Natural resource balance sheet compilation: a land resource asset accounting case

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Investigating the principles and methods of natural resource asset accounting and balance sheet compilation is an important aspect of protecting natural resources and promoting ecological civilization. Accounting should be based on physical quantity accounting and supplemented by value quantity accounting. To avoid interest distortion caused by excessive paid use and valuation, the monopolized use of natural resources should be avoided. The contents of land resource asset accounting should include the area, quality, and price, and value quantity accounting should follow the principle of marketability. The balance sheet of natural resources should belong to the category of the national balance sheet. It is proposed that emphasis should be placed on promoting the use of modern information technology, as well as surveying and mapping techniques, to conduct comprehensive and accurate surveys of various types of natural resources. Scientific, solid, and accurate investigation and monitoring data are the foundation of natural resource asset accounting.

1. Introduction

Natural resources provide the material basis for the survival and development of human societies. While such resources are indispensable, they exist in finite quantities. Over the course of human history, natural resources have always been highly valued and often fought over. In tandem with the development of human societies and economies, the contradiction between humans and nature has become increasingly salient, and the overuse of natural resources has become more serious. Therefore, achieving the sustainable utilization and protection of natural resources has become a matter of urgent importance. Governments and research bodies are important facilitators of sustainable practices. China, for example, is experiencing a serious shortage of natural resources, and in 2015, the government promulgated the ‘Overall Plan of Ecological Civilization System Reform’ to accelerate the development of ecological civilization. This plan makes specific proposals for establishing natural resource balance.
sheets, including developing accounting methods for assets and liabilities related to water, land, and forest resources; establishing a physical accounting system; specifying classification standards and statistical norms; and regularly assessing changes in natural resource assets. This plan marked the official start of the Chinese government’s effort to compile a natural resource balance sheet.

As an important type of natural resource, land resources are important carriers of other natural resources. All other natural resources depend on the land resources of a given region, which reflect the spatial distribution and composition of natural resources. For example, mineral resources are stored underground, and mineral mining results in certain land-use patterns in mining areas. Biological resources such as forests and grasslands grow on the land and are more closely related to the land; accordingly, use patterns for forestland and grassland are formed. Water resources are stored on or flow through the land surface to form corresponding reservoir surfaces, lake surfaces, river surfaces, and wetlands. Therefore, land resource asset accounting and the compilation of balance sheets have typicality and representativeness for the practice purpose. Moreover, land resources are the most marketable resources. Clear definitions of property rights and clear property attributes provide the basis for asset value accounting. Accordingly, the present study aimed to explore the basic rules and methods of land resource asset accounting and balance sheet compilation.

The next section reviews the literature on natural resource asset accounting. Section 3 describes the logic and rules of natural resource asset accounting while Section 4 presents the essential attributes of land resource accounting and explains the related methods. On that basis, Section 5 presents an empirical study of state-owned urban construction land to demonstrate the specific process of land asset accounting. Section 6 provides the main conclusions and discussion.

2. Literature review

2.1. Development of natural resource asset accounting

The origins of natural resource asset accounting can be traced back to national economic accounting. To account for the results of human economic activities, the British economist Richard Stone built the System of National Accounts (SNA), which was adopted in 1953 by international organizations such as the United Nations (UN) and the World Bank. This system takes the gross domestic product (GDP) as the main accounting index, which is used to measure the total value of the products and services a country produces in a certain period. This system has become the most commonly used economic accounting index throughout the world. However, the SNA is controversial as it only describes economic development without accounting for the loss of natural resources and environmental degradation. As a result, efforts have been made to improve the system or propose alternatives. In the 1980s, some international organizations, governments, and research bodies in developed countries began to incorporate natural resources and the environment into the scope of traditional accounting, aiming to reveal how economic activity uses natural resources. Norway was the first country to undertake this type of natural resource accounting. In 1981,
the Norwegian government adopted 15 indicators for the purpose of natural resource accounting and in 1987 published the report *Norway’s Natural Resource Accounting*.

During that period, research on the theories and methods of natural resource and environmental accounting started to be undertaken. Then, in 1992, the UN Conference on Environment and Development presented a new opportunity for additional research in this area. In 1993, the UN Statistics Division (UNSTAT) established the System of Environmental-Economic Accounting (SEEA), which was coordinated with the SNA and provided a systematic accounting of environmental resource stocks and capital flows. It also established a framework for measuring and analyzing environmental economic issues, integrating accounting methods from various different fields. Since its launch, SEEA has been implemented in various countries, including the US, Canada, Japan, Colombia, Ghana, and Indonesia. In 2000, UNSTAT and the UN Environment Program (UNEP) jointly launched the SEEA-2000. During this period, developed countries such as the Netherlands, the UK, Sweden, Canada, and Denmark began to explore the consumption value accounting of land, forest, and energy. Then, in 2003, the SEEA-2003 was issued, which included revised norms and accounting techniques. Under the influence of the SEEA, the international community has launched various environmental accounting frameworks, such as the European Framework for Integrated Environmental and Economic Accounting for Forests (IEEAF) and the Food and Agriculture Organization (FAO) of the UN’s guide on forestry and economic accounting. In 2012, aiming to solve the accounting bottlenecks in previous standards, the SEEA-2012 was introduced. Since then, more countries have adopted resource and environmental accounting to provide a basis for national environmental protection policies. Some developed countries, such as the UK, have changed the measurement scale for national resource management and demonstrated the economic value of natural resources.

Research on natural resource accounting began late in China but has developed rapidly. In the early 1980s, the Office of the Leading Group for Environmental Protection and the National Bureau of Statistics jointly established an environmental protection statistics system. In 1988, the Development Research Center of the State Council and the World Resources Institute jointly conducted a study of ‘Natural Resource Accounting and its Incorporation into the System of National Economic Accounts.’ In the same year, the State Environmental Protection Bureau calculated China’s national savings rate since 1978, focusing on the integration of natural resource accounting into national asset and liability accounting. Later, in 1994, Agenda 21 was adopted, which proposed making full use of economic means to protect natural resources and the environment and achieve sustainability. Then, in 1999, Peking University published the China Comprehensive Framework for Environmental and Economic Accounting (CSEEA), based on the SEEA model. In 2001, Chongqing was used as a pilot city to carry out resource and environmental accounting, laying a foundation for green GDP accounting. Then, in 2003, the National Bureau of Statistics compiled the National Natural Resources Physical Inventory, which covered four kinds of natural resources: land, minerals, forests and water. In 2005, on the basis of a government study of green GDP accounting, 10 ‘green GDP’ pilot provinces and cities were launched. September 2006 saw the release of the ‘Research Report on China’s Green National Economic Accounting 2004.’
More recently, in 2013, the National Bureau of Statistics and the State Forestry Administration jointly launched a framework for forest resource accounting and a green economic evaluation system. Later, in November 2013, at the third Plenary Session of the 18th CPC Central Committee, the proposition was made to ‘explore the preparation of the balance sheet of natural resources and carry out the audit of outgoing leading cadres’ natural resource assets.’ This resulted in an upsurge in research on natural resource asset accounting. The ‘green GDP’ accounting research program was relaunched in 2015. This was followed by the ‘Pilot Program for Compiling the Balance Sheet of Natural Resources’, which proposed carrying out pilot work in various regions of China. Based on the experience of the pilot regions and on expert opinion, the National Bureau of Statistics issued the ‘Natural Resource Assets Balance Sheet Preparation System’ and started to undertake its implementation. Then, in April 2019, the General Office of the State Council proposed a reform of the property rights system for natural resources, aiming to establish clear property rights. In light of the above, it can be said that China’s work on natural resource accounting has entered the middle-to-late stage of development and application.

2.2. Research on natural resource accounting

Research on the accounting of natural resource assets is still in the exploratory stage. In recent years, most studies of natural resource accounting have focused on methods for natural resource value accounting, especially ecological value accounting, including ecosystem services valuation and emergy accounting.

Some researchers have used the SEEA as a guide to explore the construction of a national framework for natural resource asset accounting. Taking Russia as an example, Korobitsyn et al. subtracted net savings from the consumption of non-renewable resources and the monetary value of the damage caused by air pollution, water pollution, and waste disposal, and carried out accounting work on that basis. Meanwhile, Morton et al., taking the Sikunga Reserve in Namibia as an example, used an integrated environmental and social accounting matrix (ESAM) to assess how natural resources are used in different sectors, as well as the direct and indirect benefits they bring to communities. Arguing that all-natural capital accounting should comply with SEEA, Stage and Uwera examined natural resource problems in Rwanda using the SEEA framework and proposed applying the corresponding account structure throughout the African continent. Also arguing for SEEA compliance, Bright et al. proposed a comprehensive natural capital accounting framework, whose elements include a comprehensive inventory flow account, physical and monetary accounts, valuation basis, measurement degradation, information display, and discount rate. Investigating the sustainability of India’s natural capital, Islam and Managi linked natural resource management with stakeholder behavior. On that basis, they suggested that environmental protection behavior, natural capital, green growth, and sustainable development goals are the most important factors related to achieving balanced economic growth.

Meanwhile, given the diversity of resource endowments in different countries, some researchers have departed from the SEEA to focus on resource-specific accounting frameworks. Noting that general methods for the economic assessment
of mineral resources have not been established, Galos et al.\textsuperscript{8} suggested that a classification of geological resources and a set of taxation-related assessment methods needed to be established. Focusing on the water accounting of the Czech agricultural sector, Ansorge et al.\textsuperscript{9} analyzed agricultural water intake data and compared it with water-demand estimation based on additional agricultural data to show the validity of the water accounting data. Roy and Thomassin\textsuperscript{10} integrated agricultural land in Quebec into the national accounting system as natural capital, proposed a hedonic price model to evaluate agricultural land, and estimated the factors that constituted the value of agricultural land. Drawing on the establishment of water accounts in Australia, Garstone et al.\textsuperscript{11} proposed a method that applied common water accounting reports to the structure and reporting of water accounts in the mining industry.

In recent years, researchers have begun to devote more attention to the application of natural resource asset accounting. Rieckhof et al.\textsuperscript{12} introduced resource efficiency into management strategy, focused on the relationship between material flow cost accounting and management control systems, and proposed a conceptual framework for applying material flow cost accounting to management control systems. Arguing that integrating natural capital into the national account system could quantify the interaction between economic activity and natural capital, Ochuodho and Alavalapati\textsuperscript{13} proposed using the SEEA framework to integrate natural capital into the SNA and suggested using a general equilibrium model, instead of the input–output method, to better analyze natural resource policies. Based on the experience of countries compiling the SEEA Extended Account, Vardon et al.\textsuperscript{14} proposed 10 principles to help make the natural capital account applicable to policy analysis, which could help natural capital account developers and policymakers make better use of SEEA information and thus enrich policy analysis.

Many studies of natural resource asset accounting have been undertaken in China in areas such as forest resource asset accounting\textsuperscript{15}, mineral resource asset accounting\textsuperscript{16}, water resource asset accounting\textsuperscript{17}, land resource asset accounting\textsuperscript{18}, and natural resource balance sheet compilation.\textsuperscript{19} Such studies have proposed systems of regional resource accounting and then incorporated them into economic accounting. Researchers have also focused on accounting methods for different resources (e.g., forestry and water resources). Some governments and organizations have subsequently carried out further exploration and practice.

While many of the abovementioned studies focused on specific accounting methods and balance sheet compilation, few have considered general problems such as the composition of natural resource assets and the logic and rules of accounting. Moreover, there is a shortage of research on the specific indicators, methods, and procedures for land resource asset accounting. The present study, therefore, focused on natural resource asset accounting and the logical rules that should be followed in the preparation of balance sheets. We also explored an accounting method for typical natural resource–land resource assets, aiming to depict a complete accounting process.
Table 1. Total asset accounting results for state-owned construction land based on different price patterns in three provincial sample areas in 2017.

<table>
<thead>
<tr>
<th>Sample area</th>
<th>Land-use type</th>
<th>Urban cadastral area (hectare)</th>
<th>Accounting based on benchmark land price</th>
<th>Accounting based on monitored land price</th>
<th>Accounting based on land transaction price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Benchmark land price (Yuan/Square Meter)</td>
<td>Asset quantity (100 Million Yuan)</td>
<td>Monitored land price (Yuan/Square Meter)</td>
</tr>
<tr>
<td>Beijing</td>
<td>Total</td>
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<td>8910.35</td>
<td>135,293.60</td>
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<td>3819.10</td>
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<td></td>
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<td>3819.10</td>
<td>27.20</td>
<td>2692.00</td>
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<td>Shandong</td>
<td>Water and Water Conservancy Facility Land</td>
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<td>3819.10</td>
<td>0.00</td>
<td>2692.00</td>
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<tr>
<td></td>
<td>Total</td>
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<td>1341.24</td>
<td>81,074.95</td>
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<td>Water and Water Conservancy Facility Land</td>
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<td>Jiangsu</td>
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<td>161,641.28</td>
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<td>1990.00</td>
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(continued)
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<tr>
<th>Sample area</th>
<th>Land-use type</th>
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<tr>
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<td>Monitored land price (Yuan/Square Meter)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Asset quantity (100 Million Yuan)</td>
<td>Asset quantity (100 Million Yuan)</td>
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<td>Conservancy Facility Land</td>
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</table>
3. Logic and rules of natural resource asset accounting

To promote the scientific accounting of natural resource assets, we must first theoretically clarify the objectives of accounting—namely, the problems accounting is expected to solve and the purpose it should serve. Then, following the goal-oriented principle, the contents and methods of accounting are studied and determined.

3.1. Basic goal of natural resource asset accounting: the rational utilization and protection of natural resources

With increases in the global population, the harmful overexploitation of natural resources has dramatically increased as well. A well-known example is the ‘Black Storm’ that occurred in the US in the 1930s. During this event, strong winds blew for three days and three nights, forming a large fast-moving black storm belt with a length of 2400 km from east to west, a width of 1440 km from south to north, and a height of 3400 m. Wherever the storm went, streams were cut off, wells dried up, fields cracked, crops withered, livestock died of thirst, and thousands of people were displaced. This is considered a case in history where human civilization was in effect ‘punished’ by nature. It is generally acknowledged that continuous land reclamation and deforestation by developers has resulted in the significant wind erosion of soil, and continuous drought has aggravated land desertification. Other examples include the Plague in India in the 1990s, the Peru Avalanche in the 1970s, and the severe haze that has occurred in North China since the beginning of this century.

The abovementioned events highlight the need to protect natural resources and use them in a sustainable way. By establishing a property rights system for natural resources, natural resource asset accounting can be achieved and incorporated into the national accounting system. In addition, changes in the physical quantity, quality, and value of natural resources can be monitored to achieve protection and sustainable utilization. The protection of natural resources may require economic measures, such as restricting waste by levying fees. The purpose of applying market approaches to ecological products is to protect resources using economic mechanisms instead of using natural resources to maximize value. As products of nature, natural resources are easily monopolized, and when their economic value is excessively pursued, it will inevitably lead to waste and an uneven distribution of social wealth. Therefore, the basic goal of natural resource asset accounting should be to promote the rational utilization and protection of natural resources.

3.2. Natural resource asset accounting based on physical quantity accounting, supplemented by value quantity accounting

Natural resources have natural, economic, and social attributes, and natural resource asset accounting often requires a comprehensive review of these various attributes. Given the premise that natural resource asset accounting aims to promote rational utilization and protection, physical quantity accounting should be the main method while value quantity accounting should be secondary. The first reason for this is that physical quantities form the basis of natural resources. Only on the basis of scientific and accurate accounting of physical quantities can other factors be considered. Second, most natural resources are
linked to externalities such as the ecological value of natural resources and the value of water resources. It is often difficult to marketize and investigate such external factors. Therefore, value quantity has some uncertainty and might not even be able to be accurately calculated. For some tradable natural resources, such as certain land and biological resources, value quantity accounting can be carried out as a complement. Thus, the value quantity accounting of natural resource assets should follow the principle of marketability. Regarding the ecological value of natural resources, because of their externalities, the accounting methods and even the marketization mechanism of ecological products can be explored. However, it is difficult to assess the value quantity through the market, and focus should not be placed on so-called ecological value accounting. Alternatively, more attention should be paid to the investigation of the physical quantities of ecological products and the quality of ecological functions.

3.3. Natural resource balance sheet as a component of the national balance sheet

The purpose of compiling a natural resource balance sheet is to calculate and characterize the total quantity of natural resource assets and its changes in a certain area using the enterprise balance sheet for reference. This enables the utilization and protection of natural resources to be monitored. Compared to the enterprise balance sheet, the national balance sheet reflects the total scale and structure of the assets and liabilities of a national economy at a certain point in time by examining its overall economic stock. Therefore, in terms of its content and purpose, the compilation of the natural resource balance sheet should belong to the category of the national balance sheet.

It follows, then, that natural resource assets with clear property rights ownership can be included in the asset accounting scope of the owners of property rights (e.g. enterprises and other economic entities). However, it is not an independent accounting method, and it is often carried out during the accounting of other enterprise assets and liabilities. Thus, it should belong to the category of the national balance sheet when conducting natural resource asset accounting in whole or in part, or even when compiling the natural resource balance sheet within a certain administrative region or country.

4. Methods of land resource asset accounting

Land resources are an important type of natural resource that other natural resources depend upon for their existence. Their characteristics and accounting methods have significant typicality and representativeness.

4.1. Essential land resource attributes: determining land resource asset accounting

As a typical natural resource, land also has natural, economic, and public attributes. The natural attributes of land include fixed location, finite quantity, sustainable utilization, and multipurpose use. These are the basic attributes of land, which highlight the differences between land and other resources and assets. When land is used by
humans, extended attributes such as economic and public attributes are produced. The economic attributes of land are as follows: It has a productive capacity, and its economic value is determined by its productivity and the ways in which it can be used. Further, it can become property and is classified as real estate because of its fixed location. In this regard, the property right system is an important factor for determining its ownership and economic relationships; it also has investment and capital attributes. The public attributes of land imply that the allocation and utilization of land can not only serve to maximize economic interests but also consider the need for social development and sustainable utilization. This is also determined by the natural attributes of land. Given the limited total amount of land, its allocation and utilization should be balanced, which includes balancing different types and different subjects. To guarantee survival, it is important that ‘farmers have their own fields’, and excessive mergers often lead to social unrest. A fixed location determines the particularity of its adjacent relationship, which will produce externalities.21

These attributes of land resources determine that land resource asset accounting can include the two aspects of physical quantity accounting and value quantity accounting. Physical quantity accounting includes land-use type, area, and quality while value quantity accounting mainly focuses on market value (price), which reflects the property value of land as a factor of production.

4.2. Land resource asset accounting methods

The physical quantity accounting of land resource assets should, first, embody all types of land use in a certain region (i.e. classified accounting). Second, it should consider the scale of different types of land use—namely, the land area. Third, it should reflect the quality of land use and should even indicate whether the use pattern is sustainable. Accounting data should be based on a land resource survey, with full coverage in a certain area at a specific point in time. Surveys of land-use status and data pertaining to land classification and grading results over a certain time period can provide an important basis for accounting. Therefore, to scientifically promote land resource asset accounting and to accurately calculate the quantity of land resource assets, it is necessary to maximize the use of modern information technology, as well as surveying and mapping techniques, to carry out accurate, comprehensive land surveys.

The value quantity accounting of land resource assets should be based on the exchange value of land; thus, it is important to determine objective market prices. Based on the physical quantity accounting of land resources, the main goal is to determine an objective market price. Under China’s current land market system, there is a market transaction price, benchmark land price, and marked land price. These three price patterns have their own characteristics, and they correspond to certain regions and land-use types. In practice, different price patterns can be adopted for accounting based on the characteristics of regions and land-use types. Then, the unified accounting results can be determined through comprehensive comparison. In general, the benchmark land price and the corresponding accounting results for various land types better conform to the purpose and standard of land resource asset accounting.

5.1. Accounting method

We begin by discussing operational construction land and non-operational construction land. Based on urban land-price data and national urban cadastral survey data, we calculated the total quantity of state-owned urban construction land in Beijing, Shandong, and Jiangsu in 2017, using provinces as the basic accounting unit and prefecture-level cities as the basic measurement unit.

The core elements of land asset accounting are quantity, price, and asset amount. The land assets of a certain area are spread over the entire area. In theory, the accounting of land assets should be carried out for specific land plots, considering the price, area, and grade of each land plot. In practice, however, considering data availability and the required workload, it is not realistic to conduct accounting using the land plot as the unit. Therefore, land asset accounting is usually carried out on a regional scale. At the regional scale, this study defines the core elements of land assets (quantity, price, asset amount) as follows: the quantity is the area of the corresponding type of construction land, the price is the regional average price of the corresponding type of construction land, and the asset amount is the total amount of construction land assets. Figure 1 shows the procedure for land asset accounting.

5.2. Data sources and processing

Using provinces as the accounting unit and prefecture-level cities as the basic element, we obtained the land-price data and urban land area data for Beijing, Shandong, and Jiangsu in 2017. Regarding land-price data, the benchmark land price was sourced from the renewal results of the benchmark land price provided by the Land Resource Bureaus of prefecture-level cities in each province. The monitored land price and land-price index were obtained from the China Land-Price Monitoring Network (http://www.landvalue.com.cn/). The transaction land price was obtained from data published on the Real Estate Big Data Information System of China Index Academy (https://creis.fang.com/). Regarding land area, urban land area data were primarily sourced from the National Land Use Change Survey. The China Land-Price Monitoring Network and China Index Academy only provide city-level data for the monitored land price and transaction land price, while the benchmark land-price data cover county-level cities. Therefore, the city was taken as the unit when monitored and transaction land-price

Figure 1. Procedure for land asset accounting.
data were used for accounting, and the county was taken as the unit when benchmark land-price data were used.

(1) Dealing with the lack of land-price data

Taking the monitored land price as an example, since price monitoring does not yet cover all cities, there may be an absence of monitored land-price data for some prefecture-level cities. Therefore, a replacement method was adopted. Land price is determined not only by its own location factor but also by various socioeconomic factors. Thus, cluster analysis can be used to supplement city data that lack land price. Cluster analysis was conducted using SPSS according to macroeconomic indicators such as regional GDP, employed population, resident income, fixed-asset investment, total retail sales of consumer goods, and the total number of domestic and foreign currency loans of financial institutions at the end of the year. For cities lacking data, land price can be replaced by the corrected land-price data for the same type of city with similar levels of socioeconomic development. The absence of transaction land-price data can be handled in the same way.

(2) Land-price date amendment

Since some prefecture-level cities did not update the benchmark land price in time, it was necessary to perform a date amendment of the collected benchmark land-price data. The detailed amendments are as follows:

\[
\text{Target Date Benchmark Land Price} = \frac{\text{Valuation Date Benchmark Land Price}}{\text{Date Correction Factor}},
\]

where the

\[
\text{Date Correction Factor} = \frac{\text{Target Date Land Price Index}}{\text{Valuation Date Land Price Index}}.
\]

The same method can be used to perform a date amendment of the transaction land price.

5.3. Accounting methods

The land asset accounting of construction land was divided into two parts: the asset accounting of operational construction land and the asset accounting of nonoperational construction land. In addition, attention was paid to the asset accounting method for operational construction land.

5.3.1. Land asset classification of urban construction land

1. Operational construction land mainly includes commercial, residential, industrial, mining, and warehouse land. Accounting for this type of land requires the two major factors of land area and land price, based on which the value quantity of land assets can be calculated. Three price patterns were adopted for operational construction land accounting: benchmark land price, monitored land price, and
transaction land price. It is necessary, then, to discuss the methods involved in operational construction land asset accounting based on different land-price patterns.

2. Nonoperational construction land mainly includes public administration and service land, special-use land, transportation land, and water and water conservancy facility land. This type of land is seldom traded on the market; thus, its accounting method was determined by referring to that of operational construction land.

5.3.2. Operational construction land accounting

Three price patterns—benchmark, monitored, and transaction land prices—were selected to discuss the methods for operational construction land asset accounting with different price patterns.

(1) Asset accounting based on benchmark land price

The benchmark land price is the average price of a certain homogeneous region, and the basic expression of a homogeneous region is the level of land. In practice, there are large price differences between commercial and residential land. According to location change rules and the characteristics of the land prices of commercial and residential land, we further evaluated the commercial route price and residential regional price of corresponding route segments and districts. This enhanced the homogeneity of the benchmark land-price region and the relative consistency of the regional land plot price level.

The basic accounting method employed in this study was to determine the weight using the grade area to calculate the average benchmark land price of the corresponding land-use type (commercial, residential, industrial) at the administrative level of a district or county. Then, the average benchmark land price was multiplied by the urban cadastral survey area of the corresponding land uses to obtain the assets of a certain land-use type at the administrative level of a district or county. The equation is

\[ A_1 = \bar{P}_1 \times S'_1 = \frac{\sum_{i=1}^{n_1} P_{1i} \times S_{1i}}{\sum_{i=1}^{n_1} S_{1i}} \times S'_1, \tag{3} \]

where \( A_1 \) is the land asset amount of a certain land-use type at the administrative level of a district or county, \( \bar{P}_1 \) is the average benchmark land price of a certain land-use type at the administrative level of a district or county, \( S'_1 \) is the urban cadastral survey area of a certain land-use type at the administrative level of a district or county, \( S_{1i} \) is the grade area of level i land of a certain land-use type at the administrative level of a district or county, \( P_{1i} \) is the grade price of level i land of a certain land-use type at the administrative level of a district or county, and \( n_1 \) is the number of grades of a certain land-use type at the administrative level of a district or county.

Using Equation 3, the average benchmark land price of a certain land-use type at the administrative level of a district or county can be calculated. Weighted by the cadastral survey area, the average benchmark land price of corresponding land uses (commercial, residential, industrial) at the municipal administrative level can be obtained. This was then multiplied by the urban cadastral survey area of
corresponding land uses to obtain the assets of a certain land-use type at the municipal administrative level. The equation is

\[ A_2 = \bar{P}_2 \times S_2' = \frac{\sum_{i=1}^{n_2} \bar{P}_{1i} \times S_{1i}'}{\sum_{i=1}^{n_2} S_{1i}} \times S_2', \]

where \( A_2 \) is the quantity of land assets of a certain land-use type at the municipal administrative level, \( \bar{P}_2 \) is the average benchmark land price of a certain land-use type at the municipal administrative level, \( S_2 \) is the urban cadastral survey area of a certain land-use type at the municipal administrative level, \( S_{1i}' \) is the urban cadastral survey area of a certain land-use type in the \( i^{th} \) district or county, \( \bar{P}_{1i} \) is the average benchmark land price of a certain land-use type in the \( i^{th} \) district or county, and \( n_2 \) is the number of districts and counties at the municipal administrative level.

Using Equation 2, the average benchmark land price of a certain land-use type at the municipal administrative level can be calculated. Weighted by the cadastral survey area, the average benchmark land price of corresponding land uses (commercial, residential, industrial) at the provincial administrative level can be obtained. This was then multiplied by the urban cadastral survey area of corresponding land uses to obtain the assets of a certain land-use type at the provincial administrative level. The equation is

\[ A_3 = \bar{P}_3 \times S_3' = \frac{\sum_{i=1}^{n_3} \bar{P}_{2i} \times S_{2i}'}{\sum_{i=1}^{n_3} S_{2i}} \times S_3', \]

where \( A_3 \) is the land asset amount of a certain land-use type at the provincial level, \( \bar{P}_3 \) is the average benchmark land price of a certain land-use type at the provincial level, \( S_3 \) is the urban cadastral survey area of a certain land-use type at the provincial level, \( S_{2i}' \) is the urban cadastral survey area of a certain land-use type in the \( i^{th} \) city, \( \bar{P}_{2i} \) is the average benchmark land price of a certain land-use type in the \( i^{th} \) city, and \( n_3 \) is the number of cities in a certain province.

(2) Asset accounting based on monitored land price

Various monitoring points were established to achieve the dynamic monitoring of the urban land price. By evaluating the market price at monitoring points, the final price (i.e., monitored land price) of land transaction samples in a single year can be obtained correcting the date, degree of land development, duration of land-use right, and plot ratio. Specifically, this includes the manifestations of the section land price, grade land price, and land-use price. China currently has a dynamic land-price monitoring network that covers 105 cities. It monitors the price level of commercial, industrial, and residential land on a quarterly basis.

The basic accounting method employed in this study was to multiply the average value of the monitored price of commercial, residential, and industrial land by the corresponding urban cadastral survey area to obtain the number of assets classified as operational land. The accounting equation is

\[ A = P \times S, \]

where \( P \) is the average monitored land price, and \( S \) is the urban cadastral survey area.
where $A$ is the quantity of land assets corresponding to a certain land-use type at the municipal administrative level, and $P$ is the land-price value corresponding to a certain land-use type at the municipal administrative level. The level value of land price is an index reflecting the level of the land price and is expressed by the average land price. $S$ is the urban cadastral survey area corresponding to a certain land-use type at the municipal administrative level.

(3) Asset accounting based on transaction land price

Transaction land price refers to the price of the land being traded in the land market, which is agreed upon by both parties. It belongs to the individual price pattern and is the true reflection of the objective and reasonable level of land price. To calculate the regional average transaction land price, it is necessary to obtain as many transaction cases as possible. Since 2003, China has operated a dynamic monitoring and supervision system for the land market. The system can be used to investigate and analyze the total amount, source, structure, layout, transaction mode, transaction price, investment subject, and industry classification of the land supply in key regions, key cities, and the whole country. At present, the system covers more than 2500 counties and cities in 30 provinces (regions and municipalities), except Tibet. Land transaction cases in various regions can be obtained based on this system.

The basic accounting method used in this study was to multiply the regional average transaction land price by the corresponding cadastral survey area to obtain the number of operational construction land assets. The accounting equation is

$$A = \bar{P} \times S = \frac{\sum_{i=1}^{n} P_i \times S_i}{\sum_{i=1}^{n} S_i} \times S,$$

where $A$ is the quantity of land assets corresponding to a certain land-use type at the municipal administrative level, $\bar{P}$ is the average transaction price for a specific land-use type at the municipal administrative level, $S$ is the urban cadastral survey area corresponding to a certain land-use type at the municipal administrative level, $S_i$ is the transaction area corresponding to a certain land-use type at the municipal administrative level, $P_i$ is the transaction unit price corresponding to a certain land-use type at the same benchmark date at the municipal administrative level, and $n$ is the number of traded plots corresponding to a certain land-use type at the municipal administrative level.

5.3.3. Nonoperational construction land accounting

Quantity and price are also two core elements to consider when calculating the quantity of nonoperational construction land assets. However, since nonoperational construction land is seldom traded on the market, there is an absence of direct market transaction price data. Therefore, for nonoperational construction land, we need to focus on how to determine the price.

In the field of land valuation, the substitution principle method, opportunity-cost method, and urban location theory can support the price estimation of nonoperational construction land. (1) According to the substitution principle, land valuation should be
Based on the market transaction price of land with the same functions and similar conditions in adjacent areas or similar areas; the valuation results should not obviously deviate from the normal price level of the land for substitution. The land-price level is determined by the price of substituted land of the same nature, which can be assessed by comparing the conditions and use value of the land. Therefore, according to the substitution principle, different types of nonoperational construction land can be compared with the relevant operational construction land. The total quantity of nonoperational assets can be calculated by obtaining the core element of the price.

(2) Given the scarcity of resources, it is necessary to constantly decide how to utilize limited resources and income. The opportunity cost of an option is the value of the corresponding abandoned goods or services. Nonoperational land produces little or no income. However, when used as nonoperational land, the income that would be generated as operational construction land is forfeited. Therefore, the total quantity of nonoperational assets can be calculated by comparing operational construction land with nonoperational construction land according to the opportunity cost principle.

(3) Urban land location refers to the relationship between a certain block or area and the surrounding environment. It plays an important role in the overall benefit of the city. Urban land location determines the land grade, and the land grade affects the price of the land. Therefore, it is necessary to determine the price of nonoperational construction land according to the grade to calculate the total quantity of nonoperational land assets.

Based on the above, we adopted the use analogy method to evaluate the price of nonoperational construction land. Since land use is greatly affected by the surrounding environment, there is a high correlation between the prices of different types of land. Therefore, it is reasonable and feasible to determine the price of nonoperational construction land by comparing it with commercial, residential, and industrial land prices. In the actual evaluation, the price of public administration and service land in better locations should be assessed by referring to the prices for land in the same region with similar uses (commercial and residential). However, the price of industrial land is generally used for evaluation. In general, the location conditions of land used for government organizations, press and publishing, science and education, health services, charity, entertainment, and public facilities are better. If referring only to the price of industrial land, it will lower the price of public administration and service land. Therefore, the average price of commercial, residential, and industrial land with similar uses in the same region can be used to determine the price of public administration and service land. In addition, since green spaces in parks and scenic spots mainly serve to beautify the landscape and indicate the overall environmental level of cities and quality of life, their geographical locations cannot compare with those of other secondary categories of public administration and service land. Therefore, the price of land utilized for parks, green spaces, and scenic spots can be assessed with reference to the prices of similar land (industrial) in the same region. In addition, owing to the relatively poor location conditions of land utilized for special use, transportation, water, and water conservancy facilities, among others, we performed the evaluation with reference to the price of industrial land.
5.4. Accounting results

Using cluster analysis in SPSS to supplement missing data, we conducted an empirical study to determine the total assets of operational and nonoperational construction land in Beijing, Shandong, and Jiangsu based on the abovementioned methods. Table 1 shows the detailed accounting results.

Comparing the results based on the three land-price patterns, in the total asset accounting of state-owned construction land in Beijing in 2017, the asset amount based on the monitored land price is the largest, with asset amounts based on the transaction and benchmark land prices ranking second and third, respectively. In the results for Shandong, the asset amount based on the monitored land price is also the largest, with asset amounts based on the benchmark and transaction land prices ranking second and third, respectively. In the results for Jiangsu, the asset amount based on the transaction land price is the largest, with asset amounts based on the benchmark and monitored land prices ranking second and third, respectively. We found that the accounting result based on the monitored land price was higher in Shandong. The main reason is that land-price monitoring did not cover certain prefecture-level cities such as Dongying, Weihai, Rizhao, Laiwu, Dezhou, Liaocheng, Binzhou, and Heze. Land prices can only be substituted with those of similar cities through cluster analysis. Using land-price data for cities with price monitoring to estimate the land price of the uncovered areas will lead to higher overall price levels. In addition, according to the comparison at the provincial level, Jiangsu had the highest number of state-owned construction land assets based on the benchmark land price, followed by Beijing. Beijing had the highest number of state-owned construction land assets based on the monitored land price. Beijing also had the highest number of state-owned construction land assets based on the transaction land price. For Beijing, the maturity of the land market is relatively high, and the land price remains at a high level. These accounting results are close to the actual situation.

Based on the results in Table 1, to determine the rationality of the accounting results, we further analyzed the structural differences in land asset accounting based on the three different land-price patterns using the proportion of operational construction land assets.

Table 2 shows that in the results obtained for Beijing, Shandong, and Jiangsu based on benchmark, monitored, and transaction land prices, the proportions of operational construction land assets are relatively similar. This indicates that for each sample area, the structure of land assets calculated based on different price patterns was stable. Based on a regional comparison, the proportion of operational construction land assets in each sample area is higher, reaching more than 75%. Since the selected

<table>
<thead>
<tr>
<th>Sample Area</th>
<th>Estimation based on benchmark land price (%)</th>
<th>Estimation based on monitored land price (%)</th>
<th>Estimation based on transaction land price (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>86.35</td>
<td>79.90</td>
<td>77.71</td>
</tr>
<tr>
<td>Shandong</td>
<td>88.30</td>
<td>89.54</td>
<td>90.61</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>85.02</td>
<td>87.97</td>
<td>91.85</td>
</tr>
</tbody>
</table>
sample areas have a higher degree of land marketization and better land-market maturity, the accounting results are broadly in line with reality.

5.5. Applicability analysis of the methods

Based on the above accounting methods and results, we considered the applicability of the accounting methods based on the three land-price patterns by calculating the ratios of state-owned construction land assets in three sample areas. The ratios of state-owned construction land assets are determined according to the asset accounting results based on the benchmark, monitored, and transaction land prices. The smallest asset amount has a ratio of 1, and the ratios of the other two amounts are calculated as the ratio of the actual asset amount to the smallest asset amount (Table 3).

The sample areas of Beijing, Shandong, and Jiangsu are all located in the eastern part of China. The socioeconomic development level in East China is relatively high, and there is a high demand for construction land in urban development. Therefore, land transactions are active, and the land marketization level is high. Consequently, the transaction land price and monitored land price are higher than the benchmark land price. By making a comparison at the provincial level, we found that there are more land transactions in Beijing, and the land-price monitoring system is relatively well established. Therefore, the accounting results based on the monitored land price and transaction land price are much higher than those based on the benchmark land price. Compared to Beijing, Shandong and Jiangsu have relatively few land transactions cases, and the land-price monitoring systems are not well established. Therefore, the accounting results based on the benchmark land price, monitored land price, and transaction land price are all relatively close.

Different regions have different levels of socioeconomic development and land market development, and the accounting results based on different land-price patterns are therefore different. Thus, when calculating land assets, it is not appropriate to simply average the land prices of the three price patterns. A suitable accounting method should be selected in consideration of the level of regional socioeconomic development, land market conditions, different price patterns, accounting purposes, data quality, and data availability. For example, in areas with active land transactions and many transaction cases, there are abundant and easily accessible sets of data, and so the transaction land price can be used for accounting. If the regional land-price monitoring system is relatively well established, the monitored land price can be selected for accounting. For areas with the timely updating of the benchmark land price and a relatively well-established evaluation system, the benchmark land price can be used for accounting.

Table 3. Ratios of state-owned construction land assets in three provincial sample areas, 2017.

<table>
<thead>
<tr>
<th>Sample area</th>
<th>Estimation based on benchmark land price</th>
<th>Estimation based on monitored land price</th>
<th>Estimation based on transaction land price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>1.00</td>
<td>4.02</td>
<td>2.43</td>
</tr>
<tr>
<td>Shandong</td>
<td>1.00</td>
<td>1.43</td>
<td>1.01</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>1.15</td>
<td>1.00</td>
<td>1.21</td>
</tr>
</tbody>
</table>
6. Conclusion and discussion

With steady population growth and expanding human needs, the exploitation of natural resources is becoming increasingly acute. Conserving natural resources and developing ecological civilization have thus become major topics in discussions of sustainable human development. The Chinese government attaches great importance to ecological civilization construction and develops projects to monitor changes in natural resource utilization by means of natural resource asset accounting. The fundamental goal of natural resource asset accounting is to promote the rational utilization and protection of natural resources. Accounting should be based on physical quantity accounting supplemented by value quantity accounting. The monopolization of natural resources should be prevented to avoid distorted interests caused by excessive paid use and valuation. Land resource asset accounting should include the area, quality, and price, and value quantity accounting should follow the principle of marketability. The natural resources balance sheet should belong to the category of the national balance sheet.

Physical quantity accounting is the foundation of natural resource asset accounting. To promote scientific natural resource asset accounting, and to accurately calculate the number of various natural resource assets, the state should promote the use of modern information technology as well as surveying and mapping techniques. This will facilitate natural resource investigations that are accurate and comprehensive. The state should also support research on the classification system of natural resource assets and investigation techniques to lay a foundation for more accurate and improved basic data. The scientific, robust, and accurate investigation and monitoring of various types of natural resources is key to achieving natural resource asset accounting and balance sheet compilation.

Different from other studies of the valuation of natural resources, we have suggested that the excessive paid use and valuation of natural resources should be avoided. However, this is not to deny the value of natural resources. For national balance sheet preparation and the unified management of natural resources, it remains necessary to investigate resources and calculate the value of natural resource assets. Therefore, to meet practical needs, this study explored the principles and methods of land resource asset accounting. Taking Beijing, Shandong, and Jiangsu as examples, we conducted an empirical study of land asset accounting. With the asset accounting of state-owned construction land as an example, we demonstrated the method of land asset accounting and discussed the applicability of different land asset accounting methods. However, owing to limited data availability, only certain provinces and cities were selected for land asset calculation; the national land asset accounting status thus could not be obtained. Therefore, the proposed methods are only for reference purposes. Future work can focus on additional data acquisition and improved methods.

It should also be noted that this study mainly adopted the direct method of accounting—that is, the product of land area and land unit price—to obtain the number of land assets. The direct method is presented in detail in the 2015 guide on land estimation by Eurostat-OECD. This method has also been widely used in many other countries. However, a shortcoming of this method is that it has very high data
requirements, including complete land-price data and area data. Although the degree of the marketization of land resources is higher than that of other types of resources, not every type of land can receive detailed price evaluation. Therefore, to provide a reference, this study selected urban construction land, which has the most transactions and the most mature marketization, and performed trial calculations and demonstrations using the abovementioned accounting ideas based on relatively complete price data. In the future, to meet the needs of the balance sheet preparation of natural resources, it will be necessary to carry out comprehensive nationwide accounting work. The present work provides some preliminary ideas and examples in this regard.

Notes

5. Stage and Uwera, “Prospects for Establishing Environmental Satellite Accounts in a Developing Country.”
9. Ansorge et al., “How Truthful Are Water Accounting Data?.”
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Disclosure statement

No potential conflict of interest was reported by the author(s).
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