land area is 122.00 million hectares, with 9.72% of it (11.80 million hectares) in Heilongjiang, followed by Henan, Shandong, Inner Mongolia and Hebei with farm land areas of 7.93, 7.51, 7.15 and 6.32 million hectares accounting for 6.51%, 6.17%, 5.87% and 5.19%, respectively. The total farm water is 756 billion m^3 and consists of two parts, i.e., green water and blue water, accounting for 57.01% and 42.99%, respectively. Due to the differences in climate conditions and resource endowments, there is an uneven distribution of regional blue water and green water uses. Especially, the green water in Xinjiang is only 3.14 billion m^3, far lower than the blue water of 38.00 billion m^3. This can be explained by the fact that Xinjiang is located in the semiarid area of China with low precipitation, but rich in water resources due to the large ice reserves. In terms of the total farm water use, Heilongjiang, Jiangsu, Shandong, Henan and Guangxi make the largest contributions with volumes of 48.60, 47.30, 47.00, 43.00 and 41.50 billion m^3, accounting for 6.43%, 6.25%, 6.22%, 5.68% and 5.49%, respectively. To reflect the land-water-matching sensitivity, the indicator of water use per farm land area is proposed in this study. The water consumption per farm land area in the southern coastal provinces is relative larger (such as Fujian, Shanghai, Hainan and etc.), because more water-efficient crops, like corn and rice, are mostly planted in southern China. In contrast, the northern provinces (such as Inner

Mongolia, Gansu, and Heilongjiang) use less water per farm land area since large areas of low water-use crops, like wheat, are grown in these regions.

Table 6.1 Direct farm land and water use by region (Li and Peng, 2009)

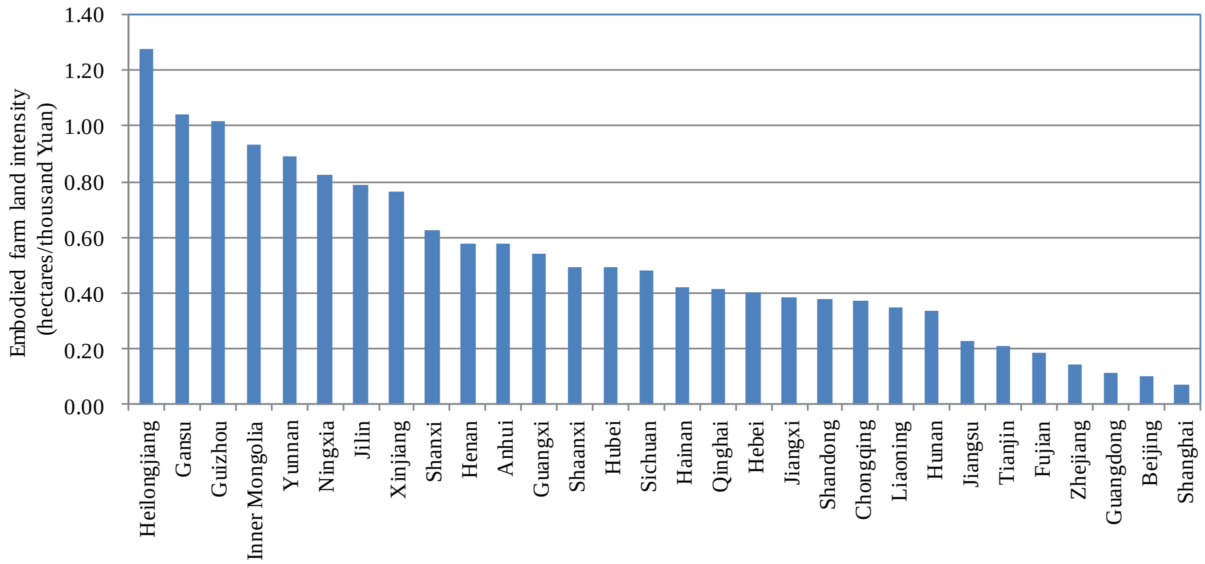
Region	Farm land use		Farm water use				Water use per farm land area
			Green water	Blue water	Total	%	
	million hectares	%	billion m^3				thousand m^3/hectares
National total	**122.00**	**100**	**431.00**	**325.00**	**756.00**	**100**	**6.20**
Beijing	0.23	0.19	0.74	0.83	1.57	0.21	6.77
Tianjin	0.44	0.36	1.50	1.36	2.85	0.38	6.42
Hebei	6.32	5.19	19.40	14.20	33.60	4.45	5.32
Shanxi	4.05	3.33	14.90	3.31	18.20	2.4	4.49
Inner Mongolia	7.15	5.87	9.33	12.80	22.20	2.93	3.10
Liaoning	4.09	3.36	14.10	8.81	22.90	3.03	5.60
Jilin	5.54	4.55	15.20	6.46	21.70	2.87	3.92
Heilongjiang	11.80	9.72	27.70	20.90	48.60	6.43	4.12
Shanghai	0.26	0.21	1.37	1.53	2.90	0.38	11.15
Jiangsu	4.76	3.91	23.40	23.90	47.30	6.25	9.94
Zhejiang	1.92	1.58	10.20	8.74	19.00	2.51	9.90
Anhui	5.73	4.71	29.40	11.40	40.90	5.4	7.14
Fujian	1.33	1.1	6.93	9.54	16.50	2.18	12.41
Jiangxi	2.83	2.32	12.90	14.70	27.60	3.65	9.75
Shandong	7.51	6.17	32.50	14.50	47.00	6.22	6.26
Henan	7.93	6.51	31.90	11.10	43.00	5.68	5.42
Hubei	4.66	3.83	21.20	12.10	33.30	4.41	7.15
Hunan	3.79	3.11	16.30	19.10	35.30	4.67	9.31

Region	Farm land use		Farm water use				Water use per farm land area
			Green water	Blue water	Total	%	
	million hectares	%	billion m^3				thousand m^3/hectares
Guangdong	2.85	2.34	12.30	18.70	31.10	4.11	10.91
Guangxi	4.21	3.46	22.20	19.30	41.50	5.49	9.86
Hainan	0.73	0.6	4.51	2.94	7.45	0.99	10.25
Chongqing	2.24	1.84	7.45	1.68	9.13	1.21	4.08
Sichuan	5.95	4.89	18.40	11.30	29.70	3.92	4.99
Guizhou	4.49	3.69	19.20	4.82	24.00	3.17	5.35
Yunnan	6.07	4.99	28.70	10.10	38.90	5.14	6.41
Shaanxi	4.05	3.33	15.20	5.03	20.20	2.67	4.99
Gansu	4.66	3.83	7.89	9.03	16.90	2.24	3.63
Qinghai	0.54	0.45	0.87	1.77	2.64	0.35	4.87
Ningxia	1.11	0.91	1.73	5.78	7.52	0.99	6.77
Xinjiang	4.11	3.38	3.14	38.00	41.10	5.43	10.00
Tibet	0.36	0.3	0.51	1.43	1.95	0.26	5.40

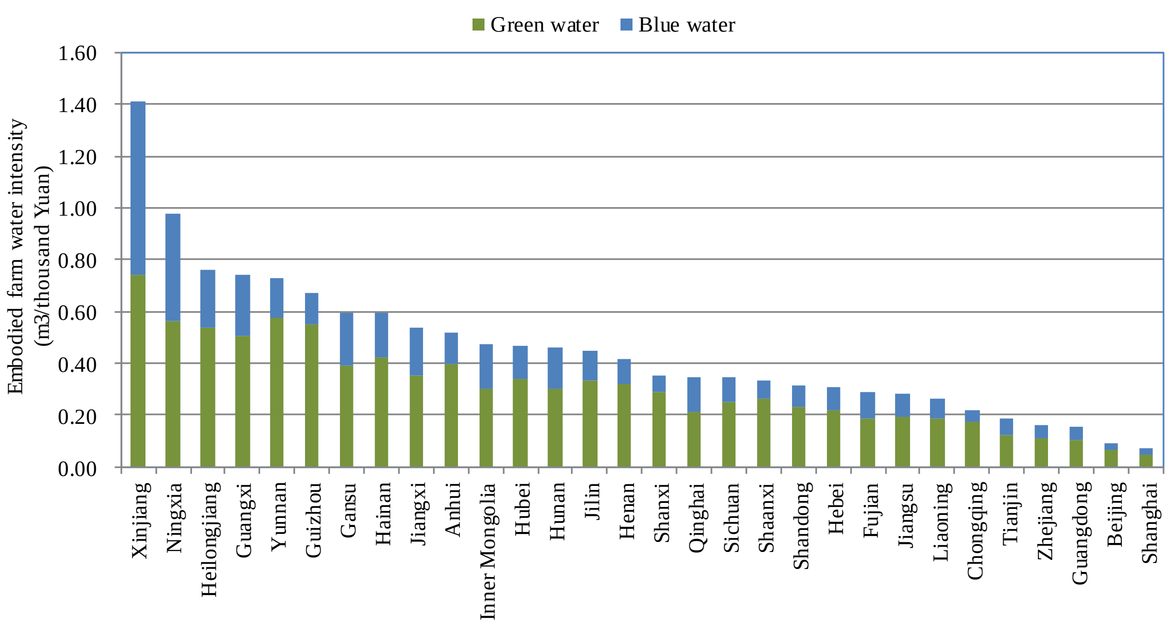
The MRIO model is used to analyze the farm land and water use associated with China's interregional trade network simultaneously. This can facilitate the policymakers to compare farm land and water using a consistent assessment framework. The algorithm design and indicator identification are the same with Section 3.3. Therefore, a duplicate description of algorithm and indicator will be not given here.

6.3 Land-water nexus

6.3.1 Farm land and water use intensity



(a) Farm land



(b) Farm water

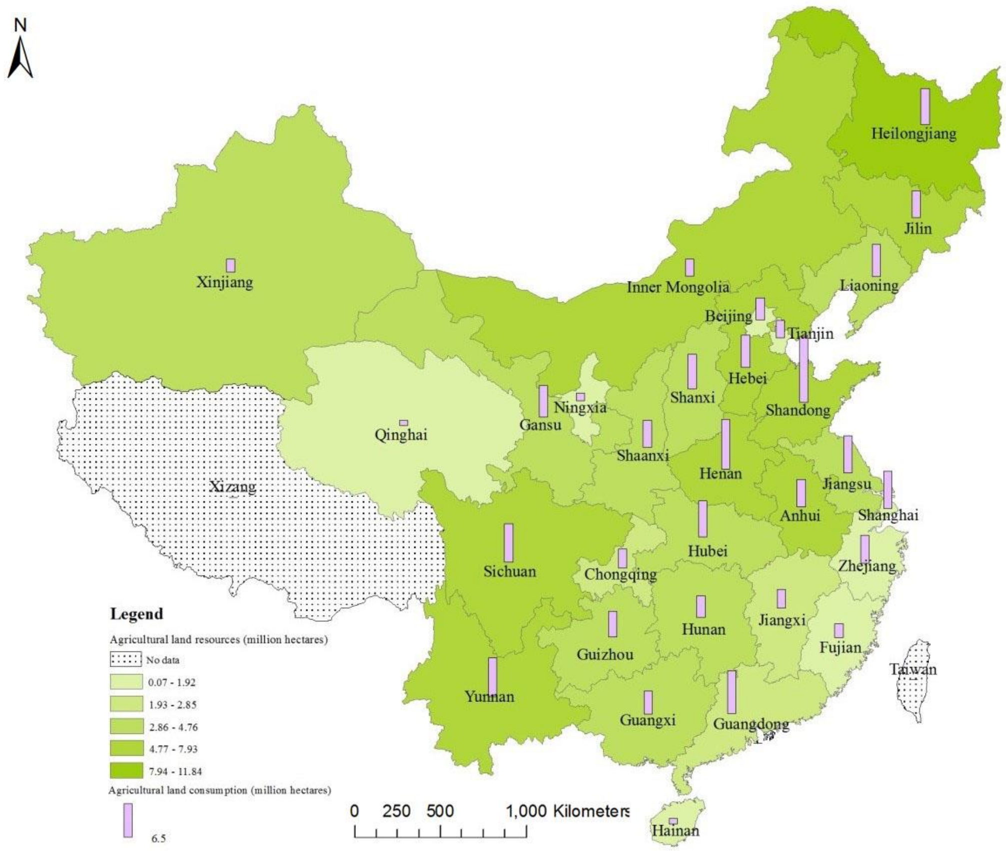
Figure 6.1 Farm land and water use intensity

Note: Regional embodied farm land intensity (a), and regional embodied farm blue and green water intensities (b).

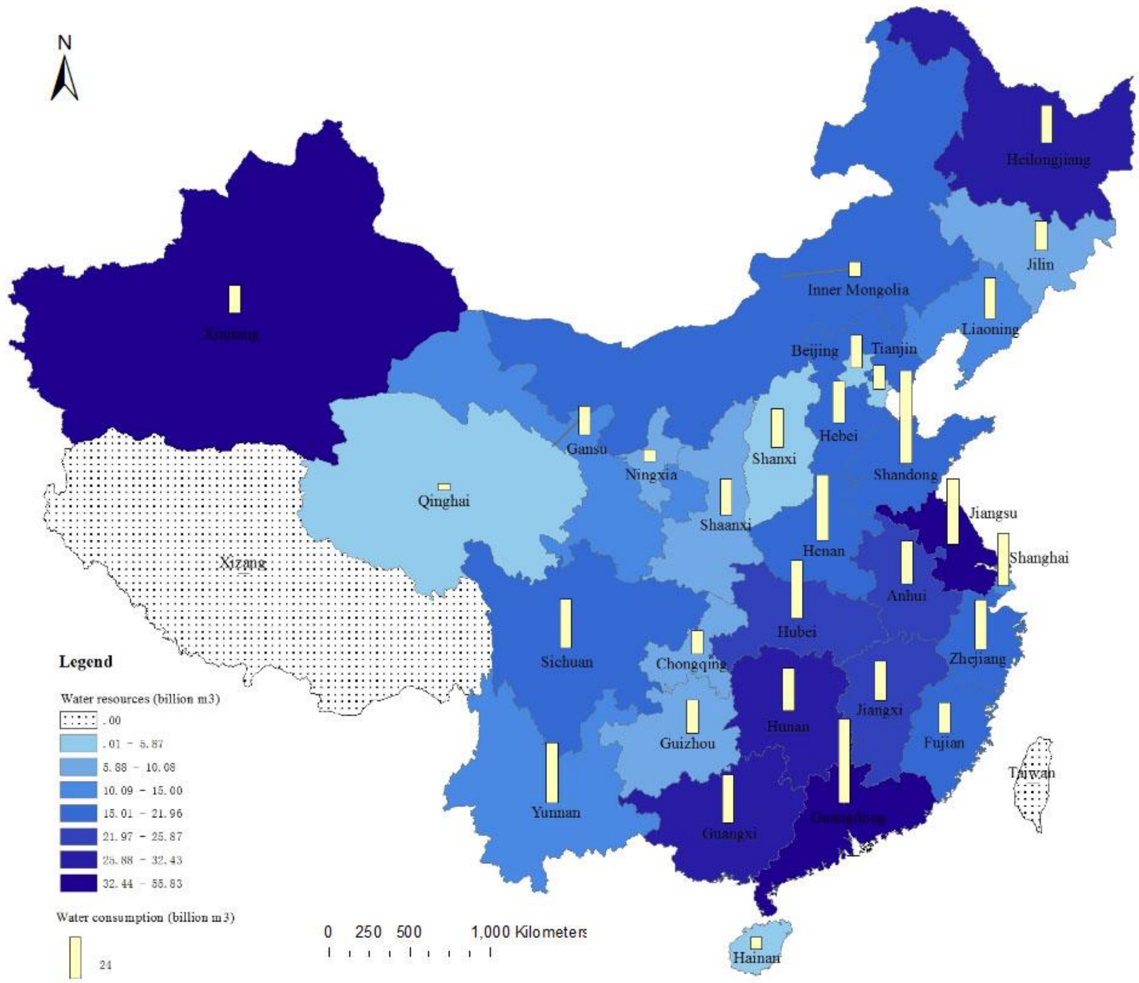
Comparing the regional resource use intensity in China as shown in Figure 6.1, the following can be observed: there is a remarkable spatial distribution discrepancy among the 30 provinces; the resource use intensity is negatively correlated with the economic level: most undeveloped provinces have higher farm land and water use intensity, i.e., higher resource costs, compared to the relatively developed provinces; the top 5 regions with the highest farm land use intensity are Heilongjiang, Gansu, Guizhou, Inner Mongolia and Yunnan with values of 1.28, 1.04, 1.02, 0.93 and 0.89 hectares/thousand Yuan respectively, most of which are undeveloped provinces; the developed provinces of Fujian, Zhejiang, Guangdong, Beijing and Shanghai, have the lowest farm land use intensity with values of 0.18, 0.14, 0.11, 0.10 and 0.07 hectares/thousand Yuan respectively; Xinjiang, Ningxia, Heilongjiang, Guangxi and Yunnan are the top five in water use intensity with values of 1.41, 0.98, 0.76, 0.74 and 0.73 m^3/Yuan respectively, while Tianjin, Zhejiang, Guangdong, Beijing and Shanghai have much lower water use efficiencies ranging from 0.19 to 0.07 m^3/Yuan.

The average China's farm land and water use intensity is 0.36 hectares/thousand Yuan and 0.32 m^3/Yuan, respectively. As for the blue and green water, the average green water use intensity in China is 0.22 m^3/Yuan, which is higher than the blue water of 0.10 m^3/Yuan. This shows the important role that green water plays in maintaining agricultural sustainable development.

6.3.2 Farm land and water use embodied in regional consumption



(a) Farm land



(b) Farm water

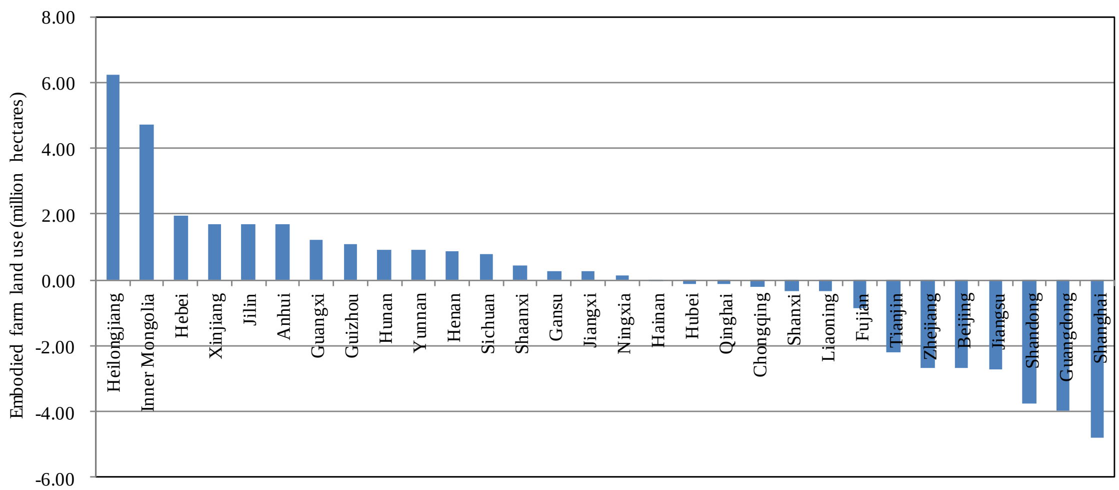
Figure 6.2 Farm land and water use embodied in final consumption

Note: The graduated colors represent the actual farm land/water use and the bars show the embodied farm land/water use. The relationship of actual vs. embodied farm land/water use is also revealed.

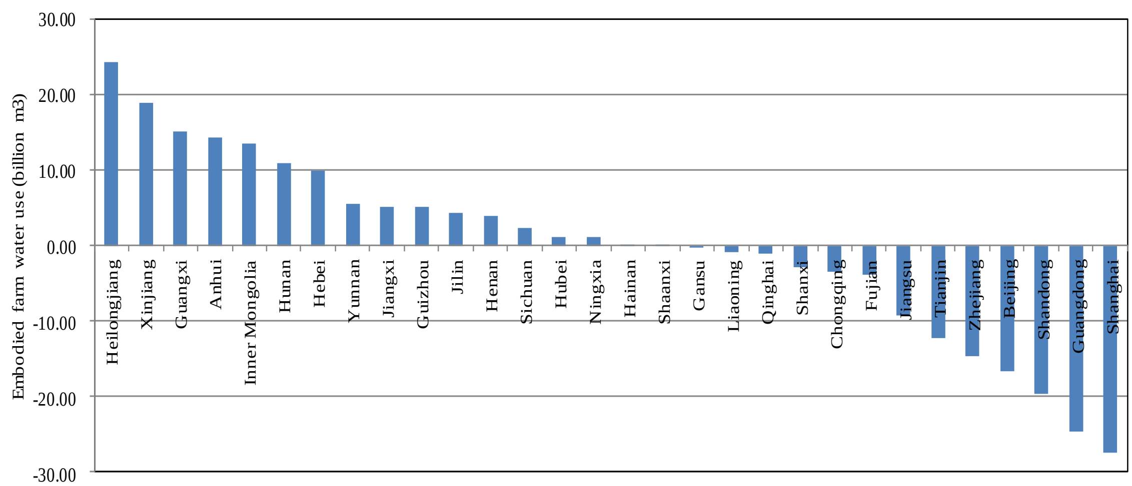
Figure 6.2(a) shows the geographical distribution of China's farm land use embodied in consumption (FLEC) with a total FLEC of 101.24 million hectares. Shandong, Henan, Guangdong, Yunnan and Sichuan have the largest FLEC of 8.09, 6.02, 5.18, 4.78 and 4.69 million hectares respectively. Together these five provinces account for 28.41% of China's total FLEC. The populous provinces of Shandong, Henan, Guangdong and Sichuan all have higher household consumption, which leads to higher virtual farm land consumption. Due to higher farm land use intensity, Yunnan also makes a great contribution to virtual farm land consumption. In contrast, Fujian, Xinjiang, Ningxia, Qinghai and Hainan have the smallest FLEC at 1.70, 1.62, 0.89, 0.65 and 0.64 million hectares respectively. The undeveloped regions of China, including Xinjiang, Ningxia, Qinghai and Hainan, have some similar characteristics, such as low level of household consumption and undeveloped economic status. Although Fujian is located on the eastern coast, it consumes less virtual farm land resources owing to its lower farm land use intensity. Figure 2(a) also reveals the relationship of actual vs. embodied farm land use. There is no significant correlation between actual and embodied farm land use. The embodied farm land use is the total (including direct and indirect) resource consumption in a targeted region, and reflects the total demand of farm land resources generated by the commodities consumed by the targeted region. Actual farm land use refers to the actual land resources could be used for crop production within a targeted region. This indicator could reveal the land resources supply capacity of this targeted region. Therefore, the mismatch of actual and embodied farm land use also shows the land resource demand-supply imbalance.

Presented in Figure 6.2(b) is the spatial distribution of farm water use embodied in consumption (FWEC) and the total value of FWEC in China is 623.69 billion m^3. There is a great similarity between the distribution of FLEC and FWEC, since both of them are deeply influenced by China's economic structure. Shandong, Guangdong, Jiangsu, Henan and Yunnan are the leading FWEC regions with values of 47.54, 42.96, 33.64, 33.47 and 30.79 billion m^3 respectively. While Chongqing, Inner Mongolia, Hainan, Ningxia and Qinghai are the regions with the minimum FWEC values of 11.90, 75.37, 63.30, 59.67 and 34.19 billion m^3 respectively. The results show that WEC is positively correlated to the economic development level, which can be measured by GDP. Figure 2(b) also clarifies the relationship between FWEC and actual farm water use. Similar to farm land resources, the distribution of FWEC in not consistent with the actual farm water use, which demonstrates an unbalanced water resource demand-supply situation.

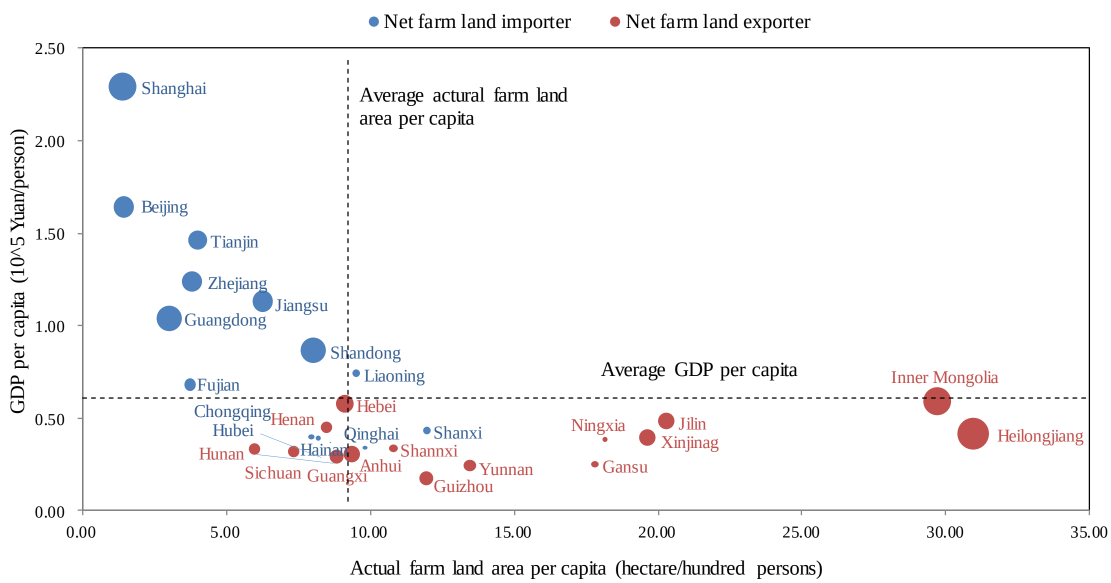
6.3.3 Farm land and water use embodied in interregional trade



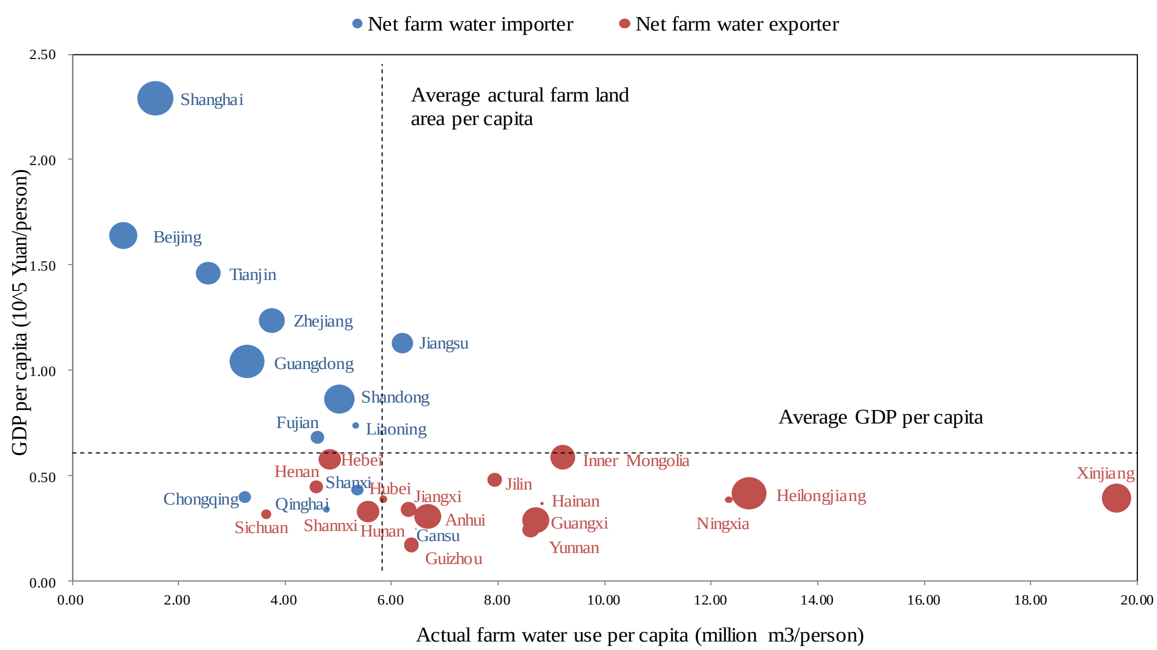
(a) Farm land



(b) Farm water



(c) Farm land



(d) Farm water

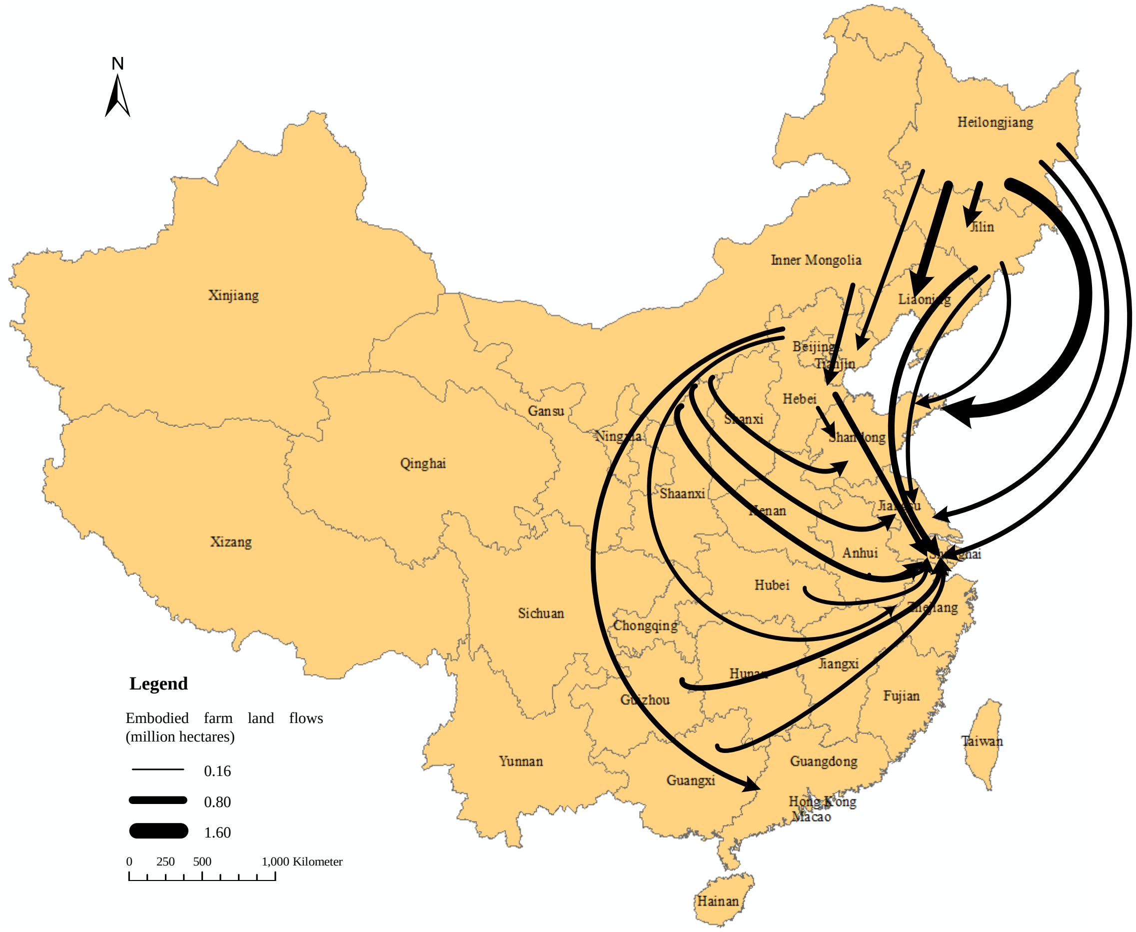
Figure 6.3 Farm land and water use embodied in international trade

Note: Farm land embodied in trade balance (a), farm water embodied in trade balance (b), relationships among actual farm land use per capita, GDP per capita and farm land trade balance (c), and relationships among actual farm water *use per capita, GDP per capita and farm water trade balance (d). Sizes of the dots represent the net importing or exporting values.*

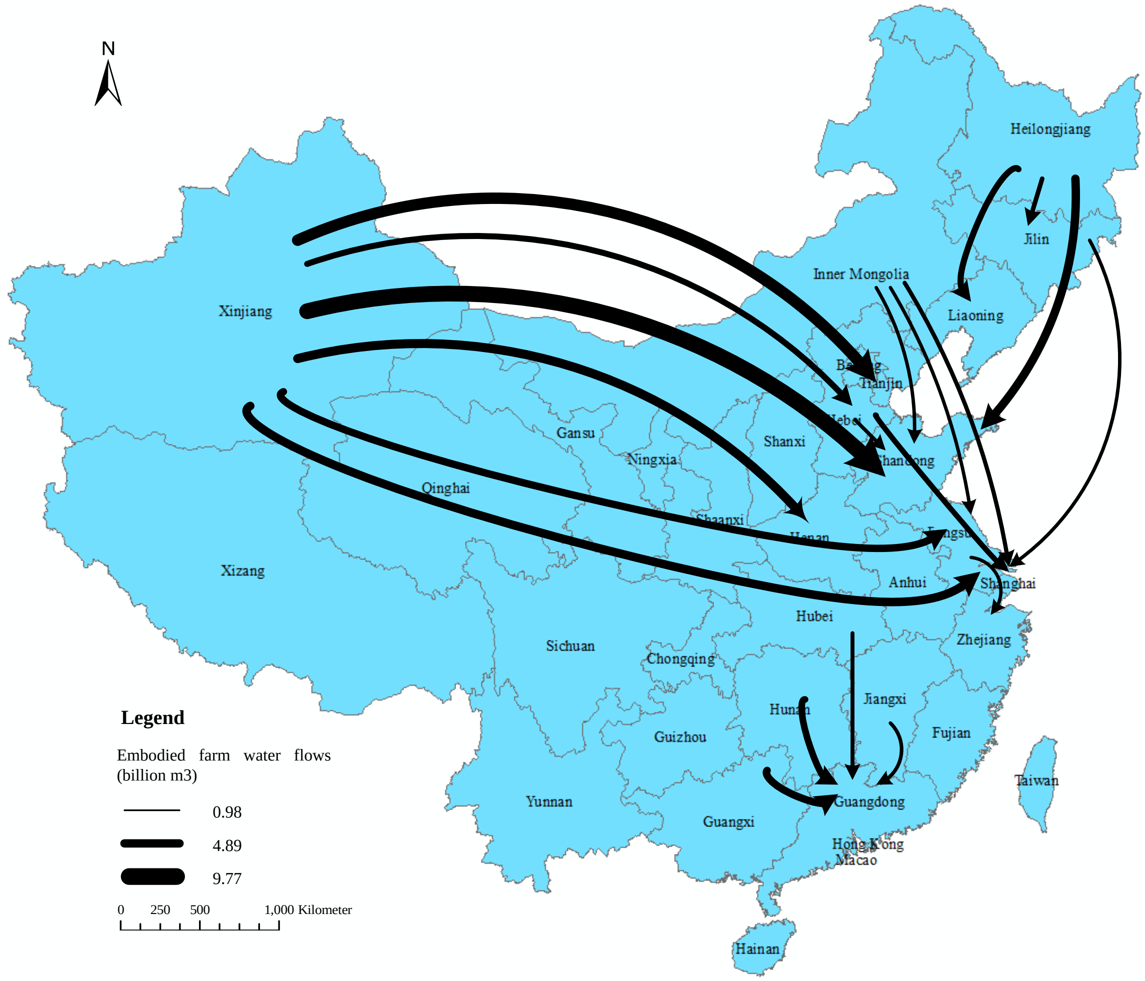
The distribution of embodied farm land and water in the trade balance is shown in Figure 6.3(a) and 6.3(b). The 30 provinces can be categorized into two groups, i.e. the regions with positive values of resources embodied in trade balance (REB) are net resource exporters, and regions with negative values are net resource importers. In terms of land resources embodied in trade balance (FLEB), there are 14 regions as exporters and 16 regions as importers. The top five largest net exporters of FLEB are Heilongjiang, Inner Mongolia, Hebei, Xinjiang and Jilin with embodied farm land overshoots of 6.25, 4.72, 1.94, 1.71 and 1.71 million hectares respectively. By contrast, Shanghai, Guangdong, Shandong, Jiangsu and Beijing are the top five importers of FLEB, with the embodied farm land deficits of 4.82, 3.99, 3.78, 2.72 and 2.70 million hectares respectively. The spatial distribution of farm water embodied in trade balance is very similar to the spatial distribution of farm land. Thirteen regions are embodied farm water exporters and seventeen regions are embodied importers. The largest exporter of water resources embodied in trade balance (FWEB) is Heilongjiang with embodied farm water overshoots of 24.33 billion m^3, followed by Xinjiang (18.96 billion m^3) Guangxi (15.10 billion m^3), Anhui (14.29 billion m^3) and Inner Mongolia (13.47 billion m^3). While for the importers of WEB, Shanghai is the largest with embodied farm water deficits of 27.37 billion m3, followed by Guangdong (24.54 billion m^3), Shandong (19.53 billion m^3), Beijing (16.67 billion m^3) and Zhejiang (14.61 billion m^3).

The driving forces of the embodied resource trade balance include the physical resource occupation (which can be measured by actual resource usage per capita) and economic flows (which can be measured by GDP per capita). Figure 6.3(c) and 6.3(d) reveal the casual relationships between actual resource usage per capita, GDP per capita and embodied resource trade volumes. To clearly show the resource- and economy-oriented characteristics of net resource importers or exporters, two lines are added to indicate "average actual resource use per capita" and "average GDP per capita". Regions under the line of "average GDP per capita" are referred as "less-developed regions", while those above this line are "more-developed regions". Regions under the line of "average actual farm land/water use per capita" are considered as "resource-poor regions", while those above this line are "resource-rich regions". Therefore, it can be concluded that the net resource exporters are generally the resource-rich and less-developed regions, such as Heilongjiang, Inner Mongolia, Xinjiang, Jilin, and Ningxia. While the net resource importers are mostly the resource-poor and more-developed regions, like Shanghai, Beijing, Tianjin, Zhejiang, and Guangdong. When both the environmental and economic conditions reach the national average levels basically, i.e., around the intersection of the two lines in each figure, the embodied resource trade balance is relatively stable.

Another remarkable phenomenon is that some resource-poor and less-developed regions, such as Sichuan, Henan and Hunan, still develop their economies at the expense of their own resources, despite the lack of natural capitals. Thus, policymakers in these regions should reconsider their development plans by encouraging less-resource-intensive industries and formulate the sustainable development mode avoiding the excessive consumption of local resources.


N
Heilongjiang
Jilin
Inner Mongolia
Liaoning
Xinjiang
Beijing
Tianjin
Hebei
Gansu
Shanxi
Ningxia
Shandong
Qinghai
Shaanxi
Jiangsu
Henan
Xizang
Anhui
Shanghai
Hubei
Sichuan
Zhejiang
Chongqing
Jiangxi
Hunan
Legend
Guizhou
Fujian
Embodied farm land flows (million hectares)
Taiwan
Yunnan
Guangdong
0.16
Guangxi
0.80
Hong Kong
Macao
1.60
0 250 500 1,000 Kilometer
Hainan

(a) Farm land



(b) Farm water

Figure 6.4 Major embodied farm land and water flows in interregional trade

Note: The direction of arrow represents the embodied resource flow direction and the width of arrow shows the size of the embodied resource flow.

Figure 6.4 shows the major embodied farm land and water flows in interregional trade, with the amounts exceeding a million hectares and a million m^3 respectively. Specific to regions, Heilongjiang and Inner Mongolia have a considerably high land supply. The counterparts to these land surpluses are the deficits in Shandong, Jiangsu and Shanghai. The largest interregional farm water trading flow is from Heilongjiang to Shandong with a value of 1.36 million hectares. Xinjiang, Heilongjiang and Inner Mongolia also contribute a massive amount of water resources through interregional trade flows; Guangdong and Shanghai are two of the recipients of these water surpluses. The embodied farm water flux from Xinjiang to Shandong has a maximum flow of 3.92 billion m^3. It is worth noting that the Yangtze River Delta and Pearl River Delta attract huge resource flows as the main hubs of China's economic development, which depend highly on the country's land and water resources.

The South-to-North Water Diversion Project aims to transfer the water in Yangtze River in South China to the more arid and industrialized north. From the perspective of embodiment of water resources, although the north borrows a massive amount of physical water from the south, the farm water is eventually re-transferred to the south in the shape of virtual water flows through commodity trading (Zhang and Anadon, 2014). That it, water consumption in southern China is partly responsible for the demand for water from northern China.

6.4 Discussions and policy implications

6.4.1 Relations and differences of China's farm land and water use

Nexus is a metaphor to depict the economic and environmental flows interconnected and intertwined within a complex social economy. Identifying the connections between resource consumption and economic activities is highly instrumental in balancing the development of human and nature. Knowledge of the links among various resources will help to avoid shifting the resource pressures from one endowment to another. Currently, the significance of the nexus among various environmental endowments has been realized and emphasized by many researchers (Apergis and Payne, 2010; Chen and Chen, 2014;

Villarroel Walker et al., 2014). Some nexus frameworks have been established to assess the linkages of environmental endowments. In particular, a range of studies have paid their attentions on the connections between water and energy at different scales, such as countries (Gu et al., 2014; Rasul, 2014), cities (Venkatesh et al., 2014), and engineering projects (Nair et al., 2014; Talebpour et al., 2014). Besides, water-climate nexus (Nanduri and Saavedra-Antolínez, 2013) and water-emission nexus (Nanduri and Saavedra-Antolínez, 2013) have been analyzed. Very few studies address the linkages between land and other endowments, although land scarcity has been an increasing concern in many developing countries (Ringler et al., 2013). To fill in the gap, this chapter investigates the nexus of China's farm land/water use and corresponding consumption or trade activities. To avoid the negative impact of a single resource protection strategy on another resource endowment, the trade-off between farm land and water resources is emphasized in this chapter. Based on the calculated results, the relations and differences of China's farm land and water use are concluded as follows.

The spatial distribution of China's farm land and water use shows some similar distribution patterns: Firstly, the embodied farm land and water intensities are both negatively correlated with the economic level: most undeveloped provinces have higher farm land and water use intensity compared to the relatively developed provinces; Secondly, there is a great similarity between the distribution of FLEC and FWEC, since both of them are deeply influenced by the economic structure of China. Based on the research findings, Shandong, Guangdong, Henan and Yunnan are the leading FLEC and FWEC regions. And Hainan, Ningxia and Qinghai are the regions with the minimal FLEC and FWEC values; Thirdly, the spatial distribution of farm land embodied in trade balance is very similar to that of farm water. Heilongjiang is the largest supplier both for farm land and water resources in contrast to Shanghai as the largest receiver. The net farm land and water exporters are generally the resource-rich but less-developed regions, like Heilongjiang, Inner Mongolia, Xinjiang, Jilin, and Ningxia. While the net farm land and water importers are mostly the resource-poor but more-developed regions, like Shanghai, Beijing, Tianjin, Zhejiang, and Guangdong.

By contrast, the distribution of China's farm land and water use also has some differences: Firstly, the physical land and water resources distribution is unbalanced. A diametric land-water pattern is shown in China, i.e., relatively abundant water resources but scare land resources in southern China, and abundant land resources but scare water resources in northwest China; Secondly, despite farm land and water resource endowments flow into the same economic structure, the virtual land and water flows embodied in interregional trade have certain differences. Virtual land and water flows associated with real commodity trade show a shift of the uneven resource pressures. For example, Hunan exports 17.51 million m^3 of embodied farm water to Gansu, in contrast, Gansu exports 4.23 thousand hectares of embodied farm land to Hunan. It is, therefore, not appropriate to evaluate the embodiment of resource transfer based on a certain kind of resource. Based on the differences among various resource endowments, farm land and farm water can be regarded as complementary to each other in the sustainability of agricultural production (Hoekstra, 2009).

6.4.2 Policy implications

This chapter quantifies the regional embodied farm land and water use in China based on an MRIO model. With an integrated consideration of both land and water, the results are expected to facilitate the making of integrated agricultural policy decisions to fulfill China's increasing food demand. Embodied land and water can be regarded as the complement of the indicators to track the main resource pressures on agricultural development. It is very helpful to understand the diversity of natural resource pressures on agricultural production and the nature of the links between economic activities and natural endowments. The corresponding policy implications are provided as follows.

Firstly, the most direct resource protection policies implemented by the local governments mainly focus on the resource utilization efficiency. Considering the conditions of local resources and climate conditions, related policies and measures, such as appropriate selection of crops taking advantages of both the local land and water resources, should be put forward to improve the land and water use efficiency (Dong et al., 2014).

Secondly, economic incentives also play a significant role in relieving resource pressures in the modern economy. The findings show that local consumption behaviors have a close relationship with the resource utilization. Shandong and Guangdong provinces, with substantial goods and services consumption, are the leading consumers of farm land and water resources. Therefore, their local governments should encourage the economical consumption of resource-intensive goods, like textile products.

Thirdly, in order to establish a sustainable development model, complementary resource advantages for the ecological benefits considering both farm land and water resources have to be understood. Farm land and water are the two key elements essential for agricultural activities. Whether a region is appropriate for large-scale agricultural production activities should be decided by the comprehensive and sustainable indicators. For example, Heilongjiang, rich in both land and water resources, has an obvious advantage when it comes to agricultural development. In contrast, Jilin's agriculture is constrained by the water resources, although it has abundant land resources. Therefore, Jilin should emphasize the importance of efficient utilization of water resources to make up its disadvantages. Hainan, with rich water resources as a coastal region, is conditioned by its limited land resources. Thus, Hainan's policies should tend to the maximum of use efficiency of land resources.

Fourthly, the interregional cooperation policies based on the regional advantages should be emphasized. Regions play the roles of either receivers (net resource importers) or suppliers (net resource exporters) of resources. Receivers, like Shanghai, Guangdong and Shandong, are capable of providing more economic and technical supports for both their own and other regions' agricultural developments. Suppliers, like Heilongjiang, Inner Mongolia and Xinjiang, should focus on the improvement of agricultural production technology and resource utilization efficiency. While for some resource-poor and less-developed suppliers, like Sichuan, Henan and Hunan, should consider to transfer some farm land/water resource-intensive industries to the resource-rich regions, avoiding the development of economy at the expense of environment (Zhang et al., 2013). In the synthesis, it is appropriate for all regional governments to join forces so that more sustainable and effective measures can be established.

6.5 Chapter summary

Land and water are the two main drivers of agricultural production. Pressure on farm land and water resources is increasing in China due to rising food demand. Viewing land and water challenges from an integrated systematical perspective, this part could help policymakers to make a better analysis for sustainable water and land use planning. Domestic trade affects China's regional farm land and water use by distributing resources associated with the production of goods and services. This chapter constructs a MRIO model to simultaneously analyze China's farm land and water uses embodied in consumption and interregional trade. Results show a great similarity for both China's farm land and water endowments. Shandong, Henan, Guangdong and Yunnan are the most important drivers of farm land and water consumption in China, even though they have relatively few land and water resource endowments. Heilongjiang and Inner Mongolia have a considerably high land supply. The counterparts to these land surpluses are the deficits in Shandong, Jiangsu and Shanghai. Xinjiang, Heilongjiang and Inner Mongolia contribute a massive amount of water resources through interregional trade flows; Guangdong and Shanghai are two of the recipients of these water surpluses. Heilongjiang is the largest farm land and water supplier in contrast to Shanghai as the largest receiver. The results help policymakers to comprehensively understand embodied farm land and water flows in a complex economy network. Improving resource utilization efficiency and reshaping the embodied resource trade nexus should be addressed by considering the transfer of regional responsibilities.

Chapter 7 Conclusions

7.1 Introduction

This chapter firstly reviews the research aim and objectives to examine whether and how they have been achieved. Secondly, research findings concerning the temporal, spatial and resource nexuses are summarized. Thirdly, the contributions, limitations, and future research directions are presented.

7.2 Review of research objectives

The research systematically explores the temporal nexus, spatial nexus and resource nexus of China's land use with insight into the concept of "virtual land", given the complex globalized economic network and close interactions between economic and land use systems. This can facilitate China's sustainable land management by establishing a comprehensive database of historical and spatial virtual land use data, and data on the land-water nexus. The specific research objectives are as follows:

(1) To identify the changing pattern of China's virtual land and industrial distribution characteristics of virtual land use; (temporal nexus)

(2) To explore regional land footprint distribution patterns and the regional spatial transfer of virtual land use; (spatial nexus)

(3) To understand the linkages and tradeoffs between land and water by identifying China's land-water nexus; (resource nexus)

(4) To draw policy implications in achieving sustainable land management by providing insight into the temporal, spatial and resource nexuses of China's virtual land use. (policy implications)

Chapter 1 initially identifies the research questions under the research backgrounds of sustainable land use management and economic globalization, Chapter 2 conducts a detailed literature review to identify the research gap, and Chapter 3 describes the methodology to investigate this research further. These three chapters provide a solid theoretical foundation to attain the research objectives. To achieve Objective 1, Chapter 4 employs time-series data to demonstrate the land occupation of the Chinese economy over time with multiple land use types, including cultivated, forest, pasture, and construction land. The calculated results are a solid reference to re-recognize the historical characteristics of virtual land requirements of the Chinese economy. This approach also provides a detailed historical database of China's virtual land to guide multiple sustainable goals in the process of globalization. To achieve Objective 2, Chapter 5 identifies the land occupation of the Chinese economy over space using China's four land use types. This chapter is expected to facilitate the creation of integrated sustainable land use decisions through optimizing industrial and regional trade structures, and allocating regional responsibility. To achieve Objective 3, Chapter 6 simultaneously analyzes China's farm land and water uses embodied in consumption and interregional trade. Uncovering the nexus of farm land and water factors in a complex social economy is especially significant as various environmental indicators commonly interact and complement each other. To achieve Objective 4, policy implications are developed and concluded in accordance with Chapters 4, 5, and 6 based on the temporal, spatial, and resource nexuses.

7.3 Summary of research findings

7.3.1 Findings from the temporal nexus

Temporal comparisons of virtual land use, including cultivated, forest, pasture, and construction land, in the period of 1987-2012 and 2000-2012 are presented to depict the changing trend of virtual land use. The findings are as follows:

(1) Temporal analysis on China's embodied land use.

China's embodied cultivated, forest, pasture, and construction land intensities in 1987–2012 or 2000–2012 all show a downward trend, declining from 0.34 to 0.02, 0.61 to 0.05, 0.70 to 0.04, and 0.11 to 0.005 hectares/thousand Yuan, respectively. This trend shows China's effort in improving its various land use efficiencies and effectiveness.

China is consistently a net exporter of cultivated, forest, pasture, and construction land in 2000–2010. The changing patterns of three agricultural land use types are similar: embodied land in trade balance varies significantly during the concerned period, and the largest values are obtained in 2007. The range of fluctuation of embodied cultivated, forest, and pasture land is 8.06–-0.23, 15.55–-0.44, and 10.41–-0.38 million hectares, respectively. The fluctuation is closely related to the evolution of China's international agricultural trade structure. The variation range of embodied construction land in the trade balance, with a value of 2.70–0.98 million hectares, is relatively smaller than that of agricultural land.

The change in consumption-based embodied land use is not highly significant. The variation range of consumption-based embodied cultivated, forest, pasture, and construction land is 103.6–132.96, 199.87–249.27, 202.81–262.15, and 21.98–29.72

million hectares, respectively. However, the embodied consumption in the four land use types has a great difference. Consumption-based forest and pasture land are approximately 10 times greater than construction land, and consumption-based cultivated land are about 5 times greater than construction land. This finding demonstrates the significance of land devoted to various agricultural activities.

(2) Sectoral analysis on China's embodied land use.

As for these three types of agricultural land, Sector 1 (Agriculture) has the highest intensity, and the sectors closely related to the necessities for daily living, such as Sectors 6 (Food Processing), 7 (Textile Industry), and 31 (Hotels, Catering Service), all have high intensities. In construction land, the intensities of all sectors move toward a leveling trend given that various economic activities are all embedded in construction land.

In the three agricultural land, Sector 1 (Agriculture) is the largest net importer of embodied cultivated, forest, and pasture land in China with values of 8.20, 15.38, and 15.73 million hectares, respectively, and Sector 8 (Garments) is the largest net exporter of embodied cultivated, forest, and pasture land in China with values of 3.78, 7.09, and 6.14 million hectares, respectively. Despite the observed structural similarity of embodied cultivated, forest, and pasture land in trade by sector, considerable differences are still observed in terms of magnitude. Embodied forest and pasture land in import and export by sector are double the embodied cultivated land. In construction land, Sector 3 (Petroleum Extraction) is the largest net importer of embodied construction land in China with a value of 0.42 million hectares, and Sector 8 (Garments) is the largest net exporter with a value of 0.52 million hectares.

From an industrial perspective, the basic necessities of clothing, food, shelter, and transportation consume a large number of land resources. Specifically, Sectors 1 (Agriculture), 6 (Food Processing), and 28 (Construction) embody the largest volumes of cultivated, forest, and pasture land at 52.74, 35.86, and 10.67 million hectares, 98.87, 67.24, and 20.00 million hectares, and 85.67, 58.26, and 17.33 million hectares, respectively. Sectors 28 (Construction), 6 (Food Processing), and 18 (Transportation Equipment) consume the largest construction land with values of 5.19, 2.20, and 1.83 million hectares, respectively.

7.3.2 Findings from the spatial nexus

As for spatial nexus, the ever-closer economic relationship among various industries in different regions through interregional trade exacerbates the pressure on resource spatial displacement. Therefore, identifying the issues of spatial transfer of land use pressure, and the spatial distribution patterns of land footprint in the whole supply chain, is important. The spatial nexuses of China's four land-use types, namely, cultivated, forest, pasture, and construction land, are identified. The findings are as follows:

(1) Supply and demand of actual land use resources.

The total share of 13 provinces with cultivated land areas of over 5 million hectares is 69.84%. This finding reflects the imbalance in the spatial distribution of the supply and demand of cultivated land. While for forest land resources, 9 provinces have forest land areas above 10 million hectares, and the share of forest areas of these 9 provinces accounts for 62.14% of the total. Provinces with few forest land resources are the developed regions, such as Shanghai, Tianjin, Jiangsu, and Beijing. The imbalance between supply and demand can also be observed by forest land. A total of 84.77% of pasture land resources are distributed among Inner Mongolia, Qinghai, and Xinjiang. Regions above China's average per capita construction land tend to be the undeveloped regions, such as Ningxia, Inner Mongolia, Qinghai, and Xinjiang. Regions under the national average are mostly provinces with fast economic development and a dense population.

(2) Regional land footprint distributions.

Shandong, Heilongjiang, Henan, Jiangsu, and Inner Mongolia are the most important drivers of cultivated land consumption in China even though they have relatively few cultivated land resource endowments. Conversely, Hainan, Ningxia, Qinghai, Fujian, and Tianjin have minimum values. Yunnan, Sichuan, Inner Mongolia, Guangdong, and Guangxi consume the largest forest land resources; by contrast, Ningxia, Hainan, Tianjin, Beijing, and Anhui have the smallest values. Qinghai, Inner Mongolia, and Xinjiang are the three largest consumers of pasture land resources, and the economies of these three regions are highly dependent on their pasture land resources. Unlike those of cultivated, forest, and pasture land, the regional distribution of actual and embodied construction land is mostly consistent. The consistency can prove the rational allocation of construction land resources to roughly achieve the supply–demand balance.

(3) Regional transfer of virtual land flows.

Cultivated land resources flow from Xinjiang, Heilongjiang, Jilin, and Inner Mongolia to Shandong, Jiangsu, Shanghai, and Zhejiang provinces, and flow from southern provinces to Guangdong. Forest land resources flow from Heilongjiang, Inner Mongolia, Ningxia, and Sichuan to Shandong, Jiangsu, and Shanghai provinces, and flow from neighboring southern provinces, such as Yunnan, Guangxi, Guizhou, Hunan, Hubei, and Jiangxi to Guangdong. The largest interregional forest land trading flow is from Heilongjiang to Shandong with a value of 2.10 million hectares. Pasture land resource flows mainly come from two regions, namely, Xinjiang in West China and Inner Mongolia in North China. Compared with cultivated and forest land, the starting points of embodied pasture land flows are mainly concentrated in pasture land-intensive regions, such as Xinjiang, Inner Mongolia, and Qinghai. The three economic regions of China with the most active trade activities attract a great deal of embodied construction land flows mainly derived from the nearby provinces.

7.3.3 Findings from the resource nexus

As for resource nexus, land and water are the two main drivers of agricultural production. Viewing land and water challenges from an integrated systematical perspective, this part can help policy makers to make a better analysis for sustainable water and land use planning. The findings are as follows:

(1) The spatial distribution of China's farm land and water use shows similar distribution patterns.

Firstly, the embodied farm land and water intensities are both negatively correlated with the economic level: most undeveloped provinces have higher farm land and water use intensity compared to the relatively developed provinces; Secondly, there is a great similarity between the distribution of FLEC and FWEC, since both of them are deeply influenced by the economic structure of China. Based on the research findings, Shandong, Guangdong, Henan and Yunnan are the leading FLEC and FWEC regions. And Hainan, Ningxia and Qinghai are the regions with the minimal FLEC and FWEC values; Thirdly, the spatial distribution of farm land embodied in trade balance is very similar to that of farm water. Heilongjiang is the largest supplier both for farm land and water resources in contrast to Shanghai as the largest receiver. The net farm land and water exporters are generally the resource-rich but less-developed regions, like Heilongjiang, Inner Mongolia, Xinjiang, Jilin, and Ningxia. While the net farm land and water importers are mostly the resource-poor but more-developed regions, like Shanghai, Beijing, Tianjin, Zhejiang, and Guangdong.

(2) The distribution of China’s farm land and water use has some differences.

Firstly, the physical land and water resources distribution is unbalanced. A diametric land-water pattern is shown in China, i.e., relatively abundant water resources but scare land resources in southern China, and abundant land resources but scare water resources in northwest China; Secondly, despite farm land and water resource endowments flow into the same economic structure, the virtual land and water flows embodied in interregional trade have certain differences. Virtual land and water flows associated with real commodity trade show a shift of the uneven resource pressures. For example, Hunan exports 17.51 million m^3 of embodied farm water to Gansu, in contrast, Gansu exports 4.23 thousand hectares of embodied farm land to Hunan. It is, therefore, not appropriate to evaluate the embodiment of resource transfer based on a certain kind of resource. Based on the differences among various resource endowments, farm land and farm water can be regarded as complementary to each other in the sustainability of agricultural production.

7.3.4 Policy implications

The most direct land resource protection policies implemented by the local governments mainly focus on the land resource utilization efficiency. Considering the conditions of local land resources, related policies and measures, such as appropriate selection of crops taking advantages of the local cultivated land resources, are put forward to improve the land use efficiency. In the context of globalization, economic incentives also play a significant role in relieving land resource pressures. The local consumption behaviors and interregional trade activities both have a close relationship with the land resource utilization. By providing insight into "virtual land" given the complex globalized economic network, this study will facilitate the making of sustainable land protection policy decisions. The corresponding policy implications are provided as follows.

(1) Policy implications from the temporal nexus

Based on the temporal nexus, China is consistently a net exporter of cultivated, forest, pasture, and construction land during the concerned period. To alleviate this situation, industrial structure adjustment is an effective measure to avoid too much land resource transfer from China.

According to the industrial analysis of embodied land in this study, establishing the shared responsibility criterion in all the industries for land conservation is important. Land-intensive industries are obligated to improve land utilization efficiency using technical development and resource reallocation. For example, agricultural mechanization and automation are highly instrumental in effectively using cultivated land in Sector 1 (Agriculture). However, industries with low land intensity can contribute significantly to consumption and trade activities. Many export products from high-tech and service industries occupying fewer land resources can help restrict the outflow of land resources from China. Therefore, China should place high priority on trade structural change, i.e., increasing export of products with low cultivated land intensity, such as electronic devices to replace the products with high cultivated land intensity, such as textile, which is beneficial to balance the economic and environmental benefits and avoid land loss.

(2) Policy implications from the spatial nexus

The interregional cooperation policies based on the regional advantages should be emphasized based on the spatial nexus. It is appropriate for all regional governments to join forces so that more sustainable and effective measures can be established.

Regions play the roles of either receivers (net land resource importers) or suppliers (net land resource exporters) of land resources. Receivers, like Shanghai, Guangdong and Shandong, should take a great share of consumer responsibility. Most receivers are regions with highly developed economies, thus they are capable of providing more economic and technical supports for both their own and other regions' developments. Suppliers, like Heilongjiang, Inner Mongolia and Xinjiang, should take more producer responsibility due to their great resource endowments. They should focus on the improvement of production technology and resource utilization efficiency.

(3) Policy implications from the resource nexus

Embodied land and water can be regarded as the complementary indicators to track the main resource pressures on agricultural development. To achieve a sustainable development, advantages of complementary resources considering both farm land and water resources have to be understood. Farm land and water are the two key elements essential for agricultural activities. Whether a region is appropriate for large-scale agricultural production activities should be decided by the comprehensive and sustainable indicators. For example, Heilongjiang, rich in both land and water resources, has an obvious advantage when it comes to agricultural development. In contrast, Jilin's agriculture is constrained by water resources, although it has abundant land resources. Therefore, Jilin should emphasize the importance of efficient utilization of water resources to make up its disadvantages. Hainan, with rich water resources as a coastal region, is constrained by its limited land resources. Thus, Hainan's policies should tend to the maximum of use efficiency of land resources.

7.3.5 Comparisons of main findings

The EF measures humanity's demand on the biologically productive land resources by calculating the area people consume (whether cropland, forest land, or pasture land) (WWF, 2013). Many studies on global EF have been done by World Wild Fund for Nature (WWF). Here the main findings of this study with Ecological Footprint and Sustainable Consumption in China published by WWF (2013) are compared.

Table 7.1 Comparison of main findings using EF and IOA (WWF, 2013)

Main findings	Method: EF (WWF)	Method: IOA (this study)	Comparisons
Regional analysis	EF is unevenly distributed across China. EF and per capita GDP show positive correlations. Provinces with high EF tend to have few EF zones.	The net resource exporters are generally the resource-rich and less-developed regions, while the net resource importers are mostly the resource-poor and more-developed regions.	These two findings are basically identical: the more-developed and resource-poor regions consume more land resources. However, the findings using EF mainly analyze the characteristics of land resource consumers. It fails to trace back to the places where the ecological impacts actually occur. The findings based on IOA reveals not only the land consumers, but also how land resources are transferred from one region to another and what are the resource- and economy-oriented characteristics of importers and exporters.
Industrial analysis	EF are affected by different kinds of consumption across China. The main factors affecting per capita EF are housing and food.	*Agriculture* and *Food Processing* are two key sectors that contribute the largest volumes of embodied cultivated, forest and pasture land to meet the household food demand. *Construction* and *Food Processing* are crucial sectors that consume the largest embodied construction land.	These two findings are basically identical: Food and housing consume more land resources in China.

7.4 Contributions of the research

First, this research contributes to the literature on virtual land use in the resource accounting field by examining China's virtual land use over time and space. Although "virtual land"

and “land footprint” have been studied in many previous works, the characteristics of China’s virtual land use have not been comprehensively investigated. This study explores the dynamics and evolution of China’s virtual land use change and identifies the regional displacement of land use in China through the interregional supply chain.

Second, this study systematically analyzes the impact of economic globalization on China’s land use change for the first time. Economic globalization increases the worldwide economic links. The displacement of land use from one place to another occurs when trading for goods among industries and regions is obtained, thus shifting the pressures of local land resources. At the national level, a large-scale and cross-border displacement of land use from other regions of the world to China can be seen. At the regional level, a net displacement of land use from developed coastal regions to undeveloped regions in China is observed.

Third, this study analyses China’s land-water nexus to highlight their interdependencies and tradeoffs for the first time. Farm land and water are the two basic elements with the most significant impact on agricultural production. Relations and differences of China’s farm land and water use are uncovered, to help multiple policymakers or stakeholders jointly address sustainable development issues associated with land-water resource nexus governance.

Fourth, a comprehensive database of China’s embodied land use intensity is established for the first time. To provide an effective data supporting basis for policy making in terms of China’s sustainable land use planning and management, establishing the historical and spatial land intensity database through a consistent accounting mechanism and unified original data is important. This study develops China's embodied land intensity database during 1987-2012, and China's 30 regional embodied land intensity database in 2010 with the latest available original data.

Fifth, policy implications are given based on a systematical analysis of China's virtual land use over time and space. In the context of economic globalization and land scarcity, establishing the shared responsibility criterion in all the regions and industries in China for land conservation is necessary and important. Land-intensive regions and industries are obligated to improve land utilization efficiency and production technology. Regions and industries with low land intensity are suggested to contribute significantly to China's consumption and trade activities.

7.5 Limitations of the research

This study has limitations in evaluating China's virtual land use and these limitations need further improvements in future research.

Although this study is able to examine China's virtual cultivated land in 1987–2012 and its virtual forest, pasture, and construction land in 2000–2012 by combining the limited cultivated land data (1987–2012), forest, pasture, and construction land data (2000–2012), and IO data (1987–2012) in China, a full analysis and observation remain to be conducted using a longer time series to observe a richer description of the changing pattern of China's virtual land use.

The scientific method used in this study is a powerful tool for virtual land accounting, but it does have its limitations. The widespread use of this method in the environmental accounting field is driven by the fast development of data availability and computing power. So far, however, this method is still limited by data availability. Thus, a strong assumption is made that "imported goods/services have the same embodied land intensities as domestic ones because of the limitation of IO economic data although the imported commodities show a substantial difference from domestic ones" (Weber et al., 2008). The research method in future studies will benefit from a more comprehensive data supporting system.

7.6 Future research directions

Exploring virtual land occupation of the Chinese economy over time and space is a complex task because it integrates systematic, ecological, land management, land economic, and modern system engineering views. Despite this study's attempt to provide a comprehensive overview of the temporal, spatial, and resource nexuses of China's virtual land use, further investigations need be conducted as follows.

First, the research scope can be expanded in further studies. This study mainly focuses on the temporal and spatial analyses of virtual land at the national level. Conducting an in-depth investigation on virtual land at larger or smaller scales (i.e., global scale and urban scale) would be meaningful. As nation and municipality are distinct responsibility entities in the world, multi-scales studies can facilitate policy suggestions for multifaceted land management authorities.

Second, the linkage of the temporal–spatial network still requires further expansion. This study only separately conducts temporal and spatial analyses of virtual land. However, the historical and accumulated effects of one region on another region are the important factors to excavate further the driving factors of the changing patterns of China's virtual land.

Further studies should try to understand how the spatial variation changes through time. How and why the temporal variation may differ from point to point on a map of China can also be explored. These investigations will be more effective in achieving a dynamic balance of land supply and demand.

Third, the nexus of various land use categories needs to be further investigated. Examining the linkages among various land use categories is highly instrumental in the sustainable land use planning and management. For example, rethinking the relations of cultivated land conversion and urban construction land expansion under the background of urbanization and globalization, is very meaningful.

Fourth, further studies can expand to policy simulation according to the use of the pulling effects to adjust industrial structures. This study has established a solid database to support the sustainable land management policy making. This database can provide an efficient data support for policy simulation.

Appendix I: China's embodied land intensity database during 1987-2012

Due to the data limitations, China's embodied cultivated land intensity database is during 1987-2012, while China's embodied forest, pasture and construction land intensity database is obtained from 2000 to 2012.

China's embodied cultivated land intensity by sector in 1987 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity	Industrial Classification	Intensity
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	250.16	Primary Industry	250.16
2	Coal Mining and Dressing	Coal Mining	8.51	Secondary Industry	35.82
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	3.11		
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	9.01		
5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	16.96		
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	129.00		
7	Textile Industry	Textile Industry	72.98		
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	59.55		
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	24.48		
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	45.34		
11	Electric Power/Steam and Hot Water Production and Supply	Electric Power	4.10		

12	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	2.72		
13	Coke, gas and coal products industry	Coke, gas and coal products in dustry	8.86		
14	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	36.98		
15	Nonmetal Mineral Products	Nonmetal Mineral Products	12.92		
16	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	6.91		
17	Metal Products	Metal Products	11.23		
18	Mechanical Industries	Mechanical Industries	8.82		
19	Transportation Equipment	Transportation Equipment	9.76		
20	Electric Equipment and Machinery	Electric Equipment	12.24		
21	Electronic and Telecommunications Equipment	Telecommunications Equipment	9.38		
22	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	8.10		
23	Machinery and Equipment R epair	Machinery Repair	9.66		
24	Other Industry	Other Industry	24.32		
25	Construction Industry	Construction	10.80		
26	Storage and Post	Storage and Post	5.06	Tertiary Industry	15.81
27	Business Industry	Business Industry	12.49		
28	Hotels, Catering Service	Hotels, Catering Service	108.72		
29	Transport	Transport	5.62		
30	Public Management and Social Organization	Public Management	9.26		
31	Culture, Education and Research	Culture, Education and Research	16.18		
32	Financial Industry	Financial Industry	0.72		
33	Administrative organizations	Administration	6.60		

China’s embodied cultivated land intensity by sector in 1990 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity		Intensity

				Industrial Classification	
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	159.19	Primary Industry	159.19
2	Coal Mining and Dressing	Coal Mining	10.84	Secondary Industry	27.71
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	4.48		
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	9.70		
5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	19.52		
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	84.96		
7	Textile Industry	Textile Industry	55.06		
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	45.71		
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	21.42		
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	36.44		
11	Electric Power/Steam and Hot Water Production and Supply	Electric Power	5.98		
12	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	4.21		
13	Coke, gas and coal products i ndustry	Coke, gas and coal products in dustry	9.04		
14	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	29.66		
15	Nonmetal Mineral Products	Nonmetal Mineral Products	12.68		
16	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	7.95		
17	Metal Products	Metal Products	11.76		
18	Mechanical Industries	Mechanical Industries	8.92		
19	Transportation Equipment	Transportation Equipment	9.28		
20	Electric Equipment and Machinery	Electric Equipment	11.25		

21	Electronic and Telecommunications Equipment	Telecommunications Equipment	8.77		
22	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	8.67		
23	Machinery and Equipment Re pair	Machinery Repair	9.74		
24	Other Industry	Other Industry	19.78		
25	Construction Industry	Construction	9.94		
26	Storage and Post	Storage and Post	5.66	Tertiary Industry	11.29
27	Business Industry	Business Industry	10.57		
28	Hotels, Catering Service	Hotels, Catering Service	70.40		
29	Transport	Transport	5.45		
30	Public Management and Social Organization	Public Management	7.86		
31	Culture, Education and Research	Culture, Education and Research	12.57		
32	Financial Industry	Financial Industry	0.74		
33	Administrative organizations	Administration	5.86		

China's embodied cultivated land intensity by sector in 1992 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity	Industrial Classification	Intensity
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	126.63	Primary Industry	126.63
2	Coal Mining and Dressing	Coal Mining	3.79	Secondary Industry	15.48
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	2.02		
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	4.73		
5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	6.43		
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	63.41		
7	Textile Industry	Textile Industry	33.19		
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	26.11		

9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	12.39		
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	21.05		
11	Electric Power/Steam and Hot Water Production and Supply	Electric Power	2.39		
12	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	2.25		
13	Coke, gas and coal products i ndustry	Coke, gas and coal products in dustry	3.77		
14	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	14.34		
15	Nonmetal Mineral Products	Nonmetal Mineral Products	6.32		
16	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	3.30		
17	Metal Products	Metal Products	4.59		
18	Mechanical Industries	Mechanical Industries	3.89		
19	Transportation Equipment	Transportation Equipment	4.27		
20	Electric Equipment and Machinery	Electric Equipment	4.62		
21	Electronic and Telecommunications Equipment	Telecommunications Equipment	4.37		
22	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	3.95		
23	Machinery and Equipment Re pair	Machinery Repair	4.11		
24	Other Industry	Other Industry	16.57		
25	Construction Industry	Construction	4.76		
26	Storage and Post	Storage and Post	2.68	Tertiary Industry	7.07
27	Business Industry	Business Industry	7.26		
28	Hotels, Catering Service	Hotels, Catering Service	42.56		
29	Transport	Transport	2.52		
30	Public Management and Social Organization	Public Management	5.47		
31	Culture, Education and Research	Culture, Education and Research	5.83		

32	Financial Industry	Financial Industry	3.59		
33	Administrative organizations	Administration	3.69		

China’s embodied cultivated land intensity by sector in 1995 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity	Industrial Classification	Intensity
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	59.22	Primary Industry	59.22
2	Coal Mining and Dressing	Coal Mining	1.84	Secondary Industry	7.75
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	1.19		
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	2.96		
5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	3.77		
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	27.78		
7	Textile Industry	Textile Industry	17.14		
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	13.18		
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	7.05		
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	11.30		
11	Electric Power/Steam and Hot Water Production and Supply	Electric Power	1.23		
12	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	1.39		
13	Coke, gas and coal products i ndustry	Coke, gas and coal products in dustry	2.25		
14	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	7.64		
15	Nonmetal Mineral Products	Nonmetal Mineral Products	3.48		

16	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	1.89		
17	Metal Products	Metal Products	2.66		
18	Mechanical Industries	Mechanical Industries	2.33		
19	Transportation Equipment	Transportation Equipment	2.47		
20	Electric Equipment and Machinery	Electric Equipment	2.48		
21	Electronic and Telecommunications Equipment	Telecommunications Equipment	2.13		
22	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	2.10		
23	Machinery and Equipment Re pair	Machinery Repair	2.29		
24	Other Industry	Other Industry	9.21		
25	Construction Industry	Construction	2.63		
26	Storage and Post	Storage and Post	1.34	Tertiary Industry	3.30
27	Business Industry	Business Industry	2.86		
28	Hotels, Catering Service	Hotels, Catering Service	20.29		
29	Transport	Transport	1.26		
30	Public Management and Social Organization	Public Management	2.83		
31	Culture, Education and Research	Culture, Education and Research	3.25		
32	Financial Industry	Financial Industry	1.56		
33	Administrative organizations	Administration	2.22		

China’s embodied cultivated land intensity by sector in 1997 (Unit: hectares/million Yuan)

Cod e	Sector	Short Name	Intensity	Industrial Classification	Intensity
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	66.50	Primary Industry	66.50
2	Coal Mining and Dressing	Coal Mining	2.48	Secondary Industry	7.93
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	0.95		
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	2.32		

5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	3.55		
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	33.65		
7	Textile Industry	Textile Industry	15.44		
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	10.84		
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	8.28		
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	7.23		
11	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	1.32		
12	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	7.81		
13	Nonmetal Mineral Products	Nonmetal Mineral Products	2.87		
14	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	1.92		
15	Metal Products	Metal Products	2.27		
16	Mechanical Industries	Mechanical Industries	2.12		
17	Transportation Equipment	Transportation Equipment	2.34		
18	Electric Equipment and Machinery	Electric Equipment	3.07		
19	Electronic and Telecommunications Equipment	Telecommunications Equipment	2.55		
20	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	2.66		
21	Machinery and Equipment Repa ir	Machinery Repair	2.30		
22	Other Industry	Other Industry	9.91		
23	Waste	Waste	0.00		
24	Electric Power/Steam and Hot Water Production and Supply	Electric Power	1.53		
25	Gas Production and Supply Industry	Gas Production and Supply	1.95		
26	Water Production and Supply Industry	Water Production and Supply	1.54		

27	Construction Industry	Construction	2.57		
28	Storage	Storage	1.66	Tertiary Industry	4.16
29	Post	Post	1.49		
30	Business Industry	Business Industry	3.53		
31	Catering Service	Catering Service	25.26		
32	Transport	Transport	1.89		
33	Financial Industry	Financial Industry	1.46		
34	Real Estate	Real Estate	0.91		
35	Social Service	Social Service	4.34		
36	Health, Social Security and Social Welfare	Health	4.65		
37	Education	Education	2.49		
38	Research	Research	2.85		
39	Polytechnic Service	Polytechnic Service	6.28		
40	Administrative Organization	Administration	2.64		

China's embodied land intensity by sector in 2000 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity: Cultivated land	Intensity: Forest land	Intensity: Pasture land	Intensity: Construction land	Industrial Classification	Intensity: Cultivated land	Intensity: Forest land	Intensity: Pasture land	Intensity: Construction land
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	60.22	107.63	123.90	3.65	Primary Industry	60.22	107.63	123.90	3.65
2	Extractive Industries	Extractive Industries	1.46	2.60	3.00	2.43					
3	Food Processing, Food Production	Food Processing	28.45	50.85	58.53	3.41					
4	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	11.35	20.29	23.36	3.59					
5	Other Industry	Other Industry	6.25	11.17	12.86	3.23					
6	Electric Power/Steam and Hot Water Production and Supply	Electric Power	1.34	2.40	2.76	2.85					
7	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	1.34	2.40	2.77	3.02	Secondary Industry	5.89	10.53	12.13	3.51
8	Chemistry Industry	Chemistry Industry	5.94	10.61	12.22	3.60					
9	Nonmetal Mineral Products	Nonmetal Mineral Products	2.65	4.74	5.46	3.40					
10	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	1.91	3.42	3.94	3.78					
11	Mechanical Industries	Mechanical Indu stries	2.24	3.99	4.60	3.78					
12	Construction Industry	Construction	2.27	4.07	4.68	3.67					
13	Storage and Post	Storage and Post	1.37	2.45	2.82	7.21					
14	Business Industry and Catering Service	Business Industry	7.27	13.00	14.96	2.33					
15	Public Utilities and Residential Service	Public Utilities	2.51	4.48	5.16	2.37	Tertiary Industry	3.57	6.38	7.35	3.17
16	Financial Industry	Financial Industry	0.69	1.23	1.42	1.30					
17	Other Services	Other Services	2.68	4.80	5.52	2.47					

China's embodied land intensity by sector in 2002 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity: Cultivated land	Intensity: Forest land	Intensity: Pasture land	Intensity: Construction land	Industrial Classification	Intensity: Cultivated land	Intensity: Forest land	Intensity: Pasture land	Intensity: Construction land
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	54.66	100.15	114.39	2.15	Primary Industry	54.66	100.15	114.39	2.15
2	Coal Mining and Dressing	Coal Mining	1.26	2.31	2.64	1.85					
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	0.53	0.97	1.11	1.53					
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	1.32	2.43	2.77	2.16					
5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	1.26	2.32	2.64	2.09					
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	21.87	40.08	45.77	2.39					
7	Textile Industry	Textile Industry	12.23	22.41	25.59	2.72					
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	8.55	15.67	17.90	2.73	Secondary Industry	4.85	8.89	10.16	2.56
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	9.16	16.78	19.17	2.60					
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	3.61	6.61	7.55	2.40					
11	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	0.75	1.37	1.56	2.33					
12	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	3.91	7.17	8.19	2.61					

13	Nonmetal Mineral Products	Nonmetal Mineral Products	1.43	2.62	2.99	2.36					
14	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	0.96	1.76	2.01	2.62					
15	Metal Products	Metal Products	1.30	2.38	2.72	2.75					
16	Ordinary Machinery	Ordinary Machinery	1.35	2.46	2.81	2.66					
17	Equipment for Special Purpose	Special Equipment	1.25	2.30	2.62	2.77					
18	Transportation Equipment	Transportation Equipment	1.59	2.91	3.32	2.77					
19	Electric Equipment and Machinery	Electric Equipment	1.37	2.51	2.87	3.06					
20	Electronic and Telecommunications Equipment	Telecommunications Equipment	1.53	2.81	3.21	2.83					
21	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	7.77	14.24	16.27	2.57					
22	Other Manufacture Products	Others	0.00	0.00	0.00	0.91					
23	Waste	Waste	0.76	1.40	1.59	1.93					
24	Manufacture of Artwork and Other Manufactures	Manufacture of Artwork	1.99	3.64	4.15	2.51					
25	Electric Power/Steam and Hot Water Production and Supply	Electric Power	0.86	1.57	1.79	1.93					
26	Gas Production and Supply Industry	Gas Production and Supply	5.86	10.73	12.25	2.67					
27	Water Production and Supply Industry	Water Production and Supply	1.42	2.60	2.97	2.63					
28	Construction Industry	Construction	1.74	3.19	3.64	1.63					
29	Wholesale, Retail Trade	Wholesale, Retail Trade	0.91	1.66	1.90	1.36	Tertiary Industry	2.66	4.87	5.56	1.45
30	Transport, Storage and Post	Transport and Storage	2.26	4.13	4.72	1.20					
31	Hotels, Catering Service	Hotels, Catering Service	13.39	24.54	28.03	1.55					
32	Information Transmission, Computer services and Software	Information	1.00	1.83	2.09	0.90					

33	Financial Industry	Financial Industry	0.74	1.36	1.55	0.78					
34	Real Estate	Real Estate	1.65	3.03	3.46	1.73					
35	Leasing and Commercial Services	Leasing	2.17	3.98	4.55	1.17					
36	Research and Experimental Development	Research	1.55	2.84	3.25	1.59					
37	Water conservancy, Environment and Public Facilities Management	Environment	1.68	3.09	3.52	1.12					
38	Service to Households and Other Service	Service to Households	3.12	5.72	6.54	1.51					
39	Education	Education	1.90	3.48	3.98	1.14					
40	Health, Social Security and Social Welfare	Health	2.01	3.68	4.20	1.51					
41	Culture, Sports and Entertainment	Culture	3.32	6.09	6.96	1.40					
42	Public Management and Social Organization	Public Management	2.19	4.01	4.58	1.20					

China's embodied land intensity by sector in 2005 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity				Industrial Classification	Intensity			
			Cultivated land	Forest land	Pasture land	Construction land		Cultivated land	Forest land	Pasture land	Construction land
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	74.24	82.56	1.51	742.44	Primary Industry	74.24	82.56	1.51	742.44
2	Coal Mining and Dressing	Coal Mining	2.64	2.94	1.21	26.42	Secondary Industry	3.93	7.59	8.44	1.52
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	1.01	1.13	0.85	10.13					
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	2.56	2.85	1.34	25.64					

5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	2.87	3.20	1.41	28.75					
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	33.28	37.01	1.49	332.79					
7	Textile Industry	Textile Industry	21.82	24.26	1.64	218.17					
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	13.26	14.75	1.57	132.63					
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	14.37	15.98	1.57	143.71					
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	7.09	7.89	1.50	70.91					
11	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	1.45	1.61	1.27	14.47					
12	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	7.04	7.83	1.57	70.42					
13	Nonmetal Mineral Products	Nonmetal Mineral Products	2.75	3.05	1.44	27.45					
14	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	1.81	2.02	1.52	18.13					
15	Metal Products	Metal Products	2.27	2.52	1.57	22.67					
16	Ordinary Machinery	Ordinary Machinery	2.47	2.75	1.56	24.71					
17	Equipment for Special Purpose	Special Equipment	2.44	2.71	1.63	24.41					
18	Transportation Equipment	Transportation Equipment	2.90	3.23	1.62	29.04					
19	Electric Equipment and Machinery	Electric Equipment	2.71	3.01	1.84	27.09					

20	Electronic and Telecommunications Equipment	Telecommunications Equipment	2.94	3.27	1.66	29.38					
21	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	13.62	15.15	1.51	136.23					
22	Other Manufacture Products	Others	0.00	0.00	0.44	0.00					
23	Waste	Waste	1.93	2.14	1.34	19.26					
24	Manufacture of Artwork and Other Manufactures	Manufacture of Artwork	2.82	3.14	1.36	28.20					
25	Electric Power/Steam and Hot Water Production and Supply	Electric Power	1.77	1.97	1.17	17.72					
26	Gas Production and Supply Industry	Gas Production and Supply	9.43	10.48	1.51	94.28					
27	Water Production and Supply Industry	Water Production and Supply	2.83	3.15	1.72	28.32					
28	Construction Industry	Construction	2.75	3.06	0.95	27.50					
29	Wholesale, Retail Trade	Wholesale, Retail Trade	1.94	2.15	0.97	19.36					
30	Transport, Storage and Post	Transport and Storage	2.45	2.73	0.58	24.54					
31	Hotels, Catering Service	Hotels, Catering Service	19.41	21.59	1.07	194.12					
32	Information Transmission, Computer services and Software	Information	1.87	2.08	0.63	18.73					
33	Financial Industry	Financial Industry	0.89	0.99	0.43	8.95					
34	Real Estate	Real Estate	3.48	3.87	1.26	34.82	Tertiary Industry	2.26	4.36	4.84	0.99
35	Leasing and Commercial Services	Leasing	3.31	3.68	1.14	33.05					
36	Research and Experimental Development	Research	4.71	5.24	1.03	47.11					
37	Water conservancy, Environment and Public Facilities Management	Environment	3.41	3.79	0.95	34.09					
38	Service to Households and Other Service	Service to Households	5.53	6.15	0.92	55.34					

39	Education	Education	3.04	3.38	0.71	30.36					
40	Health, Social Security and Social Welfare	Health	4.68	5.21	1.20	46.82					
41	Culture, Sports and Entertainment	Culture	5.74	6.38	0.95	57.40					
42	Public Management and Social Organization	Public Management	4.29	4.77	0.75	42.88					

China's embodied land intensity by sector in 2007 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity				Industrial Classification	Intensity			
			Cultivated land	Forest land	Pasture land	Construction land		Cultivated land	Forest land	Pasture land	Construction land
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	60.22	60.22	66.79	1.18	Primary Industry	60.22	60.22	66.79	1.18
2	Coal Mining and Dressing	Coal Mining	1.90	1.90	2.11	0.80					
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	1.07	1.07	1.19	0.68					
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	1.70	1.70	1.88	0.92					
5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	1.89	1.89	2.09	0.88					
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	29.21	29.21	32.39	1.12	Secondary Industry	5.51	5.51	6.11	1.07
7	Textile Industry	Textile Industry	16.26	16.26	18.03	1.19					
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	12.05	12.05	13.36	1.15					
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	12.40	12.40	13.75	1.10					

10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	5.87	5.87	6.51	1.04					
11	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	1.33	1.33	1.47	0.91					
12	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	5.01	5.01	5.55	1.10					
13	Nonmetal Mineral Products	Nonmetal Mineral Products	2.02	2.02	2.24	0.97					
14	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	1.48	1.48	1.64	1.05					
15	Metal Products	Metal Products	1.96	1.96	2.18	1.10					
16	Ordinary Machinery	Ordinary Machinery	1.80	1.80	2.00	1.08					
17	Equipment for Special Purpose	Special Equipment	2.16	2.16	2.39	1.15					
18	Transportation Equipment	Transportation Equipment	2.12	2.12	2.35	1.16					
19	Electric Equipment and Machinery	Electric Equipment	2.12	2.12	2.35	1.22					
20	Electronic and Telecommunications Equipment	Telecommunications Equipment	2.34	2.34	2.59	1.16					
21	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	10.62	10.62	11.78	1.08					
22	Other Manufacture Products	Others	0.28	0.28	0.31	0.41					
23	Waste	Waste	1.36	1.36	1.51	0.94					
24	Manufacture of Artwork and Other Manufactures	Manufacture of Artwork	1.37	1.37	1.52	0.90					
25	Electric Power/Steam and Hot Water Production and Supply	Electric Power	1.49	1.49	1.66	0.75					

26	Gas Production and Supply Industry	Gas Production and Supply	2.30	2.30	2.55	1.07					
27	Water Production and Supply Industry	Water Production and Supply	2.19	2.19	2.43	1.27					
28	Construction Industry	Construction	1.41	1.41	1.56	0.59					
29	Wholesale, Retail Trade	Wholesale, Retail Trade	1.23	1.23	1.36	0.48	Tertiary Industry	3.36	3.36	3.72	0.65
30	Transport, Storage and Post	Transport and Storage	1.70	1.70	1.89	0.46					
31	Hotels, Catering Service	Hotels, Catering Service	16.61	16.61	18.42	0.75					
32	Information Transmission, Computer services and Software	Information	1.38	1.38	1.53	0.33					
33	Financial Industry	Financial Industry	0.68	0.68	0.75	0.25					
34	Real Estate	Real Estate	3.53	3.53	3.92	0.77					
35	Leasing and Commercial Services	Leasing	4.60	4.60	5.10	0.69					
36	Research and Experimental Development	Research	1.91	1.91	2.11	0.54					
37	Water conservancy, Environment and Public Facilities Management	Environment	4.72	4.72	5.23	0.57					
38	Service to Households and Other Service	Service to Households	3.44	3.44	3.81	0.63					
39	Education	Education	2.51	2.51	2.78	0.50					
40	Health, Social Security and Social Welfare	Health	3.56	3.56	3.95	0.78					
41	Culture, Sports and Entertainment	Culture	5.08	5.08	5.64	0.63					
42	Public Management and Social Organization	Public Management	2.77	2.77	3.07	0.51					

China's embodied land intensity by sector in 2010 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity				Industrial Classification	Intensity			
			Cultivated land	Forest land	Pasture land	Construction land		Cultivated land	Forest land	Pasture land	Construction land
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	24.37	45.72	39.58	0.79	Primary Industry	24.37	45.72	39.58	0.79
2	Coal Mining and Dressing	Coal Mining	0.88	1.66	1.43	0.47	Secondary Industry	2.57	4.82	4.17	0.64
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	0.54	1.01	0.88	0.39					
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	0.85	1.60	1.39	0.54					
5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	1.00	1.87	1.62	0.56					
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	12.60	23.64	20.46	0.73					
7	Textile Industry	Textile Industry	7.22	13.55	11.73	0.69					
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	5.41	10.16	8.79	0.69					
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	5.29	9.93	8.60	0.69					
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	3.13	5.87	5.08	0.65					
11	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	0.61	1.15	0.99	0.50					
12	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	2.45	4.60	3.99	0.65					
13	Nonmetal Mineral Products	Nonmetal Mineral Products	1.13	2.13	1.84	0.61					
14	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	0.93	1.75	1.51	0.62					
15	Metal Products	Metal Products	1.10	2.07	1.79	0.65					

16	Ordinary Machinery	Ordinary Machinery	1.03	1.92	1.67	0.64					
17	Equipment for Special Purpose	Special Equipment	1.12	2.10	1.82	0.67					
18	Transportation Equipment	Transportation Equipment	1.17	2.20	1.90	0.68					
19	Electric Equipment and Machinery	Electric Equipment	1.11	2.09	1.81	0.71					
20	Electronic and Telecommunications Equipment	Telecommunications Equipment	1.16	2.18	1.89	0.67					
21	Instruments, Other Manufacture Products	Instruments, Others	3.41	6.40	5.54	0.50					
22	Waste	Waste	0.71	1.33	1.15	0.55					
23	Manufacture of Artwork and Other Manufactures	Manufacture of Artwork	0.69	1.30	1.12	0.51					
24	Electric Power/Steam and Hot Water Production and Supply	Electric Power	0.71	1.34	1.16	0.47					
25	Gas Production and Supply Industry	Gas Production and Supply	1.16	2.17	1.88	0.63					
26	Water Production and Supply Industry	Water Production and Supply	1.39	2.62	2.26	1.00					
27	Construction Industry	Construction	0.86	1.62	1.40	0.61					
28	Wholesale, Retail Trade	Wholesale, Retail Trade	0.74	1.40	1.21	0.49					
29	Transport, Storage and Post	Transport and Storage	0.59	1.11	0.96	0.39					
30	Hotels, Catering Service	Hotels, Catering Service	7.44	13.95	12.07	0.63					
31	Information Transmission, Computer services and Software	Information	0.69	1.30	1.12	0.39	Tertiary Industry	1.49	2.80	2.42	0.59
32	Financial Industry	Financial Industry	0.47	0.88	0.76	0.34					
33	Real Estate	Real Estate	1.69	3.17	2.74	0.60					
34	Leasing and Commercial Services	Leasing	2.43	4.56	3.95	0.79					
35	Research and Experimental Development	Research	1.00	1.88	1.63	0.69					

36	Water conservancy, Environment and Public Facilities Management	Environment	1.78	3.34	2.89	0.74					
37	Service to Households and Other Service	Service to Households	1.48	2.78	2.40	0.66					
38	Education	Education	0.69	1.29	1.11	0.52					
39	Health, Social Security and Social Welfare	Health	1.65	3.10	2.69	0.76					
40	Culture, Sports and Entertainment	Culture	1.94	3.65	3.16	0.68					
41	Public Management and Social Organization	Public Management	1.03	1.93	1.67	0.59					

China’s embodied land intensity by sector in 2012 (Unit: hectares/million Yuan)

Code	Sector	Short Name	Intensity				Industrial Classification	Intensity			
			Cultivated land	Forest land	Pasture land	Construction land		Cultivated land	Forest land	Pasture land	Construction land
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	18.91	35.46	30.72	0.62	Primary Industry	18.91	35.46	30.72	0.62
2	Coal Mining and Dressing	Coal Mining	0.46	0.85	0.74	0.36	Secondary Industry	1.89	3.85	3.34	0.53
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	0.31	0.58	0.50	0.32					
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	0.54	1.01	0.88	0.44					
5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	0.56	1.05	0.91	0.42					
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	9.10	17.05	14.78	0.57					

7	Textile Industry	Textile Industry	6.23	11.68	10.12	0.60					
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	3.92	7.34	6.36	0.56					
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	4.01	7.51	6.51	0.56					
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	2.21	4.15	3.60	0.53					
11	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	0.40	0.75	0.65	0.43					
12	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	2.09	3.92	3.40	0.56					
13	Nonmetal Mineral Products	Nonmetal Mineral Products	0.72	1.34	1.16	0.50					
14	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	0.49	0.93	0.80	0.53					
15	Metal Products	Metal Products	0.66	1.23	1.07	0.55					
16	Ordinary Machinery	Ordinary Machinery	0.66	1.23	1.06	0.55					

17	Equipment for Special Purpose	Special Equipment	0.69	1.29	1.12	0.54					
18	Transportation Equipment	Transportation Equipment	0.70	1.32	1.14	0.55					
19	Electric Equipment and Machinery	Electric Equipment	0.75	1.41	1.22	0.58					
20	Electronic and Telecommunications Equipment	Telecommunications Equipment	0.72	1.34	1.16	0.59					
21	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	0.70	1.31	1.14	0.55					
22	Other Manufacture Products	Others	2.58	4.84	4.19	0.63					
23	Waste	Waste	0.27	0.51	0.44	0.26					
24	Manufacture of Artwork and Other Manufactures	Manufacture of Artwork	0.64	1.21	1.05	0.56					
25	Electric Power/Steam and Hot Water Production and Supply	Electric Power	0.40	0.76	0.66	0.49					
26	Gas Production and Supply Industry	Gas Production and Supply	0.36	0.67	0.58	0.42					
27	Water Production and Supply Industry	Water Production and Supply	0.65	1.23	1.06	19.98					
28	Construction Industry	Construction	0.83	1.55	1.34	0.46					
29	Wholesale, Retail Trade	Wholesale, Retail Trade	0.29	0.55	0.47	0.20	Tertiary Industry	0.91	1.66	1.44	0.44
30	Transport, Storage and Post	Transport and Storage	0.83	1.56	1.35	0.35					
31	Hotels, Catering Service	Hotels, Catering Service	5.04	9.45	8.19	0.42					
32	Information Transmission, Computer services and Software	Information	0.55	1.03	0.89	0.31					
33	Financial Industry	Financial Industry	0.53	0.99	0.86	0.24					

34	Real Estate	Real Estate	0.24	0.45	0.39	0.18					
35	Leasing and Commercial Services	Leasing	1.10	2.07	1.79	0.39					
36	Research and Experimental Development	Research	0.95	1.78	1.54	0.62					
37	Water conservancy, Environment and Public Facilities Management	Environment	2.00	3.75	3.25	0.64					
38	Service to Households and Other Service	Service to Households	0.84	1.57	1.36	0.56					
39	Education	Education	0.61	1.14	0.99	0.42					
40	Health, Social Security and Social Welfare	Health	1.21	2.26	1.96	0.60					
41	Culture, Sports and Entertainment	Culture	1.39	2.61	2.27	0.52					
42	Public Management and Social Organization	Public Management	0.76	1.42	1.23	0.48					

Appendix II: China's regional embodied land intensity database in 2010

Regional embodied land use intensity in 2010 (Unit: hectares/million Yuan)

	Region	Sector	Code	Intensity			
				Cultivated land	Forest land	Pasture land	Construction land
1	Beijing	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	13.34	35.88	4.61	1.00
		Coal Mining and Dressing	2	0.56	1.03	0.67	0.27
		Petroleum and Natural Gas Extraction	3	0.25	0.42	0.26	0.16

		Ferrous and Nonferrous Metals Mining and Dressing	4	0.36	0.62	0.39	0.19
		Nonmetal and Other Minerals Mining and Dressing	5	0.92	1.66	0.84	0.32
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	7.06	13.61	5.34	0.41
		Textile Industry	7	3.70	6.72	7.50	0.34
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	2.91	5.19	6.65	0.31
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	1.73	3.06	1.63	0.32
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	0.79	1.38	0.93	0.23
		Petroleum Processing and Coking, Gas Production and Supply	11	0.15	0.25	0.15	0.15
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.44	2.68	1.29	0.25
		Nonmetal Mineral Products	13	0.53	0.92	0.62	0.30
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.23	0.40	0.28	0.16
		Metal Products	15	0.39	0.67	0.46	0.29
		Ordinary Machinery, Equipment for Special Purpose	16	0.38	0.65	0.39	0.23
		Transportation Equipment	17	0.38	0.63	0.36	0.26
		Electric Equipment and Machinery	18	0.39	0.67	0.39	0.24
		Electronic and Telecommunications Equipment	19	0.19	0.33	0.18	0.12
		Instruments, Meters Cultural and Office Machinery	20	0.30	0.54	0.27	0.17
		Other Manufacture Products	21	0.94	1.66	1.72	0.29
		Electric Power/Steam and Hot Water Production and Supply	22	0.38	0.67	0.42	0.22
		Gas Production and Supply Industry	23	0.66	1.16	0.74	0.24
		Construction Industry	24	0.65	1.10	0.62	0.32
		Transport, Storage and Post	25	0.46	0.79	0.44	0.40
		Wholesale, Retail Trade	26	0.52	0.97	0.44	0.19
		Hotels, Catering Service	27	4.64	8.93	3.50	0.36
		Leasing and Commercial Services	28	1.15	2.19	0.89	0.27
		Research and Experimental Development	29	1.33	2.45	1.22	0.24
		Other services	30	0.62	1.14	0.55	0.17
2	Tianjin	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	19.61	8.73	7.69	2.10
		Coal Mining and Dressing	2	0.57	0.87	0.75	0.34

		Petroleum and Natural Gas Extraction	3	0.14	0.22	0.20	0.13
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.26	0.40	0.40	0.17
		Nonmetal and Other Minerals Mining and Dressing	5	0.33	0.52	0.47	0.20
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	11.76	16.53	18.94	0.68
		Textile Industry	7	6.06	9.81	14.52	0.53
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	5.01	9.13	14.50	0.46
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	3.15	4.41	4.56	0.44
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	1.29	2.03	2.10	0.35
		Petroleum Processing and Coking, Gas Production and Supply	11	0.25	0.38	0.32	0.20
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.17	1.62	1.63	0.34
		Nonmetal Mineral Products	13	0.83	1.26	1.25	0.40
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.36	0.55	0.49	0.30
		Metal Products	15	0.45	0.69	0.62	0.35
		Ordinary Machinery, Equipment for Special Purpose	16	0.42	0.65	0.61	0.29
		Transportation Equipment	17	0.42	0.63	0.51	0.32
		Electric Equipment and Machinery	18	0.40	0.61	0.54	0.29
		Electronic and Telecommunications Equipment	19	0.35	0.52	0.42	0.24
		Instruments, Meters Cultural and Office Machinery	20	0.52	0.82	0.73	0.29
		Other Manufacture Products	21	0.79	1.24	1.45	0.23
		Electric Power/Steam and Hot Water Production and Supply	22	0.51	0.78	0.64	0.32
		Gas Production and Supply Industry	23	0.38	0.60	0.50	0.23
		Construction Industry	24	0.69	1.02	0.90	0.38
		Transport, Storage and Post	25	0.80	1.23	1.15	0.38
		Wholesale, Retail Trade	26	0.80	1.17	1.18	0.19
		Hotels, Catering Service	27	5.70	8.42	8.66	0.50
		Leasing and Commercial Services	28	0.90	1.33	1.16	0.31
		Research and Experimental Development	29	0.50	0.77	0.64	0.24
		Other services	30	0.68	1.04	0.98	0.21
3	Hebei	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	18.13	14.37	2.78	0.48

Coal Mining and Dressing	2	0.87	1.05	0.41	0.51
Petroleum and Natural Gas Extraction	3	0.31	0.42	0.20	0.40
Ferrous and Nonferrous Metals Mining and Dressing	4	0.36	0.45	0.20	0.43
Nonmetal and Other Minerals Mining and Dressing	5	0.34	0.42	0.21	0.37
Food Processing, Food Production, Beverage Production, Tobacco Processing	6	9.18	9.90	4.19	0.58
Textile Industry	7	6.64	7.60	4.17	0.58
Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	4.40	5.42	3.52	0.57
Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	4.06	5.18	2.61	0.59
Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	2.89	3.12	1.26	0.56
Petroleum Processing and Coking, Gas Production and Supply	11	0.51	0.67	0.26	0.43
Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.40	1.64	0.76	0.53
Nonmetal Mineral Products	13	0.64	0.82	0.38	0.57
Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.34	0.44	0.22	0.49
Metal Products	15	0.44	0.57	0.30	0.56
Ordinary Machinery, Equipment for Special Purpose	16	0.47	0.61	0.31	0.53
Transportation Equipment	17	0.41	0.55	0.29	0.56
Electric Equipment and Machinery	18	0.43	0.56	0.30	0.54
Electronic and Telecommunications Equipment	19	0.28	0.37	0.19	0.40
Instruments, Meters Cultural and Office Machinery	20	0.40	0.56	0.26	0.45
Other Manufacture Products	21	1.85	2.33	1.59	0.55
Electric Power/Steam and Hot Water Production and Supply	22	0.75	0.97	0.40	0.62
Gas Production and Supply Industry	23	0.44	0.59	0.24	0.44
Construction Industry	24	0.65	0.81	0.40	0.56
Transport, Storage and Post	25	1.42	1.65	0.69	0.72
Wholesale, Retail Trade	26	0.29	0.38	0.16	0.75
Hotels, Catering Service	27	4.51	5.12	2.34	0.96
Leasing and Commercial Services	28	2.78	3.11	1.22	0.99
Research and Experimental Development	29	0.46	0.63	0.27	0.56
Other services	30	0.58	0.78	0.33	0.54

4	Shanxi	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	58.63	71.29	3.20	0.73
		Coal Mining and Dressing	2	2.06	2.68	0.52	0.54
		Petroleum and Natural Gas Extraction	3	0.91	1.39	0.71	0.43
		Ferrous and Nonferrous Metals Mining and Dressing	4	5.06	6.97	2.39	0.58
		Nonmetal and Other Minerals Mining and Dressing	5	1.08	1.48	0.48	0.59
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	21.32	27.41	4.68	0.57
		Textile Industry	7	28.70	36.44	6.02	0.66
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	8.38	11.42	5.40	0.56
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	10.81	13.86	2.46	0.52
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	10.95	14.09	2.63	0.51
		Petroleum Processing and Coking, Gas Production and Supply	11	0.65	0.85	0.19	0.37
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.58	2.06	0.54	0.37
		Nonmetal Mineral Products	13	0.75	1.01	0.30	0.45
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.38	0.52	0.17	0.35
		Metal Products	15	0.49	0.65	0.19	0.45
		Ordinary Machinery, Equipment for Special Purpose	16	1.53	1.99	0.45	0.46
		Transportation Equipment	17	0.44	0.60	0.20	0.44
		Electric Equipment and Machinery	18	0.68	0.91	0.33	0.42
		Electronic and Telecommunications Equipment	19	0.41	0.58	0.21	0.41
		Instruments, Meters Cultural and Office Machinery	20	0.89	1.23	0.36	0.56
		Other Manufacture Products	21	2.80	3.62	0.67	0.46
		Electric Power/Steam and Hot Water Production and Supply	22	0.81	1.06	0.25	0.44
		Gas Production and Supply Industry	23	1.13	1.52	0.43	0.59
		Construction Industry	24	1.18	1.56	0.40	0.52
		Transport, Storage and Post	25	1.94	2.55	0.56	0.82
		Wholesale, Retail Trade	26	2.97	3.84	0.69	0.75
		Hotels, Catering Service	27	8.09	11.44	3.81	0.88
		Leasing and Commercial Services	28	1.31	1.82	0.61	0.70
		Research and Experimental Development	29	1.10	1.51	0.42	0.95

		Other services	30	1.09	1.50	0.44	0.85
5	Inner Mongolia	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	58.00	146.47	310.94	0.62
		Coal Mining and Dressing	2	0.64	1.46	2.75	0.72
		Petroleum and Natural Gas Extraction	3	0.46	0.99	1.70	0.74
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.77	1.78	3.39	0.81
		Nonmetal and Other Minerals Mining and Dressing	5	0.60	1.29	2.24	0.86
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	14.36	35.65	74.20	0.67
		Textile Industry	7	21.31	52.92	111.03	0.73
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	12.32	29.43	60.13	0.77
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	14.79	37.04	77.82	0.76
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	2.14	5.15	9.96	0.76
		Petroleum Processing and Coking, Gas Production and Supply	11	0.36	0.80	1.42	0.71
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.41	3.29	6.40	0.71
		Nonmetal Mineral Products	13	0.59	1.28	2.27	0.75
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.34	0.76	1.37	0.68
		Metal Products	15	0.91	2.00	3.63	0.84
		Ordinary Machinery, Equipment for Special Purpose	16	0.42	0.88	1.49	0.82
		Transportation Equipment	17	0.45	0.91	1.44	0.87
		Electric Equipment and Machinery	18	0.53	1.17	2.16	0.74
		Electronic and Telecommunications Equipment	19	0.19	0.41	0.67	0.62
		Instruments, Meters Cultural and Office Machinery	20	0.81	1.87	3.56	0.73
		Other Manufacture Products	21	2.07	5.05	10.17	0.66
		Electric Power/Steam and Hot Water Production and Supply	22	0.34	0.73	1.27	0.74
		Gas Production and Supply Industry	23	0.43	0.96	1.70	0.90
		Construction Industry	24	0.86	1.95	3.69	0.81
		Transport, Storage and Post	25	0.97	2.19	4.04	1.23
		Wholesale, Retail Trade	26	0.64	1.50	2.86	1.22
		Hotels, Catering Service	27	9.93	23.92	47.82	1.38
		Leasing and Commercial Services	28	1.37	3.24	6.24	1.31

		Research and Experimental Development	29	2.23	5.35	10.57	1.43
		Other services	30	0.37	0.85	1.60	1.08
6	Liaoning	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	22.63	25.85	0.77	0.69
		Coal Mining and Dressing	2	0.85	1.04	0.18	0.34
		Petroleum and Natural Gas Extraction	3	0.21	0.27	0.08	0.27
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.69	0.87	0.22	0.51
		Nonmetal and Other Minerals Mining and Dressing	5	0.78	1.00	0.29	0.51
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	12.73	15.22	1.39	0.62
		Textile Industry	7	6.66	8.42	2.90	0.56
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	6.26	7.97	2.86	0.57
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	4.83	5.90	0.83	0.56
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	3.34	4.16	0.72	0.54
		Petroleum Processing and Coking, Gas Production and Supply	11	0.24	0.32	0.10	0.33
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.80	2.22	0.39	0.47
		Nonmetal Mineral Products	13	0.81	1.05	0.36	0.54
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.35	0.45	0.15	0.40
		Metal Products	15	0.55	0.71	0.22	0.49
		Ordinary Machinery, Equipment for Special Purpose	16	0.52	0.66	0.19	0.46
		Transportation Equipment	17	0.48	0.62	0.19	0.47
		Electric Equipment and Machinery	18	0.49	0.64	0.19	0.45
		Electronic and Telecommunications Equipment	19	0.35	0.45	0.11	0.32
		Instruments, Meters Cultural and Office Machinery	20	0.54	0.70	0.19	0.39
		Other Manufacture Products	21	5.35	6.53	1.17	0.52
		Electric Power/Steam and Hot Water Production and Supply	22	0.43	0.59	0.30	0.49
		Gas Production and Supply Industry	23	0.63	0.82	0.26	0.44
		Construction Industry	24	0.69	0.88	0.25	0.52
		Transport, Storage and Post	25	0.97	1.19	0.19	0.88
		Wholesale, Retail Trade	26	0.54	0.69	0.13	0.36
		Hotels, Catering Service	27	9.61	11.63	1.29	0.60

		Leasing and Commercial Services	28	1.28	1.61	0.30	0.45
		Research and Experimental Development	29	1.07	1.35	0.26	0.45
		Other services	30	0.96	1.21	0.22	0.34
7	Jilin	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	47.74	60.53	3.56	1.00
		Coal Mining and Dressing	2	1.73	2.29	0.53	0.56
		Petroleum and Natural Gas Extraction	3	0.39	0.53	0.17	0.40
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.88	1.18	0.36	0.58
		Nonmetal and Other Minerals Mining and Dressing	5	0.87	1.18	0.40	0.58
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	21.64	28.00	5.46	0.84
		Textile Industry	7	3.49	4.91	2.98	0.60
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	5.47	7.50	3.00	0.58
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	14.45	18.87	3.42	0.79
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	2.97	4.20	0.92	0.64
		Petroleum Processing and Coking, Gas Production and Supply	11	0.34	0.46	0.14	0.47
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	3.97	5.19	1.09	0.59
		Nonmetal Mineral Products	13	1.06	1.44	0.50	0.67
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.57	0.78	0.29	0.56
		Metal Products	15	0.94	1.28	0.41	0.61
		Ordinary Machinery, Equipment for Special Purpose	16	0.71	0.96	0.34	0.59
		Transportation Equipment	17	0.77	1.04	0.39	0.69
		Electric Equipment and Machinery	18	0.77	1.05	0.46	0.59
		Electronic and Telecommunications Equipment	19	0.50	0.69	0.24	0.46
		Instruments, Meters Cultural and Office Machinery	20	0.83	1.12	0.35	0.57
		Other Manufacture Products	21	8.28	10.79	1.94	0.64
		Electric Power/Steam and Hot Water Production and Supply	22	0.64	0.90	0.43	0.63
		Gas Production and Supply Industry	23	0.49	0.67	0.24	0.52
		Construction Industry	24	1.00	1.36	0.42	0.64
		Transport, Storage and Post	25	4.74	6.15	1.07	1.27
		Wholesale, Retail Trade	26	0.60	0.82	0.25	0.59

		Hotels, Catering Service	27	11.98	15.52	4.83	0.91
		Leasing and Commercial Services	28	1.41	1.94	0.59	0.80
		Research and Experimental Development	29	1.31	1.72	0.42	0.33
		Other services	30	1.02	1.37	0.39	0.29
8	Heilongjiang	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	77.02	105.99	6.43	1.39
		Coal Mining and Dressing	2	1.43	1.98	0.33	0.60
		Petroleum and Natural Gas Extraction	3	0.09	0.13	0.03	0.29
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.58	0.81	0.20	0.59
		Nonmetal and Other Minerals Mining and Dressing	5	0.46	0.63	0.14	0.59
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	35.48	48.76	4.96	1.06
		Textile Industry	7	13.21	18.24	2.98	0.76
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	17.10	23.66	4.44	0.81
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	16.22	22.39	2.48	0.83
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	9.07	12.56	1.44	0.79
		Petroleum Processing and Coking, Gas Production and Supply	11	0.16	0.22	0.05	0.43
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	3.16	4.33	0.57	0.65
		Nonmetal Mineral Products	13	1.05	1.45	0.31	0.73
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.68	0.95	0.24	0.61
		Metal Products	15	0.99	1.35	0.29	0.71
		Ordinary Machinery, Equipment for Special Purpose	16	0.65	0.89	0.22	0.64
		Transportation Equipment	17	0.79	1.09	0.27	0.72
		Electric Equipment and Machinery	18	0.75	1.03	0.23	0.62
		Electronic and Telecommunications Equipment	19	1.41	1.94	0.28	0.56
		Instruments, Meters Cultural and Office Machinery	20	0.67	0.93	0.17	0.56
		Other Manufacture Products	21	9.31	12.81	1.37	0.60
		Electric Power/Steam and Hot Water Production and Supply	22	0.60	0.84	0.18	0.62
		Gas Production and Supply Industry	23	0.60	0.82	0.18	0.56
		Construction Industry	24	0.86	1.19	0.28	0.71
		Transport, Storage and Post	25	0.98	1.35	0.22	1.64

		Wholesale, Retail Trade	26	0.99	1.37	0.23	0.69
		Hotels, Catering Service	27	21.79	29.81	3.76	1.06
		Leasing and Commercial Services	28	2.09	2.89	0.43	0.86
		Research and Experimental Development	29	1.65	2.28	0.33	0.93
		Other services	30	1.39	1.91	0.28	0.78
9	Shanghai	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	10.20	5.85	2.65	0.30
		Coal Mining and Dressing	2	0.00	0.00	0.00	0.00
		Petroleum and Natural Gas Extraction	3	0.25	0.39	0.23	0.16
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.00	0.00	0.00	0.00
		Nonmetal and Other Minerals Mining and Dressing	5	0.00	0.00	0.00	0.00
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	3.26	4.58	2.97	0.21
		Textile Industry	7	2.56	3.81	3.21	0.31
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	1.66	2.53	2.09	0.27
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	1.71	2.65	1.28	0.28
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	0.53	0.86	0.38	0.23
		Petroleum Processing and Coking, Gas Production and Supply	11	0.20	0.32	0.21	0.19
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	0.75	1.05	0.72	0.22
		Nonmetal Mineral Products	13	0.39	0.59	0.35	0.28
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.30	0.47	0.36	0.26
		Metal Products	15	0.37	0.59	0.37	0.26
		Ordinary Machinery, Equipment for Special Purpose	16	0.29	0.46	0.30	0.24
		Transportation Equipment	17	0.32	0.51	0.29	0.23
		Electric Equipment and Machinery	18	0.32	0.50	0.32	0.23
		Electronic and Telecommunications Equipment	19	0.14	0.22	0.13	0.13
		Instruments, Meters Cultural and Office Machinery	20	0.25	0.40	0.23	0.17
		Other Manufacture Products	21	0.56	0.85	0.52	0.26
		Electric Power/Steam and Hot Water Production and Supply	22	0.49	0.69	0.50	0.32
		Gas Production and Supply Industry	23	0.43	0.62	0.46	0.30
		Construction Industry	24	0.50	0.76	0.41	0.31

		Transport, Storage and Post	25	0.57	0.86	0.51	0.28
		Wholesale, Retail Trade	26	0.18	0.28	0.16	0.13
		Hotels, Catering Service	27	3.79	5.44	3.56	0.27
		Leasing and Commercial Services	28	0.42	0.66	0.39	0.22
		Research and Experimental Development	29	0.35	0.56	0.31	0.19
		Other services	30	0.40	0.63	0.36	0.15
10	Jiangsu	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	14.65	3.25	1.56	0.61
		Coal Mining and Dressing	2	0.52	0.52	0.26	0.29
		Petroleum and Natural Gas Extraction	3	0.15	0.17	0.10	0.17
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.47	0.50	0.28	0.34
		Nonmetal and Other Minerals Mining and Dressing	5	0.56	0.62	0.35	0.39
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	7.84	5.27	3.18	0.47
		Textile Industry	7	4.46	3.30	2.36	0.43
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	2.77	2.40	1.81	0.39
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	3.96	2.90	1.44	0.43
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	1.73	1.38	0.80	0.37
		Petroleum Processing and Coking, Gas Production and Supply	11	0.27	0.34	0.18	0.27
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.09	1.01	0.61	0.37
		Nonmetal Mineral Products	13	0.63	0.69	0.36	0.41
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.41	0.46	0.29	0.37
		Metal Products	15	0.53	0.58	0.34	0.39
		Ordinary Machinery, Equipment for Special Purpose	16	0.42	0.46	0.27	0.36
		Transportation Equipment	17	0.43	0.47	0.27	0.36
		Electric Equipment and Machinery	18	0.44	0.49	0.30	0.37
		Electronic and Telecommunications Equipment	19	0.26	0.28	0.16	0.25
		Instruments, Meters Cultural and Office Machinery	20	0.39	0.42	0.24	0.30
		Other Manufacture Products	21	2.56	2.08	1.33	0.39
		Electric Power/Steam and Hot Water Production and Supply	22	0.53	0.65	0.34	0.37
		Gas Production and Supply Industry	23	0.24	0.28	0.16	0.23

		Construction Industry	24	0.70	0.72	0.40	0.41
		Transport, Storage and Post	25	0.47	0.57	0.34	0.72
		Wholesale, Retail Trade	26	0.27	0.27	0.16	0.33
		Hotels, Catering Service	27	4.93	4.20	2.45	0.53
		Leasing and Commercial Services	28	0.92	0.87	0.50	0.48
		Research and Experimental Development	29	1.76	1.45	0.90	0.40
		Other services	30	0.48	0.47	0.27	0.26
11	Zhejiang	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	11.40	31.39	0.74	0.84
		Coal Mining and Dressing	2	0.49	1.03	0.23	0.19
		Petroleum and Natural Gas Extraction	3	0.00	0.00	0.00	0.00
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.30	0.56	0.18	0.27
		Nonmetal and Other Minerals Mining and Dressing	5	0.47	0.92	0.26	0.31
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	5.47	12.24	2.04	0.43
		Textile Industry	7	2.07	3.93	1.29	0.34
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	1.58	2.90	1.07	0.31
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	2.18	4.61	0.98	0.35
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	0.56	1.07	0.31	0.28
		Petroleum Processing and Coking, Gas Production and Supply	11	0.14	0.26	0.24	0.25
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	0.73	1.50	0.34	0.28
		Nonmetal Mineral Products	13	0.40	0.72	0.23	0.33
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.30	0.54	0.26	0.34
		Metal Products	15	0.34	0.63	0.26	0.34
		Ordinary Machinery, Equipment for Special Purpose	16	0.31	0.57	0.22	0.29
		Transportation Equipment	17	0.33	0.60	0.24	0.31
		Electric Equipment and Machinery	18	0.41	0.76	0.29	0.31
		Electronic and Telecommunications Equipment	19	0.18	0.35	0.12	0.19
		Instruments, Meters Cultural and Office Machinery	20	0.28	0.53	0.18	0.24
		Other Manufacture Products	21	0.76	1.43	0.49	0.31
		Electric Power/Steam and Hot Water Production and Supply	22	0.40	0.68	0.21	0.30

		Gas Production and Supply Industry	23	0.31	0.60	0.20	0.24
		Construction Industry	24	0.48	0.95	0.28	0.31
		Transport, Storage and Post	25	0.36	0.72	0.22	0.68
		Wholesale, Retail Trade	26	0.29	0.60	0.16	0.32
		Hotels, Catering Service	27	4.38	9.58	1.76	0.52
		Leasing and Commercial Services	28	0.73	1.52	0.37	0.40
		Research and Experimental Development	29	2.64	5.92	1.01	0.35
		Other services	30	0.61	1.31	0.27	0.23
12	Anhui	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	24.43	17.20	1.50	1.04
		Coal Mining and Dressing	2	0.85	0.86	0.27	0.63
		Petroleum and Natural Gas Extraction	3	0.00	0.00	0.00	0.00
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.37	0.47	0.19	0.69
		Nonmetal and Other Minerals Mining and Dressing	5	0.79	0.92	0.38	0.86
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	12.12	11.73	3.86	0.97
		Textile Industry	7	9.71	9.34	3.26	0.96
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	6.82	6.52	2.34	0.92
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	8.50	7.94	2.15	0.94
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	2.04	2.43	0.96	0.83
		Petroleum Processing and Coking, Gas Production and Supply	11	0.29	0.42	0.18	0.56
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.45	1.56	0.59	0.78
		Nonmetal Mineral Products	13	0.56	0.67	0.27	0.84
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.34	0.46	0.22	0.67
		Metal Products	15	0.28	0.38	0.17	0.62
		Ordinary Machinery, Equipment for Special Purpose	16	0.46	0.58	0.25	0.74
		Transportation Equipment	17	0.40	0.54	0.24	0.76
		Electric Equipment and Machinery	18	0.50	0.65	0.28	0.78
		Electronic and Telecommunications Equipment	19	0.26	0.34	0.15	0.55
		Instruments, Meters Cultural and Office Machinery	20	0.40	0.51	0.21	0.63
		Other Manufacture Products	21	2.50	2.71	1.07	0.86

		Electric Power/Steam and Hot Water Production and Supply	22	0.53	0.62	0.25	0.75
		Gas Production and Supply Industry	23	0.53	0.64	0.27	0.69
		Construction Industry	24	0.79	0.87	0.32	0.82
		Transport, Storage and Post	25	0.80	0.94	0.35	1.20
		Wholesale, Retail Trade	26	0.47	0.54	0.19	0.94
		Hotels, Catering Service	27	9.84	9.42	3.04	1.26
		Leasing and Commercial Services	28	1.43	1.61	0.56	1.13
		Research and Experimental Development	29	0.36	0.46	0.18	0.60
		Other services	30	1.15	1.33	0.51	0.72
13	Fujian	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	7.46	43.42	0.45	0.48
		Coal Mining and Dressing	2	0.26	1.02	0.09	0.21
		Petroleum and Natural Gas Extraction	3	0.00	0.00	0.00	0.00
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.20	0.66	0.10	0.33
		Nonmetal and Other Minerals Mining and Dressing	5	0.64	2.46	0.22	0.42
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	3.83	16.48	1.04	0.40
		Textile Industry	7	2.06	7.03	0.95	0.43
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	1.07	3.33	0.55	0.37
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	2.34	10.82	0.53	0.41
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	0.58	1.68	0.27	0.39
		Petroleum Processing and Coking, Gas Production and Supply	11	0.36	1.31	0.15	0.31
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.05	4.37	0.31	0.36
		Nonmetal Mineral Products	13	0.31	0.91	0.15	0.40
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.19	0.55	0.10	0.36
		Metal Products	15	0.25	0.76	0.13	0.41
		Ordinary Machinery, Equipment for Special Purpose	16	0.26	0.80	0.13	0.37
		Transportation Equipment	17	0.31	0.95	0.15	0.36
		Electric Equipment and Machinery	18	0.29	0.95	0.13	0.36
		Electronic and Telecommunications Equipment	19	0.19	0.60	0.09	0.27
		Instruments, Meters Cultural and Office Machinery	20	0.27	0.89	0.12	0.30

		Other Manufacture Products	21	0.56	1.68	0.29	0.39
		Electric Power/Steam and Hot Water Production and Supply	22	0.24	0.72	0.12	0.37
		Gas Production and Supply Industry	23	0.24	0.71	0.12	0.31
		Construction Industry	24	0.50	1.86	0.19	0.39
		Transport, Storage and Post	25	0.35	1.20	0.15	0.68
		Wholesale, Retail Trade	26	0.25	0.86	0.11	0.36
		Hotels, Catering Service	27	3.59	14.53	1.09	0.54
		Leasing and Commercial Services	28	0.46	1.62	0.19	0.45
		Research and Experimental Development	29	0.52	1.85	0.20	0.33
		Other services	30	0.34	1.22	0.14	0.27
14	Jiangxi	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	21.02	70.38	0.27	1.47
		Coal Mining and Dressing	2	1.16	3.50	0.19	0.68
		Petroleum and Natural Gas Extraction	3	0.00	0.00	0.00	0.00
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.52	1.46	0.14	0.79
		Nonmetal and Other Minerals Mining and Dressing	5	0.48	1.31	0.14	0.77
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	9.52	29.15	1.42	1.03
		Textile Industry	7	3.88	11.93	0.55	0.92
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	2.25	6.76	0.40	0.87
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	2.14	6.47	0.35	0.84
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	1.72	5.24	0.26	0.79
		Petroleum Processing and Coking, Gas Production and Supply	11	0.30	0.82	0.11	0.55
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.27	3.81	0.23	0.75
		Nonmetal Mineral Products	13	0.58	1.61	0.15	0.76
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.35	0.94	0.10	0.76
		Metal Products	15	0.38	1.04	0.11	0.81
		Ordinary Machinery, Equipment for Special Purpose	16	0.36	1.00	0.10	0.74
		Transportation Equipment	17	0.35	0.97	0.10	0.78
		Electric Equipment and Machinery	18	0.33	0.90	0.09	0.74
		Electronic and Telecommunications Equipment	19	0.17	0.50	0.04	0.45

		Instruments, Meters Cultural and Office Machinery	20	0.32	0.89	0.09	0.63
		Other Manufacture Products	21	2.74	8.21	0.49	0.80
		Electric Power/Steam and Hot Water Production and Supply	22	0.52	1.39	0.16	0.77
		Gas Production and Supply Industry	23	0.44	1.23	0.12	0.64
		Construction Industry	24	0.47	1.34	0.11	0.69
		Transport, Storage and Post	25	0.52	1.51	0.11	1.15
		Wholesale, Retail Trade	26	0.52	1.46	0.14	0.83
		Hotels, Catering Service	27	5.09	15.23	0.93	1.07
		Leasing and Commercial Services	28	3.61	11.02	0.56	1.07
		Research and Experimental Development	29	0.74	2.09	0.20	1.13
		Other services	30	0.49	1.41	0.11	0.92
15	Shandong	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	15.08	5.34	2.14	0.58
		Coal Mining and Dressing	2	0.82	0.70	0.48	0.35
		Petroleum and Natural Gas Extraction	3	0.53	0.48	0.32	0.33
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.87	0.78	0.52	0.44
		Nonmetal and Other Minerals Mining and Dressing	5	0.65	0.59	0.39	0.35
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	7.91	6.74	4.74	0.52
		Textile Industry	7	5.73	4.43	3.22	0.52
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	3.28	2.68	1.94	0.48
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	2.98	2.51	1.76	0.46
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	1.95	1.57	1.08	0.45
		Petroleum Processing and Coking, Gas Production and Supply	11	0.36	0.33	0.22	0.31
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.58	1.34	0.90	0.42
		Nonmetal Mineral Products	13	0.86	0.77	0.52	0.44
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.50	0.46	0.31	0.37
		Metal Products	15	0.69	0.64	0.43	0.44
		Ordinary Machinery, Equipment for Special Purpose	16	0.74	0.68	0.46	0.41
		Transportation Equipment	17	0.55	0.52	0.34	0.42
		Electric Equipment and Machinery	18	0.62	0.57	0.38	0.42

		Electronic and Telecommunications Equipment	19	0.33	0.30	0.20	0.28
		Instruments, Meters Cultural and Office Machinery	20	0.69	0.63	0.42	0.37
		Other Manufacture Products	21	2.53	2.05	1.48	0.43
		Electric Power/Steam and Hot Water Production and Supply	22	0.65	0.60	0.40	0.43
		Gas Production and Supply Industry	23	0.95	0.87	0.56	0.42
		Construction Industry	24	0.80	0.70	0.48	0.42
		Transport, Storage and Post	25	0.87	0.78	0.52	0.71
		Wholesale, Retail Trade	26	0.41	0.39	0.26	0.41
		Hotels, Catering Service	27	5.60	5.09	3.49	0.60
		Leasing and Commercial Services	28	0.78	0.72	0.47	0.50
		Research and Experimental Development	29	0.71	0.68	0.45	0.35
		Other services	30	0.56	0.50	0.33	0.31
16	Henan	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	19.06	9.66	1.67	0.59
		Coal Mining and Dressing	2	0.99	0.87	0.44	0.58
		Petroleum and Natural Gas Extraction	3	0.71	0.65	0.34	0.56
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.52	0.50	0.26	0.57
		Nonmetal and Other Minerals Mining and Dressing	5	0.72	0.70	0.36	0.68
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	8.43	6.32	3.01	0.67
		Textile Industry	7	5.83	4.47	2.31	0.67
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	6.86	5.11	2.49	0.68
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	4.31	3.66	2.04	0.65
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	1.97	1.61	0.78	0.64
		Petroleum Processing and Coking, Gas Production and Supply	11	0.56	0.53	0.27	0.52
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.81	1.53	0.78	0.64
		Nonmetal Mineral Products	13	0.92	0.86	0.45	0.72
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.45	0.44	0.25	0.61
		Metal Products	15	0.83	0.78	0.43	0.71
		Ordinary Machinery, Equipment for Special Purpose	16	0.83	0.77	0.42	0.66
		Transportation Equipment	17	0.72	0.70	0.37	0.66

		Electric Equipment and Machinery	18	0.82	0.75	0.41	0.67
		Electronic and Telecommunications Equipment	19	0.43	0.40	0.21	0.49
		Instruments, Meters Cultural and Office Machinery	20	0.61	0.57	0.30	0.58
		Other Manufacture Products	21	2.51	2.10	1.10	0.69
		Electric Power/Steam and Hot Water Production and Supply	22	0.87	0.85	0.43	0.74
		Gas Production and Supply Industry	23	0.74	0.72	0.37	0.67
		Construction Industry	24	0.77	0.71	0.38	0.68
		Transport, Storage and Post	25	0.86	0.81	0.43	1.14
		Wholesale, Retail Trade	26	0.86	0.77	0.40	0.79
		Hotels, Catering Service	27	6.09	5.14	2.66	0.96
		Leasing and Commercial Services	28	1.06	0.98	0.50	0.89
		Research and Experimental Development	29	1.30	1.17	0.60	0.76
		Other services	30	0.97	0.88	0.45	0.70
17	Hubei	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	19.60	32.11	0.84	1.05
		Coal Mining and Dressing	2	1.51	2.53	0.59	0.65
		Petroleum and Natural Gas Extraction	3	1.19	2.00	0.36	0.63
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.82	1.37	0.25	0.73
		Nonmetal and Other Minerals Mining and Dressing	5	0.81	1.36	0.26	0.71
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	10.29	17.23	2.16	0.88
		Textile Industry	7	3.96	6.56	1.05	0.83
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	3.77	6.26	0.98	0.82
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	3.35	5.59	0.68	0.71
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	1.94	3.25	0.45	0.73
		Petroleum Processing and Coking, Gas Production and Supply	11	0.67	1.13	0.22	0.51
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	0.75	1.25	0.23	0.63
		Nonmetal Mineral Products	13	0.48	0.78	0.18	0.68
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.45	0.73	0.19	0.62
		Metal Products	15	0.31	0.52	0.12	0.63
		Ordinary Machinery, Equipment for Special Purpose	16	0.31	0.51	0.11	0.61

		Transportation Equipment	17	0.72	1.20	0.21	0.65
		Electric Equipment and Machinery	18	0.28	0.46	0.11	0.59
		Electronic and Telecommunications Equipment	19	0.17	0.29	0.06	0.46
		Instruments, Meters Cultural and Office Machinery	20	0.25	0.41	0.09	0.54
		Other Manufacture Products	21	0.67	1.12	0.20	0.64
		Electric Power/Steam and Hot Water Production and Supply	22	0.60	1.00	0.20	0.58
		Gas Production and Supply Industry	23	0.43	0.72	0.14	0.52
		Construction Industry	24	0.83	1.37	0.24	0.76
		Transport, Storage and Post	25	0.82	1.36	0.22	0.80
		Wholesale, Retail Trade	26	0.34	0.57	0.10	0.61
		Hotels, Catering Service	27	5.46	9.22	1.47	0.96
		Leasing and Commercial Services	28	0.90	1.52	0.26	0.94
		Research and Experimental Development	29	1.57	2.63	0.36	0.38
		Other services	30	0.36	0.60	0.10	0.28
18	Hunan	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	13.30	38.94	0.36	0.64
		Coal Mining and Dressing	2	0.60	1.55	0.12	0.60
		Petroleum and Natural Gas Extraction	3	0.00	0.00	0.00	0.00
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.34	0.86	0.10	0.63
		Nonmetal and Other Minerals Mining and Dressing	5	0.41	1.00	0.12	0.64
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	4.68	12.80	0.65	0.57
		Textile Industry	7	3.91	10.79	0.50	0.63
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	2.71	7.37	0.41	0.62
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	4.74	13.34	0.46	0.62
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	2.45	6.81	0.27	0.57
		Petroleum Processing and Coking, Gas Production and Supply	11	0.19	0.43	0.12	0.39
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	0.47	1.20	0.11	0.54
		Nonmetal Mineral Products	13	0.31	0.72	0.11	0.60
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.27	0.65	0.09	0.53
		Metal Products	15	0.42	1.08	0.11	0.59

		Ordinary Machinery, Equipment for Special Purpose	16	0.25	0.60	0.08	0.54
		Transportation Equipment	17	0.30	0.74	0.09	0.57
		Electric Equipment and Machinery	18	0.28	0.69	0.08	0.54
		Electronic and Telecommunications Equipment	19	0.16	0.39	0.05	0.43
		Instruments, Meters Cultural and Office Machinery	20	0.28	0.71	0.08	0.47
		Other Manufacture Products	21	0.66	1.61	0.21	0.58
		Electric Power/Steam and Hot Water Production and Supply	22	0.39	0.96	0.12	0.66
		Gas Production and Supply Industry	23	0.24	0.59	0.09	0.51
		Construction Industry	24	0.58	1.50	0.12	0.64
		Transport, Storage and Post	25	0.62	1.67	0.11	1.06
		Wholesale, Retail Trade	26	0.19	0.50	0.04	0.78
		Hotels, Catering Service	27	3.00	8.05	0.51	0.94
		Leasing and Commercial Services	28	0.53	1.40	0.11	0.93
		Research and Experimental Development	29	0.33	0.85	0.08	0.83
		Other services	30	0.40	1.05	0.08	0.78
19	Guangdong	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	9.21	34.08	0.49	0.71
		Coal Mining and Dressing	2	0.00	0.00	0.00	0.00
		Petroleum and Natural Gas Extraction	3	0.11	0.25	0.06	0.15
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.29	0.72	0.19	0.32
		Nonmetal and Other Minerals Mining and Dressing	5	0.16	0.31	0.10	0.25
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	4.94	15.15	0.99	0.46
		Textile Industry	7	2.07	4.42	1.18	0.40
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	1.87	4.24	0.98	0.37
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	2.50	7.03	0.69	0.39
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	0.43	0.91	0.21	0.32
		Petroleum Processing and Coking, Gas Production and Supply	11	0.12	0.21	0.10	0.23
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	0.68	1.73	0.26	0.31
		Nonmetal Mineral Products	13	0.34	0.64	0.18	0.35
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.28	0.68	0.23	0.40

		Metal Products	15	0.31	0.71	0.20	0.38
		Ordinary Machinery, Equipment for Special Purpose	16	0.24	0.55	0.15	0.33
		Transportation Equipment	17	0.31	0.70	0.17	0.33
		Electric Equipment and Machinery	18	0.27	0.64	0.17	0.33
		Electronic and Telecommunications Equipment	19	0.11	0.24	0.07	0.21
		Instruments, Meters Cultural and Office Machinery	20	0.19	0.41	0.10	0.26
		Other Manufacture Products	21	0.51	1.18	0.29	0.35
		Electric Power/Steam and Hot Water Production and Supply	22	0.38	0.68	0.20	0.37
		Gas Production and Supply Industry	23	0.22	0.52	0.11	0.23
		Construction Industry	24	0.50	1.29	0.20	0.36
		Transport, Storage and Post	25	0.24	0.55	0.12	0.53
		Wholesale, Retail Trade	26	0.24	0.62	0.09	0.30
		Hotels, Catering Service	27	3.06	9.05	0.68	0.47
		Leasing and Commercial Services	28	0.51	1.23	0.23	0.37
		Research and Experimental Development	29	0.40	0.97	0.15	0.28
		Other services	30	0.27	0.71	0.10	0.20
20	Guangxi	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	17.63	52.68	0.21	0.76
		Coal Mining and Dressing	2	0.74	1.95	0.14	0.61
		Petroleum and Natural Gas Extraction	3	0.00	0.00	0.00	0.00
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.58	1.49	0.14	0.72
		Nonmetal and Other Minerals Mining and Dressing	5	0.47	1.19	0.12	0.63
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	9.36	26.59	0.69	0.76
		Textile Industry	7	6.29	16.91	1.03	0.68
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	5.38	14.64	0.77	0.66
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	5.09	14.25	0.47	0.68
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	2.73	7.56	0.30	0.64
		Petroleum Processing and Coking, Gas Production and Supply	11	0.19	0.46	0.06	0.56
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.93	5.32	0.24	0.63
		Nonmetal Mineral Products	13	0.52	1.29	0.15	0.74

		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.30	0.72	0.10	0.66
		Metal Products	15	0.35	0.85	0.12	0.73
		Ordinary Machinery, Equipment for Special Purpose	16	0.32	0.78	0.11	0.64
		Transportation Equipment	17	0.35	0.84	0.11	0.76
		Electric Equipment and Machinery	18	0.33	0.82	0.11	0.64
		Electronic and Telecommunications Equipment	19	0.21	0.51	0.06	0.45
		Instruments, Meters Cultural and Office Machinery	20	0.24	0.60	0.08	0.49
		Other Manufacture Products	21	1.08	2.80	0.21	0.58
		Electric Power/Steam and Hot Water Production and Supply	22	0.22	0.51	0.07	0.58
		Gas Production and Supply Industry	23	0.27	0.67	0.07	0.51
		Construction Industry	24	0.66	1.67	0.16	0.76
		Transport, Storage and Post	25	0.95	2.60	0.14	1.49
		Wholesale, Retail Trade	26	0.13	0.33	0.03	0.59
		Hotels, Catering Service	27	4.75	12.95	0.54	0.92
		Leasing and Commercial Services	28	1.03	2.58	0.25	0.96
		Research and Experimental Development	29	0.64	1.61	0.16	1.02
		Other services	30	0.30	0.77	0.07	0.81
21	Hainan	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	10.26	17.09	0.16	0.86
		Coal Mining and Dressing	2	0.00	0.00	0.00	0.00
		Petroleum and Natural Gas Extraction	3	0.00	0.00	0.00	0.00
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.46	0.80	0.12	0.47
		Nonmetal and Other Minerals Mining and Dressing	5	0.48	0.85	0.13	0.40
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	5.36	9.18	0.15	0.59
		Textile Industry	7	1.14	1.98	0.17	0.55
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	0.94	1.63	0.22	0.59
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	2.14	3.67	0.14	0.54
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	3.65	6.24	0.13	0.56
		Petroleum Processing and Coking, Gas Production and Supply	11	0.74	1.29	0.20	0.48
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.63	2.82	0.14	0.45

		Nonmetal Mineral Products	13	0.70	1.23	0.16	0.57
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.71	1.24	0.18	0.51
		Metal Products	15	1.32	2.27	0.22	0.56
		Ordinary Machinery, Equipment for Special Purpose	16	0.72	1.26	0.19	0.45
		Transportation Equipment	17	0.43	0.78	0.12	0.35
		Electric Equipment and Machinery	18	0.94	1.65	0.16	0.48
		Electronic and Telecommunications Equipment	19	0.38	0.67	0.08	0.26
		Instruments, Meters Cultural and Office Machinery	20	0.92	1.64	0.27	0.47
		Other Manufacture Products	21	0.65	1.15	0.13	0.39
		Electric Power/Steam and Hot Water Production and Supply	22	0.63	1.11	0.16	0.39
		Gas Production and Supply Industry	23	0.83	1.44	0.17	0.64
		Construction Industry	24	1.41	2.45	0.19	0.61
		Transport, Storage and Post	25	0.85	1.49	0.16	0.92
		Wholesale, Retail Trade	26	1.00	1.74	0.22	1.40
		Hotels, Catering Service	27	4.39	7.50	0.18	1.48
		Leasing and Commercial Services	28	1.67	2.91	0.42	1.50
		Research and Experimental Development	29	0.76	1.32	0.15	1.03
		Other services	30	1.13	1.95	0.19	1.09
22	Chongqing	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	25.93	40.83	1.09	0.49
		Coal Mining and Dressing	2	0.45	0.79	0.11	0.41
		Petroleum and Natural Gas Extraction	3	0.31	0.54	0.11	0.48
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.20	0.36	0.07	0.36
		Nonmetal and Other Minerals Mining and Dressing	5	1.07	1.80	0.23	0.61
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	8.04	13.71	1.35	0.50
		Textile Industry	7	7.09	11.59	0.92	0.53
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	2.54	4.20	0.46	0.51
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	2.73	4.55	0.50	0.58
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	0.65	1.06	0.15	0.50
		Petroleum Processing and Coking, Gas Production and Supply	11	0.27	0.48	0.09	0.44

		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	0.99	1.68	0.19	0.48
		Nonmetal Mineral Products	13	0.63	1.11	0.17	0.52
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.39	0.70	0.14	0.51
		Metal Products	15	0.41	0.74	0.15	0.55
		Ordinary Machinery, Equipment for Special Purpose	16	0.36	0.64	0.12	0.52
		Transportation Equipment	17	0.23	0.42	0.10	0.54
		Electric Equipment and Machinery	18	0.41	0.73	0.15	0.55
		Electronic and Telecommunications Equipment	19	0.11	0.20	0.04	0.36
		Instruments, Meters Cultural and Office Machinery	20	0.32	0.56	0.11	0.47
		Other Manufacture Products	21	3.11	5.13	0.43	0.55
		Electric Power/Steam and Hot Water Production and Supply	22	0.29	0.53	0.11	0.48
		Gas Production and Supply Industry	23	0.44	0.77	0.14	0.51
		Construction Industry	24	0.99	1.69	0.22	0.59
		Transport, Storage and Post	25	1.33	2.21	0.22	0.93
		Wholesale, Retail Trade	26	0.25	0.43	0.07	0.33
		Hotels, Catering Service	27	4.92	8.80	1.12	0.52
		Leasing and Commercial Services	28	0.54	0.95	0.17	0.49
		Research and Experimental Development	29	0.67	1.14	0.17	0.50
		Other services	30	0.42	0.74	0.12	0.43
23	Sichuan	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	19.69	64.01	31.42	0.51
		Coal Mining and Dressing	2	0.63	1.87	0.92	0.61
		Petroleum and Natural Gas Extraction	3	0.42	1.19	0.59	0.59
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.44	1.27	0.64	0.59
		Nonmetal and Other Minerals Mining and Dressing	5	0.48	1.38	0.69	0.68
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	7.16	22.12	10.60	0.57
		Textile Industry	7	5.73	17.83	8.71	0.60
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	3.83	11.62	5.60	0.61
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	4.43	13.77	6.69	0.62
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	2.55	7.82	3.82	0.60

		Petroleum Processing and Coking, Gas Production and Supply	11	0.24	0.68	0.35	0.50
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.20	3.67	1.86	0.58
		Nonmetal Mineral Products	13	0.56	1.64	0.82	0.66
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.26	0.73	0.38	0.58
		Metal Products	15	0.32	0.87	0.45	0.62
		Ordinary Machinery, Equipment for Special Purpose	16	0.32	0.88	0.45	0.59
		Transportation Equipment	17	0.39	1.10	0.55	0.61
		Electric Equipment and Machinery	18	0.34	0.96	0.50	0.58
		Electronic and Telecommunications Equipment	19	0.36	1.04	0.52	0.45
		Instruments, Meters Cultural and Office Machinery	20	0.41	1.16	0.56	0.53
		Other Manufacture Products	21	1.53	4.50	2.18	0.61
		Electric Power/Steam and Hot Water Production and Supply	22	0.46	1.33	0.65	0.63
		Gas Production and Supply Industry	23	0.35	1.01	0.53	0.57
		Construction Industry	24	0.47	1.35	0.67	0.62
		Transport, Storage and Post	25	0.38	1.12	0.55	1.48
		Wholesale, Retail Trade	26	0.51	1.52	0.73	0.75
		Hotels, Catering Service	27	4.84	14.63	6.86	0.86
		Leasing and Commercial Services	28	0.82	2.42	1.15	0.90
		Research and Experimental Development	29	0.51	1.50	0.72	0.83
		Other services	30	0.70	2.07	1.00	0.85
24	Guizhou	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	47.15	93.15	1.05	0.53
		Coal Mining and Dressing	2	1.13	2.25	0.19	0.89
		Petroleum and Natural Gas Extraction	3	0.00	0.00	0.00	0.00
		Ferrous and Nonferrous Metals Mining and Dressing	4	1.16	2.31	0.20	0.96
		Nonmetal and Other Minerals Mining and Dressing	5	0.89	1.75	0.18	0.81
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	14.12	28.43	0.90	0.68
		Textile Industry	7	11.32	22.48	1.06	0.83
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	4.27	8.19	0.98	0.78
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	13.95	28.11	1.02	0.81

		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	1.17	2.24	0.26	0.76
		Petroleum Processing and Coking, Gas Production and Supply	11	0.47	0.91	0.12	0.74
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	4.06	8.15	0.36	0.80
		Nonmetal Mineral Products	13	1.15	2.30	0.19	0.87
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.56	1.13	0.13	0.85
		Metal Products	15	0.67	1.37	0.17	0.87
		Ordinary Machinery, Equipment for Special Purpose	16	0.47	0.96	0.15	0.74
		Transportation Equipment	17	0.49	1.00	0.14	0.74
		Electric Equipment and Machinery	18	0.82	1.67	0.18	0.85
		Electronic and Telecommunications Equipment	19	0.37	0.74	0.10	0.60
		Instruments, Meters Cultural and Office Machinery	20	0.48	0.98	0.13	0.63
		Other Manufacture Products	21	1.30	2.62	0.14	0.55
		Electric Power/Steam and Hot Water Production and Supply	22	0.47	0.94	0.10	0.86
		Gas Production and Supply Industry	23	0.72	1.43	0.16	0.79
		Construction Industry	24	0.82	1.65	0.21	0.94
		Transport, Storage and Post	25	2.30	4.57	0.26	1.36
		Wholesale, Retail Trade	26	1.05	2.07	0.24	0.91
		Hotels, Catering Service	27	9.15	18.79	0.95	1.03
		Leasing and Commercial Services	28	1.99	3.99	0.38	1.07
		Research and Experimental Development	29	2.79	5.59	0.36	0.90
		Other services	30	0.80	1.60	0.17	0.80
25	Yunnan	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	41.90	153.74	1.33	0.68
		Coal Mining and Dressing	2	2.50	8.42	0.32	0.59
		Petroleum and Natural Gas Extraction	3	0.00	0.00	0.00	0.00
		Ferrous and Nonferrous Metals Mining and Dressing	4	2.80	9.70	0.30	0.62
		Nonmetal and Other Minerals Mining and Dressing	5	1.13	3.62	0.23	0.70
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	6.91	24.12	0.56	0.37
		Textile Industry	7	15.35	53.56	1.32	0.60
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	3.98	10.55	1.49	0.54

		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	7.64	26.50	0.65	0.63
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	3.39	11.25	0.42	0.56
		Petroleum Processing and Coking, Gas Production and Supply	11	0.98	3.15	0.17	0.52
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	2.20	7.49	0.31	0.63
		Nonmetal Mineral Products	13	1.28	4.00	0.28	0.71
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.80	2.58	0.16	0.58
		Metal Products	15	0.57	1.72	0.16	0.59
		Ordinary Machinery, Equipment for Special Purpose	16	0.47	1.31	0.16	0.51
		Transportation Equipment	17	0.45	1.25	0.16	0.56
		Electric Equipment and Machinery	18	0.61	1.87	0.17	0.57
		Electronic and Telecommunications Equipment	19	0.37	1.04	0.13	0.39
		Instruments, Meters Cultural and Office Machinery	20	0.55	1.59	0.18	0.47
		Other Manufacture Products	21	1.27	4.40	0.13	0.33
		Electric Power/Steam and Hot Water Production and Supply	22	0.65	2.05	0.14	0.56
		Gas Production and Supply Industry	23	1.11	3.54	0.23	0.61
		Construction Industry	24	0.84	2.60	0.21	0.64
		Transport, Storage and Post	25	1.99	6.76	0.24	2.80
		Wholesale, Retail Trade	26	0.42	1.23	0.12	1.22
		Hotels, Catering Service	27	7.32	24.88	0.80	1.32
		Leasing and Commercial Services	28	1.97	5.99	0.44	1.61
		Research and Experimental Development	29	0.73	2.16	0.20	1.17
		Other services	30	0.71	2.10	0.18	1.14
26	Shannxi	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	28.33	78.88	15.86	0.37
		Coal Mining and Dressing	2	0.34	0.71	0.24	0.41
		Petroleum and Natural Gas Extraction	3	0.23	0.46	0.18	0.37
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.40	0.81	0.36	0.50
		Nonmetal and Other Minerals Mining and Dressing	5	0.40	0.81	0.30	0.48
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	8.22	21.36	5.05	0.51
		Textile Industry	7	10.93	28.38	6.81	0.51

		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	4.89	10.84	3.70	0.54
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	1.54	3.12	0.91	0.50
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	2.18	5.41	1.33	0.51
		Petroleum Processing and Coking, Gas Production and Supply	11	0.15	0.31	0.13	0.38
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.11	2.60	0.82	0.49
		Nonmetal Mineral Products	13	0.67	1.35	0.55	0.56
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.26	0.50	0.26	0.47
		Metal Products	15	0.31	0.56	0.28	0.51
		Ordinary Machinery, Equipment for Special Purpose	16	0.32	0.61	0.27	0.49
		Transportation Equipment	17	0.33	0.60	0.28	0.53
		Electric Equipment and Machinery	18	0.38	0.70	0.34	0.51
		Electronic and Telecommunications Equipment	19	0.28	0.55	0.23	0.39
		Instruments, Meters Cultural and Office Machinery	20	0.33	0.63	0.25	0.42
		Other Manufacture Products	21	2.97	7.56	1.80	0.41
		Electric Power/Steam and Hot Water Production and Supply	22	0.27	0.53	0.20	0.50
		Gas Production and Supply Industry	23	0.32	0.65	0.23	0.51
		Construction Industry	24	0.79	1.68	0.57	0.63
		Transport, Storage and Post	25	0.31	0.64	0.22	1.10
		Wholesale, Retail Trade	26	0.58	1.29	0.38	0.87
		Hotels, Catering Service	27	5.23	13.08	3.34	0.93
		Leasing and Commercial Services	28	1.09	2.39	0.69	0.95
		Research and Experimental Development	29	0.42	0.89	0.28	0.61
		Other services	30	0.85	1.88	0.57	0.69
27	Gansu	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	58.30	66.43	64.52	0.64
		Coal Mining and Dressing	2	2.12	2.60	2.49	0.78
		Petroleum and Natural Gas Extraction	3	0.58	0.76	1.08	0.60
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.89	1.22	2.16	0.85
		Nonmetal and Other Minerals Mining and Dressing	5	0.72	0.91	1.04	0.65
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	20.99	24.43	23.22	0.66

		Textile Industry	7	18.77	21.86	20.86	0.65
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	19.58	22.77	21.76	0.72
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	4.40	5.53	4.32	0.59
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	2.19	2.64	2.50	0.65
		Petroleum Processing and Coking, Gas Production and Supply	11	0.22	0.36	1.15	0.55
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.56	2.03	2.78	0.55
		Nonmetal Mineral Products	13	0.94	1.26	1.73	0.70
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.58	0.83	2.11	0.72
		Metal Products	15	0.58	0.77	1.32	0.74
		Ordinary Machinery, Equipment for Special Purpose	16	0.58	0.76	1.14	0.71
		Transportation Equipment	17	0.58	0.74	1.00	0.58
		Electric Equipment and Machinery	18	0.97	1.28	1.66	0.75
		Electronic and Telecommunications Equipment	19	0.36	0.48	0.67	0.45
		Instruments, Meters Cultural and Office Machinery	20	0.70	0.90	1.01	0.57
		Other Manufacture Products	21	1.36	1.70	1.69	0.68
		Electric Power/Steam and Hot Water Production and Supply	22	0.74	0.95	1.12	0.78
		Gas Production and Supply Industry	23	0.76	0.96	1.05	0.69
		Construction Industry	24	1.51	1.89	2.25	0.84
		Transport, Storage and Post	25	4.09	4.79	4.73	1.74
		Wholesale, Retail Trade	26	1.30	1.57	1.47	2.59
		Hotels, Catering Service	27	11.72	13.95	12.68	2.37
		Leasing and Commercial Services	28	0.69	0.86	0.79	2.42
		Research and Experimental Development	29	0.78	0.98	0.99	1.91
		Other services	30	0.95	1.17	1.17	1.88
28	Qinghai	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	30.94	184.12	2110.69	3.45
		Coal Mining and Dressing	2	0.27	1.18	11.97	1.18
		Petroleum and Natural Gas Extraction	3	0.23	0.87	8.29	1.09
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.46	1.99	20.01	1.60
		Nonmetal and Other Minerals Mining and Dressing	5	0.23	0.97	9.58	1.00

		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	17.38	99.71	1127.29	2.58
		Textile Industry	7	9.10	43.33	458.57	1.82
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	5.76	23.20	227.54	1.31
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	0.47	1.94	19.05	1.59
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	0.64	1.69	12.47	1.13
		Petroleum Processing and Coking, Gas Production and Supply	11	0.21	0.70	5.82	1.17
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.50	8.39	94.13	1.14
		Nonmetal Mineral Products	13	0.36	1.37	12.84	1.41
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.25	0.96	9.02	1.29
		Metal Products	15	0.17	0.56	4.85	1.04
		Ordinary Machinery, Equipment for Special Purpose	16	0.35	1.13	9.80	1.42
		Transportation Equipment	17	0.65	2.68	26.21	1.58
		Electric Equipment and Machinery	18	0.43	1.82	18.28	1.21
		Electronic and Telecommunications Equipment	19	0.00	0.00	0.00	0.00
		Instruments, Meters Cultural and Office Machinery	20	0.00	0.00	0.00	0.00
		Other Manufacture Products	21	0.39	1.74	17.69	1.43
		Electric Power/Steam and Hot Water Production and Supply	22	0.36	0.99	7.69	1.84
		Gas Production and Supply Industry	23	0.39	1.62	15.91	1.30
		Construction Industry	24	0.35	1.39	13.42	1.40
		Transport, Storage and Post	25	0.41	1.58	14.94	3.72
		Wholesale, Retail Trade	26	0.36	1.58	15.97	1.29
		Hotels, Catering Service	27	6.48	34.29	374.19	1.90
		Leasing and Commercial Services	28	0.70	3.04	30.63	1.68
		Research and Experimental Development	29	0.70	3.13	32.21	1.60
		Other services	30	0.59	2.90	30.89	1.03
29	Ningxia	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	43.52	27.02	51.16	0.55
		Coal Mining and Dressing	2	0.45	0.43	0.52	1.04
		Petroleum and Natural Gas Extraction	3	0.33	0.36	0.31	0.86
		Ferrous and Nonferrous Metals Mining and Dressing	4	0.64	0.71	0.70	1.17

		Nonmetal and Other Minerals Mining and Dressing	5	0.39	0.41	0.41	0.90
		Food Processing, Food Production, Beverage Production, Tobacco Processing	6	18.04	12.41	21.79	0.99
		Textile Industry	7	14.53	9.79	17.69	0.83
		Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	8.91	6.30	10.83	0.88
		Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	1.70	2.59	2.21	1.00
		Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	5.16	4.04	5.98	1.07
		Petroleum Processing and Coking, Gas Production and Supply	11	0.19	0.23	0.33	0.99
		Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.32	1.16	1.54	1.02
		Nonmetal Mineral Products	13	0.61	0.62	0.79	1.17
		Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.32	0.40	0.51	1.06
		Metal Products	15	0.38	0.44	0.42	1.12
		Ordinary Machinery, Equipment for Special Purpose	16	0.44	0.47	0.52	1.12
		Transportation Equipment	17	0.77	0.69	0.93	1.03
		Electric Equipment and Machinery	18	0.52	0.60	0.57	1.07
		Electronic and Telecommunications Equipment	19	0.40	0.42	0.40	0.96
		Instruments, Meters Cultural and Office Machinery	20	0.46	0.51	0.50	1.01
		Other Manufacture Products	21	7.60	5.21	9.24	0.88
		Electric Power/Steam and Hot Water Production and Supply	22	0.29	0.31	0.34	1.23
		Gas Production and Supply Industry	23	0.33	0.37	0.48	1.00
		Construction Industry	24	0.68	0.71	0.82	1.28
		Transport, Storage and Post	25	0.54	0.54	0.62	2.03
		Wholesale, Retail Trade	26	0.39	0.36	0.43	1.31
		Hotels, Catering Service	27	11.37	8.99	13.51	1.65
		Leasing and Commercial Services	28	0.89	0.89	0.96	2.06
		Research and Experimental Development	29	0.95	0.90	1.03	3.36
		Other services	30	0.57	0.57	0.62	3.15
30	Xinjiang	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	1	33.37	58.26	229.14	1.74
		Coal Mining and Dressing	2	0.54	0.88	2.25	0.74
		Petroleum and Natural Gas Extraction	3	0.19	0.30	0.68	0.51

Ferrous and Nonferrous Metals Mining and Dressing	4	0.28	0.44	0.98	0.69
Nonmetal and Other Minerals Mining and Dressing	5	0.53	0.83	1.75	0.90
Food Processing, Food Production, Beverage Production, Tobacco Processing	6	17.02	29.25	109.17	1.49
Textile Industry	7	17.72	30.13	112.01	1.46
Garments and Other Fiber Products, Leather, Furs, Down and Related Products	8	5.69	8.90	25.54	1.02
Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	9	2.21	3.33	8.69	0.79
Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	10	5.04	8.36	28.86	1.05
Petroleum Processing and Coking, Gas Production and Supply	11	0.15	0.24	0.52	0.69
Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	12	1.42	2.38	7.69	0.79
Nonmetal Mineral Products	13	0.53	0.84	1.77	0.90
Smelting and Pressing of Ferrous and Nonferrous Metals	14	0.16	0.24	0.42	0.60
Metal Products	15	0.37	0.51	0.79	0.79
Ordinary Machinery, Equipment for Special Purpose	16	0.47	0.70	1.37	0.96
Transportation Equipment	17	0.41	0.58	0.89	0.74
Electric Equipment and Machinery	18	0.30	0.43	0.74	0.67
Electronic and Telecommunications Equipment	19	0.29	0.45	0.99	0.71
Instruments, Meters Cultural and Office Machinery	20	0.69	1.01	2.23	0.77
Other Manufacture Products	21	2.27	3.57	10.97	0.83
Electric Power/Steam and Hot Water Production and Supply	22	0.41	0.65	1.51	0.85
Gas Production and Supply Industry	23	0.32	0.50	1.04	0.81
Construction Industry	24	0.72	1.11	2.48	0.95
Transport, Storage and Post	25	0.94	1.49	3.80	2.23
Wholesale, Retail Trade	26	0.42	0.70	1.79	1.62
Hotels, Catering Service	27	9.60	16.38	58.22	2.04
Leasing and Commercial Services	28	1.18	1.94	5.24	1.90
Research and Experimental Development	29	1.10	1.82	5.31	0.92
Other services	30	0.77	1.25	3.49	0.66

Appendix III: Sectors for China's economic input-output table 2012

Sectors for China's economic input-output table 2012

Code	Sector	Short Name	Industrial Classification
1	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	Agriculture	Primary Industry
2	Coal Mining and Dressing	Coal Mining	Secondary Industry
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	
4	Ferrous and Nonferrous Metals Mining and Dressing	Metals Mining and Dressing	
5	Nonmetal and Other Minerals Mining and Dressing	Minerals Mining and Dressing	
6	Food Processing, Food Production, Beverage Production, Tobacco Processing	Food Processing	
7	Textile Industry	Textile Industry	
8	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	Garments	
9	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	Timber Processing	
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	Paper Products	
11	Petroleum Processing and Coking, Gas Production and Supply	Petroleum Processing	
12	Raw Chemical Materials and Chemical Products, Medical and Pharmaceutical Products, Chemical Fiber, Rubber Products, Plastic Products	Chemical Products	
13	Nonmetal Mineral Products	Nonmetal Mineral Products	
14	Smelting and Pressing of Ferrous and Nonferrous Metals	Smelting and Pressing of metal	
15	Metal Products	Metal Products	
16	Ordinary Machinery	Ordinary Machinery	
17	Equipment for Special Purpose	Special Equipment	
18	Transportation Equipment	Transportation Equipment	
19	Electric Equipment and Machinery	Electric Equipment	
20	Electronic and Telecommunications Equipment	Telecommunications Equipment	
21	Instruments, Meters Cultural and Office Machinery	Instruments, Meters	
22	Other Manufacture Products	Others	
23	Waste	Waste	
24	Manufacture of Artwork and Other Manufactures	Manufacture of Artwork	
25	Electric Power/Steam and Hot Water Production and Supply	Electric Power	
26	Gas Production and Supply Industry	Gas Production and Supply	
27	Water Production and Supply Industry	Water Production and Supply	
28	Construction Industry	Construction	
29	Wholesale, Retail Trade	Wholesale, Retail Trade	Tertiary Industry
30	Transport, Storage and Post	Transport and Storage	
31	Hotels, Catering Service	Hotels, Catering Service	
32	Information Transmission, Computer services and Software	Information	
33	Financial Industry	Financial Industry	
34	Real Estate	Real Estate	
35	Leasing and Commercial Services	Leasing	
36	Research and Experimental Development	Research	
37	Water conservancy, Environment and Public Facilities Management	Environment	
38	Service to Households and Other Service	Service to Households	
39	Education	Education	
40	Health, Social Security and Social Welfare	Health	
41	Culture, Sports and Entertainment	Culture	
42	Public Management and Social Organization	Public Management	

Appendix IV: Abbreviations

IOA input-output analysis

SRIO single regional input-output

MRIO multiregional input-output

ELP land use embodied in production

ELC land use embodied in consumption

ECLC cultivated land use embodied in consumption

EFLC forest land use embodied in consumption

EPLC pasture land use embodied in consumption

ECoLC construction land use embodied in consumption

LET land embodied in interregional trade

LEB land embodied in trade balance

ECLB cultivated land use embodied in trade balance

EFLB forest land use embodied in trade balance

EPLB pasture land use embodied in trade balance

ECoLB construction land use embodied in trade balance

EF ecological footprint

FLEC farm land embodied in consumption

FWEC farm water embodied in consumption

FLEB farm land embodied in trade balance

FWEB farm water embodied in trade balance

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