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Fiscal Ecological Cost of Land in China: Estimation and Regional Differences

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Abstract: This study explains the fiscal ecological costs of land in China by dividing them into three periods: *early ecological cost* refers to loss of ecosystem service value after the conversion of agricultural land, *mid-term ecological cost* refers to land development in urban built-up areas, and *later ecological cost* refers to the investment cost of increasing the fiscal ecological service function of the land. Using data for 31 Chinese provinces from 2003 to 2017, we perform a "link between groups" cluster analysis with SPSS 22.0 statistical software. Squared Euclidean distance is used to analyze land in these provinces. Ecological cost in the early, middle, and late stages is clustered, and the provinces are divided into five areas according to the ecological cost of each stage in absolute terms and as a proportion of land fiscal revenue. The research shows that: (1) the fiscal ecological cost of land in China presents a spatial pattern of "higher in the east than in the west, higher in the south than in the north," and (2) the cost is highest in the early stage, second highest in the late stage, and lowest in the middle stage. The findings yield differentiated policy recommendations for reducing the fiscal ecological cost of land in different areas.

Keywords: land finance; ecological cost estimation; regional differences; China

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1. Introduction

As a key factor connecting land resources and regional development [1], land finance in China (*tudi caizheng*) is an activity in which the local government uses the land resources within its jurisdiction to carry out and distribute fiscal revenues and expenditure. Land finance has played an important role in China's economic and social development [2–4]. In recent years, the high dependence of local governments on land finance has aroused the attention of academic circles [5]. As shown in Figure 1, in 2003, China's land fiscal revenue was 632.2 billion yuan (1 yuan is equal to about 0.15 dollars), accounting for 41.4% of local fiscal revenue. The total area of transferred land was 193,604.0 hm^2 and total land transferred fees were 542.1 billion yuan. By 2017, China's land fiscal revenue was 6842.3 billion yuan, about 10.8 times that of 2003, accounting for 47.7% of local fiscal revenues. The area of land transferred was 230,898.6 hm^2, and the land transfer fees amounted to 51,984.5 billion yuan, which was about 9.6 times that of 2003.

Many scholars have studied regional differences in the positive and negative effects of land finance on socioeconomic development in China. These scholars are mainly focusing on the following aspects: First, in terms of the scale of land revenue, from 1999 to 2009, the average proportion of land taxes in fiscal revenues in various regions of China was about 18–38%, with few regional differences. Moreover, the proportion of land finance in fiscal revenues in most regions was at a moderate level [6]. Second, in terms of land finance and economic growth, the land finance index shows an increasing trend in the process of economic growth in the eastern, middle and western regions of China [7]. Third, land finance significantly increases the supply of economic public goods/services, but it has an inhibitory effect on the supply of non-economic public goods [8]. In addition, the impact of land finance on the supply of public goods differs significantly across time and space: land finance increases the supply of public goods in the eastern region but decreases it in the central and western regions [9]. Fourth, there is a two-way linkage relationship between land finance and urbanization, and land finance has a continuous positive effect on land urbanization. The promotion of urbanization reduces the urban–rural income gap in western provinces, but it is not conducive to income gap improvement in China's eastern and central provinces [10].

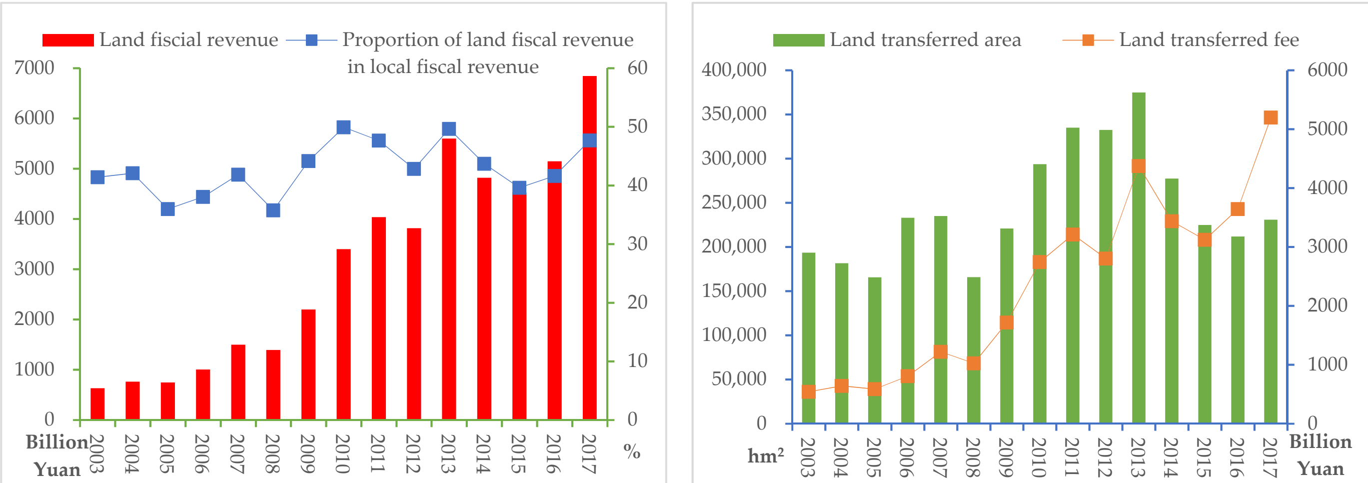

Figure 1. Changes in land finance in China from 2003 to 2017.

These findings underscore the growing importance of land finance in China. However, these studies do not address the ecological costs of land transfers; that is, the actual monetary costs of the ecological changes caused by land transfers. In this study, we address this gap by developing a mechanism framework for understanding the fiscal ecological cost of land transfers.

2. Literature Review

In the 21st century, land finance provides funds and land for rapid urbanization, but it also generates huge environmental pressures [11,12]. In developing countries in particular, rapid urbanization not only increases the consumption of resources and energy [13] but also has a negative impact on the social and ecological environment [14]. The rapid growth of urban land cover not only leads to the loss of cultivated land, abandonment of farmland, and landscape fragmentation [15,16], but it also reduces crop yields, carbon storage, and environmental purification, and it also threatens flood control capabilities [17–20] and biodiversity [21]. In addition, the rapid advancement of urbanization leads to urban diseases, such as water pollution [22], air pollution [23], and traffic congestion [24], thus posing a threat to human health [25]. However, rapid urbanization increases the value of ecosystem waste disposal and cultural entertainment [26], and urbanization can also have a positive impact on the urban environment through green infrastructure, industrial upgrading, and environmental management [27]. In sum, the impact of rapid urbanization on the ecosystem is very complex, and coordinating the relationship between social and economic growth and environmental protection has become an urgent problem to be solved [28].

There are also significant regional differences in the relationship between urbanizaion and the ecological environment specific to China. The impact of urban expansion on the quality of the ecological environment has a spatial spillover effect [29]. Urban expansion in the eastern region has improved the quality of the ecological environment in the target province as well as neighboring provinces. In contrast, urban expansion in central China has had little impact on neighboring provinces. In the western region, urban expansion has led to a decline of the ecological quality of these provinces and an increase in the ecological quality of the neighboring provinces. There is an N-type relationship be-tween urbanization and urban ecological efficiency in China, which first rises, then de-clines and then rises again [30]. A study on the eco-efficiency of 30 provincial capital cities in China finds that almost half have high eco-efficiency, and the low-efficiency cities are mainly located in the southwestern and northwestern regions [13]. To achieve the goal of sustainable cities, the relationship between urbanization, energy, and environmental efficiency is also worthy of attention. The population peri-urbanization caused by China's urban–rural dual household registration system inhibits the improvement of energy efficiency in the eastern and western regions, but it contributes to the improvement of energy efficiency in the central region [31]. Wang et al. studied the coupling relationship of energy and environmental efficiency with urbanization in Guangdong Province using slack data envelopment analysis; they found that only Guangzhou and Shenzhen were in the high coupling stage, while the rest of the cities remained in medium and low coupling stages [15]. Renewable energy consumption and urbanization in various regions of China are affected by other regions, but there is no causal relationship between renewable energy consumption and urbanization in most provinces and geographic regions [32].

Based on the premise of harmony between humans, nature, and society, agricultural land has economic, social, and ecological value. It also performs ecological service functions such as air purification, water conservation, and soil conservation. These positive externalities should be included in cost accounting systems for agricultural land conversion [33]. Moreover, performance evaluation systems focusing on environmental protection and farmland protection have a restrictive effect on illegal land use [34]. However, because ecological environmental risks are driven by economic interests in nature and involve complex issues such as ecological protection, we cannot quantitatively distinguish the degree of ecological environmental risk. China's current land finance policy does not pay sufficient attention to the ecological risk of land finance, so there has been little research on the ecological costs of land finance [35]. Most scholars focus on the value of land ecosystem services and landscape design [36]. In 1997, Costanza put forward the importance of ecosystem service value assessment [37], and the Millennium Ecosystem Assessment (MA) in 2005 tabulated ecosystem service functions as supporting functions, supplying functions, regulating functions, and cultural functions, with reference to previous studies [38]. On this basis, Xie Gao-di established the ecological service value table per unit area of China's terrestrial ecosystem to correct the ecosystem service function, and the research results have been widely used in many studies [39–41].

In fact, land taxes can also protect land ecology. When private property rights cannot be directly allocated, land taxation can protect biodiversity and increase ecosystem sustainability by internalizing the negative externalities generated by land transfers [42]. It can also promote sustainable land use by preventing the acquisition of all land whose marginal productivity is below the tax rate [43]. In terms of specific practice, the ancient rural land tax in Brazil, for example, has been shown to be of great benefit to the coordination of society, agriculture, and the social environment [44]. For instance, the local government of Karacalba will increase the proportion of resource and land taxes in its budget revenue [45]. Similarly, the local government in Poland promotes the use of low-carbon energy through property tax benefits [46]. The United States has also tried to integrate green buildings into its federal low-income housing production program, the largest in the world, to protect the ecological environment [47].

At present, most studies on land finance focus on its causes [48], the positive and negative impacts it has on the economy and society [49], and the transformation and optimization of land finance [50]. However, no scholars have studied the formation mechanism of the ecological cost of land finance. Nor have they explored the regional differences in this cost under the land finance model. To address this gap, this study explains the formation mechanism of the fiscal ecological cost of land in China. This cost includes ecological value loss due to the conversion of agricultural land as well as fuel consumption, exhaust gas, and dust. The urban heat island effect, fragmentation of land as a result of infrastructure construction in development zones, the construction cost of gardens and green space in urban areas, the cost of urban cleaning, and the cost of cultivated land reclamation are also included to achieve a balance of agricultural land occupation and compensation. Based on panel data from 2003 to 2017, the study estimates the fiscal ecological costs of land in 31 Chinese provinces of China. These costs are scientifically divided to reveal the reasons for the formation of regional differences. Based on these findings, different policy recommendations for reducing the fiscal ecological cost of land are put forward.

3. Theoretical Analysis

3.1. Formation Mechanism of Land Finance Ecological Cost

Since the reform of the tax-sharing system in China in 1994, the "upper collection of financial rights and decentralization of administrative powers" has led local governments to rely on land transfer fees and related taxes to develop financial resources [51]. The performance assessment system for local officials in China, which focuses on economic growth, incentivizes local governments to rely on land fiscal revenue to raise funds needed for economic construction [52]. During this transformation period, urbanization and industrialization are promoted by expanding cities and industrial parks, thereby driving the development of the local economy [53]. However, China's unique dual land ownership system (rural land is owned by peasant collectives and urban land is owned by the state) makes local governments the only intermediary for non-agricultural utilization of agricultural land. Local governments expropriate agricultural land at low prices and sell state-owned construction land at high prices, forming differential land rents and related tax revenues [54,55]. Local governments use the public funds raised in this process (i.e., fiscal revenue from land) for infrastructure construction [56], thus forming the cyclical process of "agricultural land expropriation—infrastructure construction—state-owned land transfer—agricultural land expropriation" under the land finance model [57,58]. In this process, land-related fiscal revenues provide impetus for local economic and social construction, which brings related benefits. However, these revenues produce ecological and environmental losses. The ecological environment based on land resources not only provides human beings with a variety of raw materials for production, but it also maintains the necessary life systems for human beings. These environmental resources also maintain the biogeochemical and hydrological cycles in nature and help sustain species and genetic diversity. They also purify the environment and maintain the balance and stability of atmospheric chemistry [59]. In the process of close interaction between humans and nature, changes in land use patterns have accelerated changes in ecosystem services [60]. Thus, the fiscal ecological cost of land represents the loss of ecosystem service value. It also represents the cost of urban infrastructure construction and ecological environment maintenance in the process of converting agricultural land into urban construction land. A framework for the formation mechanism of the fiscal ecological cost of land is shown in Figure 2 [61].

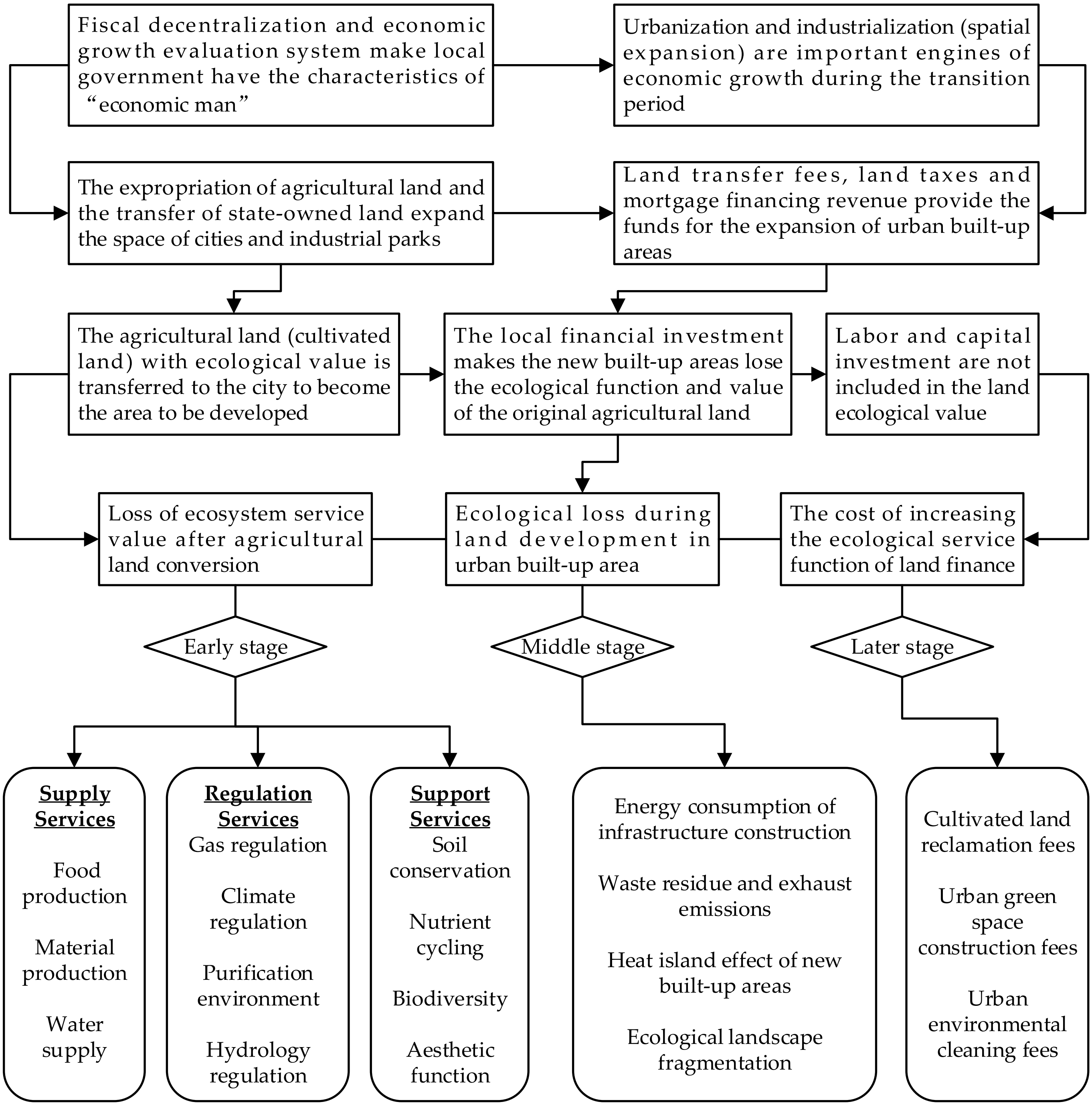

Figure 2. The formation mechanism framework of land fiscal ecological cost.

3.2. Loss of Ecosystem Service Value after Agricultural Land Conversion

In the early stage of the land finance model, cultivated land with ecosystem service functions was expropriated as state-owned land and converted into construction land for urban and industrial parks [62]. Agricultural land provides important outputs for ecosystem services, including air conditioning, environmental purification, water conservation, soil conservation, and nutrient cycling. The long-term low-density and low-intensity land use characteristics of agricultural land are conducive to the protection of biodiversity and cultural service functions [63,64]. These ecosystem services are manifestations of the positive externalities of agricultural land, which are provided by agricultural land for free. This land also yields agricultural products, but these positive externalities will disappear and lead to environmental damage after agricultural land conversion. Thus, the problem of the disappearance of ecological functions of agricultural land in the land finance model is becoming more prominent. To address this problem, we should price the ecological cost scientifically and reasonably and provide ecological compensation accordingly.

3.3. Ecological Loss during Land Development in Urban Built-Up Areas

In the middle stage of the land finance model, the local government develops the expropriated farmland and completes the infrastructure construction of water supply routes, roads, electricity, communications, and gas to realize land urbanization. The conversion of agricultural land has promoted the development of other industries and greatly promoted the growth of GDP. However, the process of economic development is also accompanied by negative externalities, such as air pollution, water pollution, solid waste pollution, and land fragmentation [65]. For example, urban development is accompanied by an increase in artificial, impervious pavement, which promotes the development of traffic and commerce but also produces a heat island effect and urban waterlogging [66]. In the process of economic development, additional resources such as coal, oil, diesel, and steel will inevitably be consumed. In order to ensure the efficient use of land resources, resource consumption in the process of economic development must be considered when calculating the transfer of land resources from agricultural departments to other departments to obtain benefits. The fragmentation of the ecological landscape caused by urbanization not only reduces the ability of the ecological environment to provide important ecosystem services [67], but it also reduces the utilization rate of infrastructure, resulting in idle costs or repeated infrastructure construction costs.

3.4. Cost of Increasing the Ecological Service Function of Land Finance

In the later stage of the land finance model, local governments still need to pay eco-logical costs. On the one hand, in order to achieve the "balance of occupation and compensation" of cultivated land, the newly developed farmland produces reclamation costs. Although the economic and social value of newly developed cultivated land is supplemented, the ecological services value of climate regulation, water conservation, and other services declines. On the other hand, in order to protect the ecological environment of cities and industrial parks, local governments need to construct and maintain urban green spaces such as vegetation, grasslands, and water bodies [68]. They also need to promote clean cities, all of which require investment in human, material, and financial resources.

4. Data Source and Calculation Method

4.1. Data Source

Due to differences in land management systems and lack of statistical data, "China" in this paper does not include Hong Kong, Macao, and Taiwan.

Data on land transferred area, land transferred fee, amount of transferred land, and land expropriation area come from the "China Land and Resources Statistical Yearbook" (2004–2018). The net profit per unit area of rice, corn, and wheat is the average from 2003 to 2017, which comes from "The Compilation of Cost and Income Data of National Agri-cultural Products" (2003–2017). The proportion of the sown area of rice, wheat, and corn in each province to the total sown area of the three crops was unchanged in 2016, according to the "China Food Yearbook" (2017). The composition of the cultivated land area in each province is the value in 2017, which comes from the "China Rural Statistical Year-book" in 2021. The data for new urban road area, length of drainage pipeline, length of water supply pipeline, length of gas pipeline, length of heating pipeline, and the maxi-mum monthly average temperature of each province were obtained from the "China Statistical Yearbook (2002–2018)." The annual maximum temperature data for each province are taken from the "China Environmental Statistics Yearbook (2018)." Data on newly added urban green space area and newly added urban road cleaning area come from the "China Urban Construction Statistical Yearbook (2022–2017)." The total amount of major air pollutants emitted by the combustion of 1 m^3 diesel comes from the "Chinese Environmental Impact Assessment Training Textbook."

4.2. Calculation Methods

4.2.1. Loss of Ecosystem Service Value after Land Conversion

The ecosystem service value equivalent factor is the relative rate of contribution to the ecosystem potential service value. Xie Gao-di et al. believed that the ecosystem service value of a standard equivalent factor can be replaced by the net profit from the grain production of the agricultural ecosystem per unit area [69]. The equivalent value for China can be obtained by calculating rice, wheat, and corn. Considering the fluctuations in planting area and grain price caused by natural and market factors, the average net profit of grain in China from 2003 to 2017 was taken as the standard equivalent factor value in this study. The standard equivalent factor is calculated as follows:

$$D_i = P_i^1 \times S_i^1 + P_i^2 \times S_i^2 + P_i^3 \times S_i^3 \quad (1)$$

In the above formula, D refers to the ecosystem service value (yuan/hm^2) of a standard equivalent factor. P1, P2, and P3 refer to the net profit per unit area (yuan/hm^2) of rice, wheat, and corn, respectively. S1, S2, and S3 refer to the ratio of the sown area of rice, wheat, and corn to the total sown area of the three crops, respectively; i is for province. The average net profit per unit area of the three crops from 2003 to 2017 is 0.52 yuan/kg for rice, 0.28 yuan/kg for wheat, and 0.23 yuan/kg for corn.

$$ESV_i = (D_i \times ZSM_i^p \times V_i^p + D_i \times ZSM_i^d \times V_i^d) \times 50\text{a} \quad (2)$$

In the above formula, ESV is the total value of cultivated land ecosystem services (in billion yuan); ZSM_p and ZSM_d are the paddy land and dry land expropriated area, respectively. V_p and V_d represent the ecosystem service value of paddy land and dry land, respectively; i is for province. The total ecological value of paddy land ecosystems is equivalent to 3.89 equivalent factors, and that of dry land ecosystems is equivalent to 4.01 equivalent factors. The composition of cultivated land area in each province takes the value for 2017, and the transfer year is 50 years, as is standard.

4.2.2. Ecological Loss during Land Development in Urban Built-Up Area

(1) Energy consumption for infrastructure construction in the development zone. The cost of resource consumption reduction (energy consumption, exhaust dust emission, and residual soil and stone) was calculated based on the urban road area and the length of drainage, water supply, and gas and heating pipelines in China from 2002 to 2017. The engineering machinery used in infrastructure construction mainly consumes diesel oil. The following items are used to calculate the energy consumption calculation of five types of infrastructure construction (water supply, roads, electricity, communication, and gas): diesel fuel consumption for topsoil stripping and transportation on urban roads; consumption of diesel oil for the excavation and shipment of roadbed concrete, asphalt, and gravel; diesel consumption for water supply, drainage, and gas and heating pipeline ditching and filling; diesel fuel consumption for transport of residual soil; and volume and total price of diesel fuel consumption. At the same time, the waste dust emission scale is calculated according to diesel consumption. The calculation process and formula are as follows:

$$CER_i = URA_i \times (SST_i + CAT_i) \times 0.4\ \text{L/m}^3 \times 10^{-4} \quad (3)$$

$$FCR_i = \frac{URA_i \times (SST_i + CAT_i)}{25.0\ \text{m}^3/\text{Train}} \times 25.0\ \text{km} \times 2 \times 0.5\ \text{L/km} \times 10^{-4} \quad (4)$$

In Formulas (3) and (4), CER is the total fuel consumption of earthwork excavated from urban roads. URA is new urban road area. SST is surface soil stripping thickness of plough layer (value: 0.25 m). CAT is subgrade concrete thickness and pavement asphalt thickness (0.4 m). The average transport distance is 25.0 km, and the average round trip is 50 km. FCR is the total transportation fuel consumption of stripped topsoil, subgrade concrete, and asphalt gravel. i is the province.

$$FCP_i = (LDP_i + LSP_i + LGP_i + LHP_i) \times (2 \times DPG + PD) \times TWP \times 0.4\ \mathrm{L/m^3} \times 10^{-4} \quad (5)$$

$$FCT_i = \frac{(LDP_i + LSP_\mathrm{i} + LGP_i + LHP_\mathrm{i}) \times PD \times TWP}{25.0\ \mathrm{m^3/Train}} \times 25\ \mathrm{km} \times 2 \times 0.5\ \mathrm{L/km} \times 10^{-4} \quad (6)$$

In Formulas (5) and (6), *FCP* is the fuel consumption of soil excavation and covering of pipeline. *LDP* is the length of drainage pipeline. *LSP* is the length of water supply pipeline. *LGP* is the length of gas pipeline. *LHP* is the length of heating pipeline. *DPG* is the distance between the top of the pipeline and ground (value: 1.5 m). *PD* is the pipeline diameter (1 m). *TWP* is the trench width of pipeline laying (value: 1.5 m). *FCT* is the fuel consumption of residual soil transportation caused by the space occupied by pipelines.

$$DA_i = TDC_i \times DP_i \quad (7)$$

$$TDC_i = CER_i + FCR_i + FCP_i + FCT_i \quad (8)$$

$$TEE_i = TDC_i \times (8.57\ \mathrm{kg}\ NO_2 + 10.0\ \mathrm{kg}\ SO_2 + 1.8\ \mathrm{kg}\ DD)/\mathrm{m^3} \times 10^{-2} \quad (9)$$

In Formulas (7)–(9), *DA* is the amount of diesel consumed. *TDC* is the total amount of diesel consumed. *DP* is the price of diesel oil, as of 16 March 2022. *TEE* is the total amount of exhaust dust emissions. *DD* is dust.

(2) Heat island effect of hardened roads in built-up areas. The heat island effect in this land finance model refers to fiscal funds put into urban road construction, which change the nature of the underlying surface by covering it with asphalt. Because of its good thermal conductivity and fast heating transfer rates, it absorbs a lot of radiation from the sun in the daytime. After sunset, it continuously emits heat to the air, heating the surrounding atmosphere [70]. It is assumed that the near-surface air temperature is mainly determined by road surface temperature and is not affected by wind speed and other conditions; the relationship between road surface temperature and near-surface air temperature is calculated as in [71]:

$$AT_{Hi} - AT_{Li} = k_i \times (RT_{Hi} - RT_{Li}) \quad (10)$$

In Formula (10), AT_H and AT_L are the daily maximum and minimum atmospheric temperatures. RT_H and RT_L are the maximum and minimum temperature of road surface. *k* is the correlation coefficient between atmospheric temperature and road temperature. *i* is the province.

$$AT_{ai} = (AT_{Hi} - AT_{Li}) \times \frac{URA_i}{UBA_i} \times \frac{RA_H - RA_L}{\overline{RA}} \quad (11)$$

In Formula (11), AT_{ai} is the influence of ground temperature on atmospheric temperature. *URA* is new urban road area, and *UBA* is new urban built-up area. *RA* is the heat absorption rate of pavement, and $\overline{RA}$ is the average heat absorption rate of pavement. The temperature difference across the 31 provinces is twice the difference between the annual maximum temperature and the average monthly maximum temperature in 2017. The maximum and minimum heat absorption rates of pavement is 0.9 and 0.65, respectively, and the average heat absorption rate of pavement was 0.8 [72].

(3) The fragmentation of the land ecological landscape in the built-up area. The agricultural landscape has the characteristics of contiguous homogeneity and single cover. After infrastructure construction in the urban built-up area is completed, the local government transfers it to various land units in the form of land parcels (plots), and the ecological landscape changes from a single agricultural landscape to a variety of landscapes, such as industrial, commercial, and residential land. The degree of fragmentation of the ecological landscape caused by the land finance model is measured by three indicators: degree of

fragmentation of transferred land, average area of transferred land, and degree of urban agglomeration of transferred land. The calculation process is as follows:

$$DFL_i = 100 \times \frac{NTL_i}{LTA_i} \tag{12}$$

$$AAL_i = \frac{LTA_i}{NTL_i}, \tag{13}$$

$$DAL_i = \frac{100 \times UBA_i}{LTA_i} \times 100\% \tag{14}$$

In Formulas (12)–(14), *DFL* is the degree of fragmentation of transferred land. *NTL* is the number of transferred lands. *LTA* refers to the land transferred area. *AAL* is the average area of transferred land. *DAL* is the degree of urban agglomeration of transferred land. *i* is the province.

4.2.3. The Cost of Increasing the Ecological Service Function of Land Finance

In the later stage of the land finance model, activities to increase ecological service functions, such as newly developed land, urban cleaning, and urban green space construction require money to be spent. In order to implement the policy of agricultural land occupation and compensation balance, 31 provinces have formulated corresponding standards for the reclamation fees of general agricultural land occupied due to construction within the province. This study structures these fees in accordance with the minimum standards for cultivated land reclamation fees in each region before 2017. For regions without specific standards, it is calculated according to the standard of 10 yuan/m^2. The cost of lawn and tree planting is mainly calculated for the construction of garden green space. The price of lawn is 30.0 yuan/m^2. The distance for trees is 6.0 m, and the price is 80.0 yuan per tree. The cost of urban cleaning is calculated as 12.0 yuan/m^2 for labor and 4.0 yuan/m^2 for machinery. The calculation process of the cost of increasing ecological service function in the land finance model is as follows:

$$FLR_i = ALE_i \times LRP_i \times 10^4 \times 10^{-9} \tag{15}$$

$$UGE_i = IUG_i \times 10^4 \times \left[30 \text{ yuan/m}^2 + 80 \text{ yuan}/(6 \text{ m} \times 6 \text{ m})\right] \times 10^{-9} \tag{16}$$

$$CCE_i = (MCA_i \times 4 \text{ yuan/m}^2 + ACA_i \times 12 \text{ yuan/m}^2) \times 10^4 \times 10^{-9}/\text{a} \times 2\text{a} \tag{17}$$

In Formulas (15)–(17), *FLR* is the fees of land reclamation. *ALE* is the area of land expropriated. *LRP* is the land reclamation fee per square meter. *UGE* is the new urban green space construction expense. *IUG* is the increment of urban green space area. *CCE* is the city cleaning expenses. *IUC* is the increment of urban cleaning area. *MCA* is the mechanical cleaning area. *ACA* refers to artificial cleaned area. *i* is for province.

5. Results

5.1. Land Fiscal Ecological Cost at Each Stage

5.1.1. Loss of Ecosystem Service Value after Agricultural Land Conversion

According to Formulas (1) and (2), the ecological cost in the early stage of land finance model and its proportion in total fiscal funds for land in the 31 provinces in China from 2003 to 2017 are calculated, as shown in Table 1.

Table 1. Ecological cost in the early stage of the land finance model and its proportion in fiscal land funds for the 31 provinces in China from 2003 to 2017.

Provinces	Net Profit Per Unit Area (yuan/kg)			D (yuan/hm^2)	LTA (hm^2)	Earlier Costs	
	Wheat	Corn	Rice			Amount (Billion Yuan)	Proportion (%)
Beijing	1411.1	1376.2	3394.2	1388.2	33,277.3	9.3	0.50
Tianjin	1411.7	1213.5	3824.1	1410.0	63,483.1	17.9	1.76
Hebei	1521.1	1182.1	3376.4	1354.5	183,573.1	49.8	3.64
Shanxi	976.4	1212.0	2657.5	1143.5	62,727.8	14.4	3.37
Inner Mongolia	864.2	1419.0	3852.8	1395.8	131,006.2	36.7	6.18
Liaoning	1261.2	1405.0	3898.6	1901.1	191,500.9	72.7	4.09
Jilin	867.7	1659.0	4141.1	2095.5	65,718.1	27.5	5.86
Heilongjiang	949.7	1232.0	3497.9	2083.1	69,338.2	28.8	6.30
Shanghai	1097.3	1509.8	4230.6	3385.3	47,124.3	31.3	1.81
Jiangsu	1380.2	1209.3	4116.8	2639.0	401,155.3	208.5	3.95
Zhejiang	1021.3	1011.5	3498.2	3122.3	227,126.8	139.0	3.64
Anhui	1424.9	1065.8	3174.8	2078.0	183,121.3	75.1	4.26
Fujian	857.3	877.0	3005.3	2865.8	111,594.2	62.5	4.33
Jiangxi	549.4	964.3	2936.8	2910.2	123,226.9	70.1	6.79
Shandong	1641.3	1481.9	4226.5	1608.0	390,632.1	125.9	4.00
Henan	1652.4	1268.9	3798.0	1666.5	162,479.2	54.1	3.78
Hubei	973.4	1098.8	3900.0	2593.5	159,322.9	81.6	5.80
Hunan	755.3	1243.0	3229.3	3062.7	112,821.0	67.7	6.48
Guangdong	849.2	1030.9	2805.6	2649.7	180,447.0	94.0	2.80
Guangxi	423.8	974.4	2759.8	2331.5	86,236.1	39.8	5.64
Hainan	0.0	692.1	2172.3	2172.3	19,595.8	8.4	3.00
Chongqing	860.9	1227.1	3642.3	2571.4	83,650.1	42.6	3.38
Sichuan	983.1	1166.4	3768.4	2278.5	154,404.3	69.7	4.05
Guizhou	548.3	1021.3	3055.3	1780.3	62,901.4	22.3	3.93
Yunnan	545.7	1015.2	3064.0	1702.8	78,094.4	26.5	4.13
Tibet	1810.6	1232.7	2877.6	1771.4	4540.2	1.6	11.10
Shaanxi	1011.4	1043.0	3433.0	1153.0	66,102.8	15.2	2.82
Gansu	836.0	1183.8	3298.5	788.8	58,488.1	9.2	4.35
Qinghai	1087.7	1697.3	441.2	1231.3	15,724.4	3.9	6.80
Ningxia	873.3	1697.2	4275.5	1876.9	41,816.0	15.7	13.35
Xinjiang	1541.7	1643.1	4414.9	1669.9	105,144.7	35.2	13.00

Table 1 shows that under the influence of climate, hydrology, topography, and other factors in different regions, the main grain crops in North China, Northeast China, and Northwest China are wheat and corn, which yield low net profits. In contrast, rice, with high net profits, is planted in East China, South China, and Southwest China. The ecosystem service value of the standard equivalent factors over the 31 provinces of China was higher in the south and lower in the north. It was also higher in the east and lower in the west. More specifically, eastern provinces have the highest ecological cost in the early stage of the land finance model, and the fiscal ecological costs of land in the central provinces are next. The ecological cost of land finance is lowest in the western provinces. However, due to the influence of the level of economic development, the proportions of early ecological costs in the land finance funds show different rules. The ratio of early ecological costs is the highest in Ningxia, Xinjiang, Tibet, and Qinghai. Provinces in north, central and northeast China are next. In Beijing, Tianjin, and Shanghai, the proportion of early ecological costs to fiscal land revenue is the lowest. Therefore, the local government should avoid ignoring the ecological cost of agricultural land in the process of land expropriation and the occupation of farmland in the process of urbanization.

5.1.2. Ecological Loss during Land Development in Urban Built-Up Areas

According to Formulas (3)–(14), the energy consumption and emission scale of infrastructure construction, impact of road temperature on air temperature, and fragmentation degree of the ecological landscape in newly built-up areas in 31 provinces across China from 2003 to 2017 are calculated, as shown in Table 2.

Table 2. The ecological cost in the middle stage of the land finance model and its proportion in fiscal land funds for 31 provinces in China from 2003 to 2017.

Provinces	Energy Consumption of Infrastructure Construction				Heat Island Effect	Ecological Landscape Fragmentation			Proportion (%)
	TDC (10,000 L)	DA (Billion Yuan)	TEE (t)	RE (10,000 m^3)	AT ai (°C)	DFL (plot/km^2)	AAL (hm^2/plot)	DAL (%)	
Beijing	26,978	2.1	5495.4	36,768.6	1.04	34.9	2.9	120.8	0.11
Tianjin	31,879	2.5	6493.7	41,897.1	1.02	27.3	3.7	99.8	0.24
Hebei	44,852	3.5	9136.3	52,665.1	1.44	43.6	2.3	57.0	0.25
Shanxi	24,071	1.9	4903.2	27,747.8	1.86	46.2	2.2	81.4	0.44
Inner Mongolia	27,905	2.1	5684.2	30,465.3	1.86	46.9	2.1	46.1	0.36
Liaoning	48,409	3.7	9861.0	61,943.5	1.17	32.1	3.1	51.4	0.21
Jilin	25,721	2.0	5239.3	31,584.8	0.89	77.3	1.3	97.7	0.42
Heilongjiang	22,174	1.7	4516.9	26,704.6	1.18	53.9	1.9	75.0	0.37
Shanghai	20,946	1.6	4266.7	32,224.8	0.00	27.1	3.7	95.3	0.09
Jiangsu	122,369	9.4	24,926.5	146,715.4	1.28	40.3	2.5	62.0	0.18
Zhejiang	73,241	5.6	14,919.1	91,293.3	1.09	64.7	1.5	70.0	0.15
Anhui	47,974	3.7	9772.3	55,568.4	1.47	43.8	2.3	58.1	0.21
Fujian	28,938	2.2	5894.7	31,813.2	0.94	40.8	2.4	90.9	0.15
Jiangxi	29,316	2.3	5971.6	33,027.0	0.82	41.6	2.4	77.3	0.22
Shandong	125,268	9.7	25,517.2	146,897.8	1.15	37.4	2.7	78.3	0.31
Henan	42,917	3.3	8742.2	48,669.9	0.90	40.7	2.5	88.4	0.23
Hubei	39,265	3.0	7998.2	48,670.7	0.97	91.2	1.1	57.9	0.22
Hunan	33,240	2.6	6770.9	37,960.6	1.30	149.0	0.7	72.0	0.25
Guangdong	97,586	7.5	19,878.3	117,307.5	0.77	75.8	1.3	205.8	0.22
Guangxi	23,316	1.8	4749.4	25,301.4	1.17	141.6	0.7	89.6	0.26
Hainan	6713	0.5	1367.5	7801.4	1.19	27.6	3.6	90.4	0.19
Chongqing	29,022	2.3	5911.7	33,584.7	1.00	38.3	2.6	117.8	0.18
Sichuan	54,940	4.3	11,191.3	67,556.8	0.85	162.9	0.6	105.6	0.25
Guizhou	14,793	1.2	3013.4	17,507.4	0.60	73.0	1.4	105.9	0.20
Yunnan	17,882	1.4	3642.6	20,742.6	0.67	168.0	0.6	100.9	0.22
Xizang	2629	0.2	535.6	3537.4	0.58	91.5	1.1	166.6	1.50
Shaanxi	24,175	1.8	4924.5	27,042.6	1.18	45.0	2.2	122.5	0.34
Gansu	9677	0.7	1971.2	10,062.8	1.55	46.4	2.2	67.3	0.35
Qinghai	4643	0.4	945.7	5603.0	1.83	51.8	1.9	64.2	0.62
Ningxia	10,146	0.8	2066.7	11,751.7	1.46	30.7	3.3	69.4	0.66
Xinjiang	21,922	1.7	4465.6	25,859.6	0.34	72.3	1.4	68.7	0.62

Table 2 shows that among the 31 provinces, diesel consumption in the eastern provinces, such as Shandong, Jiangsu, Guangdong, and Zhejiang, is the largest, followed by the central regions such as Hebei, Henan, Hubei, and Hunan. Less developed regions such as Gansu, Qinghai, Ningxia, Tibet, and Hainan have the lowest diesel consumption and cost, which matches the urbanization construction speed of these regions over the past 15 years. Beijing and Shanghai have low diesel fuel consumption and capital over the past 20 years due to their strong infrastructure and high urbanization level. However, the proportion of diesel fuel consumption funds to land finance funds shows the opposite tendency. Tibet, Ningxia, Qinghai, Xinjiang, and other places have a small scale of land finance, so the proportion is relatively high. Shanxi, Heilongjiang, Sichuan, Henan, and other east and central provinces accounted for the second. Due to the large scale of land finance, Beijing, Shanghai, Zhejiang, Fujian, and Jiangsu have the lowest proportion of diesel consumption funds.

The change in the nature of the underlying urban surface is one of the reasons for the heat island effect. The influence of road surface temperature on atmospheric temperature is also closely related to the temperature difference between day and night, but the latter also depends on natural geographical conditions and can be ignored here. In addition, different types of land use, such as public service facilities, residential, commercial, and green space, also have an impact on the urban thermal environment [73]. Pavement temperature can be reduced by increasing pavement albedo and permeability, and green infrastructure such as ecological sidewalks or green roofs can be built to alleviate the urban heat island effect.

In terms of the degree of fragmentation of the ecological landscape in newly built-up areas, among the 31 provinces, Yunnan, Sichuan, Hunan, Guangxi, Tibet, Hubei, and other mountainous, plateau, and hilly areas have complex topography, and the land transferred here has the highest fragmentation degree [74]. In the middle and lower reaches of the Yangtze River, the middle and lower reaches of the Yellow River, the Northeast Plain, the Pearl River Delta, and other plains areas, the fragmentation of the transferred land is relatively low and is closely related to the level of social and economic development. The higher the economic development, the higher the fragmentation of transferred land. The fragmentation of the transferred land has a significant negative correlation with the area of transferred land. Generally, the larger the average area of the land to be transferred, the lower the fragmentation degree. In terms of the urban agglomeration degree of land, the higher the level of economic development, the higher the degree of agglomeration, indicating that these areas allocate a high proportion of land resources to tertiary industries such as commerce and real estate [75].

5.1.3. Cost of Increasing the Ecological Service Function of Land Finance

According to Formulas (15)–(17), the cost of increasing land fiscal ecological service function in the 31 provinces from 2003 to 2017 is calculated, as shown in Table 3.

Table 3. The cost of increasing the fiscal ecological service function of land in 31 provinces from 2003 to 2017.

Provinces	FLR (Billion Yuan)	UGE (Billion Yuan)	CCE (Billion Yuan)	Late Cost (Billion Yuan)	Proportion (%)
Beijing	7.7	13.2	0.6	21.5	1.15
Tianjin	5.9	8.7	0.8	15.4	1.51
Hebei	16.3	17.7	1.9	35.9	2.62
Shanxi	10.7	10.2	0.9	21.8	5.10
Inner Mongolia	14.8	10.9	2.4	28.2	4.76
Liaoning	15.7	16.5	1.8	33.9	1.91
Jilin	8.9	8.5	0.9	18.4	3.91
Heilongjiang	2.0	9.1	1.9	12.9	2.83
Shanghai	19.4	6.3	1.5	27.2	1.57
Jiangsu	33.0	37.1	4.2	74.3	1.41
Zhejiang	49.0	22.6	4.2	75.9	1.99
Anhui	11.2	18.6	2.2	32.0	1.81
Fujian	22.2	14.7	1.5	38.3	2.65
Jiangxi	19.3	15.9	2.3	37.5	3.63
Shandong	27.4	43.4	4.4	75.1	2.39
Henan	23.0	20.8	2.1	45.9	3.20
Hubei	23.5	12.6	2.1	38.2	2.72
Hunan	23.2	13.0	3.0	39.2	3.75
Guangdong	18.4	53.5	13.7	85.6	2.55
Guangxi	17.9	10.2	2.6	30.7	4.35
Hainan	2.8	2.4	1.6	6.8	2.43
Chongqing	14.0	15.1	2.0	31.1	2.47
Sichuan	23.5	25.0	3.4	51.8	3.01
Guizhou	12.4	8.7	1.4	22.5	3.97
Yunnan	26.3	9.9	2.0	38.1	5.95
Tibet	1.2	1.6	0.1	2.9	20.02
Shaanxi	12.2	11.8	1.4	25.3	4.69
Gansu	5.3	6.6	0.7	12.6	5.94
Qinghai	0.5	1.4	0.3	2.3	3.98
Ningxia	1.6	4.7	1.1	7.4	6.33
Xinjiang	0.7	10.3	1.3	12.3	4.53

Table 3 shows that the total cost of increasing the ecological service function of the land finance model is the largest in Guangdong, Zhejiang, Shandong, Jiangsu, and other eastern provinces, which is positively correlated with the land transfer area and infrastructure construction in these regions. At the same time, this value is also affected by the manner of cleaning (artificial cleaning or mechanical cleaning) used by the cities in each region. The larger the area of mechanized cleaning is, the lower the cost is, such as in Beijing, Shanghai, and Tianjin. However, the ratio of ecological cost to land finance capital in the later stage of land finance in the 31 provinces shows the opposite tendency: The more developed the economy is, the lower the proportion of ecological cost to land finance capital in the later stage of land finance.

5.1.4. Fiscal Ecological Cost of land in 31 Provinces

During the 15 years from 2003 to 2017, the 31 provinces witnessed rapid urbanization and improved infrastructure: a process in which land finance played an important role. However, it has also brought negative effects, such as reduced value for agricultural land ecosystem services, energy consumption, exhaust gas and dust emissions, urban heat island effects, and ecological landscape fragmentation. The construction of a good urban living environment for cleaning, green space construction, and the implementation of the "agricultural land occupation and compensation balance policy" requires corresponding investment. According to the formation mechanism of the fiscal ecological cost of land, the scale of various ecological costs in the early, middle, and late stages of the land finance model for the 31 provinces and their proportions in fiscal land funds are estimated, as shown in Table 4.

Table 4. The fiscal ecological cost of land and proportion in land fiscal funds in 31 provinces.

Provinces	Early Cost (Billion Yuan)	Middle Cost (Billion Yuan)	Late Cost (Billion Yuan)	Land Fiscal Ecological Cost (Billion Yuan)	Proportion (%)
Jiangsu	208.5	9.4	74.3	292.2	5.54
Zhejiang	139.0	5.6	75.9	220.5	5.77
Shandong	125.9	9.7	75.1	210.7	6.70
Guangdong	94.0	7.5	85.6	187.2	5.58
Sichuan	69.7	4.3	51.8	125.8	7.30
Hubei	81.6	3.0	38.2	122.8	8.73
Anhui	75.1	3.7	32.0	110.8	6.28
Liaoning	72.7	3.7	33.9	110.3	6.20
Jiangxi	70.1	2.3	37.5	109.9	10.65
Hunan	67.7	2.6	39.2	109.4	10.48
Henan	54.1	3.3	45.9	103.3	7.21
Fujian	62.5	2.2	38.3	103.1	7.14
Hebei	49.8	3.5	35.9	89.1	6.51
Chongqing	42.6	2.3	31.1	75.9	6.03
Guangxi	39.8	1.8	30.7	72.3	10.24
Inner Mongolia	36.7	2.1	28.2	67.0	11.30
Yunnan	26.5	1.4	38.1	66.0	10.30
Shanghai	31.3	1.6	27.2	60.1	3.47
Xinjiang	35.2	1.7	12.3	49.1	18.15
Jilin	27.5	2.0	18.4	47.8	10.20
Guizhou	22.3	1.2	22.5	46.0	8.10
Heilongjiang	28.8	1.7	12.9	43.4	9.50
Shaanxi	15.2	1.8	25.3	42.4	7.85
Shanxi	14.4	1.9	21.8	38.0	8.91
Tianjin	17.9	2.5	15.4	35.8	3.52
Beijing	9.3	2.1	21.5	32.8	1.76
Ningxia	15.7	0.8	7.4	23.9	20.34
Gansu	9.2	0.7	12.6	22.6	10.64
Hainan	8.4	0.5	6.8	15.7	5.62
Qinghai	3.9	0.4	2.3	6.5	11.40
Tibet	1.6	0.2	2.9	4.7	32.61

As can be seen in Table 4, Jiangsu, Zhejiang, Shandong, and Guangdong, four coastal provinces, have the most fiscal ecological land cost. In Sichuan, Hubei, Anhui, Liaoning, Jiangxi, Hunan, Henan, and other regions of that scale, the fiscal ecological land cost is second. Ningxia, Gansu, Hai-nan, Qinghai, Tibet, and other less developed western provinces have the smallest fiscal ecological land cost. This is related to the speed of local economic development and the scale of new infrastructure. However, the fiscal ecological land cost in Beijing, Shanghai, and Tianjin is relatively small. This is due to the highly developed infrastructure and high level of urbanization. The scale of fiscal ecological land cost in China presents a spatial pattern of "higher in the east than in the west, higher in the south than in the north".

5.2. Total Fiscal Ecological Cost of Land in China

From 2003 to 2017, China transferred a total of 376,374.0 hm^2 of state-owned construction land, with a total land finance fund of 39,815.6 billion yuan. Based on the formation mechanism of the fiscal ecological cost of land, the comprehensive scale of fiscal ecological land cost in China from 2003 to 2017 is estimated, as shown in Table 5.

Table 5. Comprehensive scale of fiscal ecological costs of land in China from 2003 to 2017.

Project		Amount	Cost/Billion Yuan Land Fiscal Fund
Land finance	Land transferred area	3,676,374.0 hm^2	92.3 hm^2/billion yuan
	Land fiscal fund	39,815.6 billion yuan	——
Early cost	Loss of cultivated land ecosystem service value	1556.9 billion yuan	39.1 million yuan/ billion yuan
Middle cost	Energy costs	87.3 billion yuan	2.2 million yuan/ billion yuan
	Exhaust dust emission	230,772.7 t	5.8 t/billion yuan
	Residual soil and stone	13.6 billion m^3	340,000 m^3/billion yuan
	Heat island effect	——	——
	Number of land transfers	2,256,407 plots	56.7 plots/billion yuan
	Fragmentation degree of transferred land	61.4 plots/km^2	——
	New urban built-up area	30,253.4 km^2	76.0 hm^2/billion yuan
	Average area of transferred land	1.6 hm^2/plot	——
	Degree of urban agglomeration of transferred land	82.3%	——
Late cost	Fees of land reclamation	469.8 billion yuan	11.8 million yuan/ billion yuan
	New urban green space construction expenses	460.8 billion yuan	11.6 million yuan/ billion yuan
	City cleaning expenses	70.3 billion yuan	1.8 million yuan/ billion yuan
The total cost	Quantifiable cost	2645.1 billion yuan	66.4 million yuan/ billion yuan

It can be seen from Table 5 that the quantifiable land fiscal ecological cost in China from 2003 to 2017 is 2645.1 billion yuan, and the ecological cost of each additional 1 billion yuan of land finance revenue is 664,000 yuan, accounting for 6.64% of fiscal land revenue. The ecological cost accounts for 3.91%, 0.22%, and 2.51% in the early, middle, and late periods of the land finance model operation. At the same time, 5.8 t of waste gas and dust and 341,000 m^3 of residual soil and stone were generated for every 1 billion yuan of land finance funding. On average, 56.7 plots of land were transferred, and 76 hm^2 of land was used for urban expansion. During the past 15 years, the fragmentation of transferred land in China under the land finance model was 61.4 plots/km^2, and the degree of urban agglomeration of transferred land was 82.3%. The climate of the 31 provinces varies greatly, and urban road construction has different degrees of influence on air temperature.

5.3. Cluster Partition and Robustness Tests of the Fiscal Ecological Cost of Land

5.3.1. Cluster Partition of Land Fiscal Ecological Cost

Jiangsu, Zhejiang, Shandong, and Guangdong, all located in the eastern region, have the highest level of economic development in the country. Therefore, revealing the law of regional differences in the scale of fiscal ecological land costs and classifying regions with approximately the same situation into the same category can provide a reference for the construction of policies to reduce the scale of fiscal ecological land costs and eliminate disadvantages in the process of urbanization. In order to study the regional differences of fiscal ecological land cost scale in the 31 provinces, the method of "linking between groups" in cluster partition using SPSS 22.0 statistical software was adopted, and the number of clusters was set to four to six for clustering, with square Euclidean distance as the metric standard. Table 6 shows the clustering of the ecological cost of land finance in the early, middle, and late stages for the 31 provinces in Table 5.

Table 6. Clustering results of land fiscal ecological cost of 31 provinces in 4, 5, and 6 class.

Provinces	Class IV	Provinces	Class V	Provinces	Class VI
Jiangsu	I	Jiangsu	I	Jiangsu	I
Zhejiang	II	Zhejiang	II	Zhejiang	II
Shandong	II	Shandong	II	Shandong	II
Guangdong	II	Guangdong	II	Guangdong	II
Sichuan	III	Sichuan	III	Sichuan	III
Hubei	III	Hubei	III	Hubei	III
Anhui	III	Anhui	III	Anhui	III
Liaoning	III	Liaoning	III	Liaoning	III
Jiangxi	III	Jiangxi	III	Jiangxi	III
Hunan	III	Hunan	III	Hunan	III
Henan	III	Henan	III	Henan	III
Fujian	III	Fujian	III	Fujian	III
Hebei	III	Hebei	IV	Hebei	IV
Chongqing	III	Chongqing	IV	Chongqing	IV
Guangxi	III	Guangxi	IV	Guangxi	IV
Inner Mongolia	III	Inner Mongolia	IV	Inner Mongolia	IV
Yunnan	III	Yunnan	IV	Yunnan	IV
Shanghai	III	Shanghai	IV	Shanghai	IV
Xinjiang	IV	Xinjiang	V	Xinjiang	V
Jilin	IV	Jilin	V	Jilin	V
Guizhou	IV	Guizhou	V	Guizhou	V
Heilongjiang	IV	Heilongjiang	V	Heilongjiang	V
Shaanxi	IV	Shaanxi	V	Shaanxi	V
Shanxi	IV	Shanxi	V	Shanxi	V
Tianjin	IV	Tianjin	V	Tianjin	V
Beijing	IV	Beijing	V	Beijing	V
Ningxia	IV	Ningxia	V	Ningxia	VI
Gansu	IV	Gansu	V	Gansu	VI
Hainan	IV	Hainan	V	Hainan	VI
Qinghai	IV	Qinghai	V	Qinghai	VI
Tibet	IV	Tibet	V	Tibet	VI

In order to make the zoning results more accurate, the three zoning results in Tables 5 and 6 are compared and combined, and the 31 provinces are divided into five areas based on urbanization development status, physical–geographical conditions, and land finance situation. The scale of the ecological land finance cost and its proportion in land finance funds in Beijing, Shanghai, and Tianjin is very low, while the level of economic development and urbanization is high, so they are classified as Area I (Developed–Low Ecological Cost Area). Jiangsu, Zhejiang, Shandong, and Guangdong are Area II (Highest Ecological Cost Area). Sichuan, Hubei, Anhui, Liaoning, Jiangxi, Hunan, Henan, Fujian, and Hebei are Area III (Higher Ecological Cost Area). Chongqing, Guangxi, Inner Mongolia, Yunnan, Jilin, Guizhou, Heilongjiang, Shaanxi, Shanxi, and Hainan are Area IV (Medium Ecological Cost Area). Finally, in Xinjiang, Ningxia, Gansu, Qinghai, and Tibet, the scale of ecological land finance cost is very low. However, the proportion of land finance funds is high, so this region is Area V (Less Developed–Low Ecological Cost Area). The clustering results of the fiscal ecological land cost scale are shown in Figure 3.

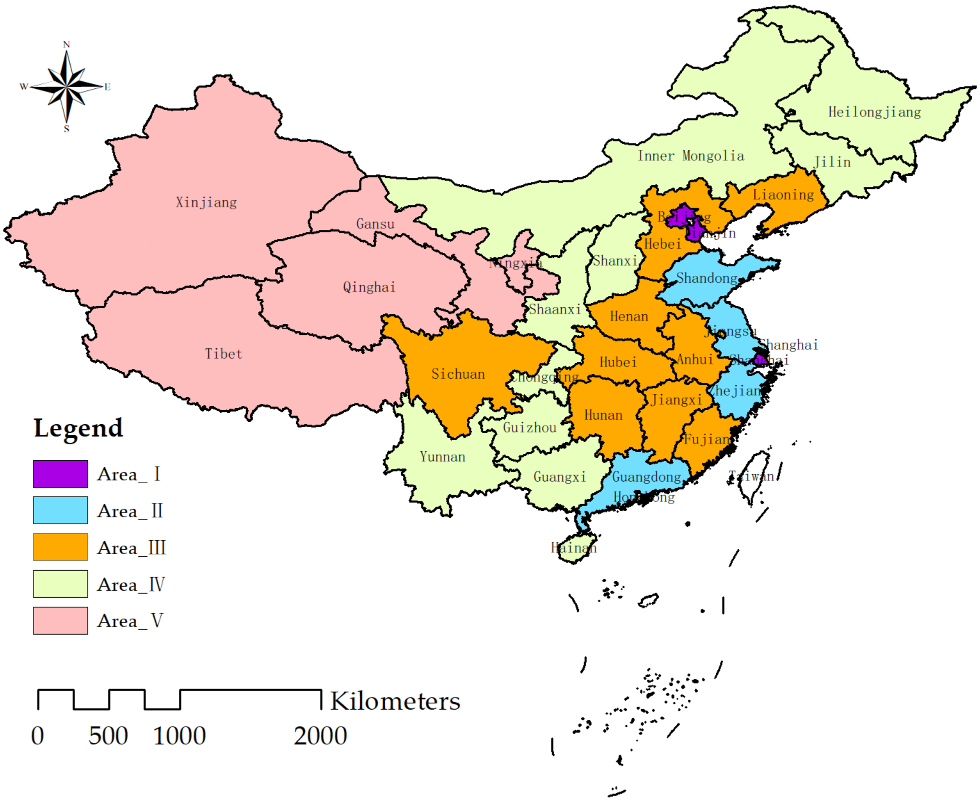

Figure 3. Clustering results of land fiscal ecological cost scale in 31 provinces.

5.3.2. ANOVA of Cluster Partition of Fiscal Ecological Land Cost

According to the results of the cluster partition, we selected the amount of fiscal ecological land cost and its proportion in land fiscal revenue for the 31 provinces from 2003 to 2017 as the dependent variable to conduct a one-way analysis of variance (ANOVA) test with the area as the independent variable, as shown in Table 7.

Table 7. One-way ANOVA of land fiscal ecological cost and its proportion to land finance revenue in 31 provinces.

		Sum of Squares	df	Mean Square	F	Sig.
Fiscal ecological cost of land (billion yuan)	Between Groups	123,552.198	4	30,888.050	67.312	0.000
	Within Groups	11,930.913	26	458.881		
	Total	135,483.111	30			
Proportion (%)	Between Groups	624.781	4	156.195	10.869	0.000
	Within Groups	373.638	26	14.371		
	Total	998.419	30			

Sig. > a = 0.05 indicates that the fiscal ecological land cost and its proportion to land fiscal revenue is significantly different in the different areas. That is, the partition result in this study is reasonable.

5.4. Regional Difference and Reasons for Fiscal Ecological Cost of Land

According to the clustering results, the total scale of fiscal ecological land costs and the cost of land finance per 1 billion yuan from 2003 to 2017 were calculated for each area, as shown in Tables 8 and 9.

Table 8. Total scale of land fiscal ecological cost in each area from 2003 to 2017.

	Project	Area I	Area II	Area III	Area IV	Area V
Land finance	Land transferred area (hm^2)	14,388.5	119,936.1	138,204.4	72,537.1	22,571.3
	Land fiscal fund (billion yuan)	4609.9	15,601.2	12,992.6	5939.9	672.0
Early cost	Loss of cultivated land ecosystem service value (billion yuan)	58.5	567.5	603.3	262.1	65.6
Middle cost	Energy costs (billion yuan)	6.2	32.2	28.6	16.6	3.8
	Exhaust dust emission (t)	16,255.9	85,241	75,338.3	43,952.7	9984.9
	Residual soil and stone (10,000 m^3)	110,890.5	502,214.1	437,875.1	248,482.6	56,814.3
	Heat island effect	——	——	——	——	——
	Number of land transfers (plot)	41,733	591,558	949,870	544,979	128,267
	Fragmentation degree of transferred land (plot/km^2)	29.0	49.3	68.7	75.1	56.8
	New urban built-up area (km^2)	1484.8	10,847.8	9861.8	6475.8	1583.2
	Average area of transferred land (hm^2/plot)	3.5	2.0	1.5	1.3	1.8
	Degree of urban agglomeration of transferred land (%)	103.2	90.5	71.4	89.3	70.2
Late cost	Land reclamation fees (billion yuan)	32.9	127.8	177.7	122.0	9.4
	New urban green space construction expenses (billion yuan)	28.2	156.6	154.7	96.7	24.6
	City cleaning expenses (billion yuan)	2.8	26.5	20.3	17.2	3.5
The total amount	Quantifiable cost (billion yuan)	128.7	910.6	984.5	514.6	106.8

Area I (Developed–Low Ecological Cost Area): During the 15 years from 2003 to 2017, a total of 143,884.7 hm^2 of land was transferred in Area I, and the land fiscal revenue was 4609.9 billion yuan. The quantifiable ecological cost in Area I under the land finance model is 128.7 billion yuan, and the ecological cost of each increase of 1 billion yuan in fiscal land revenue is 27.9 million yuan, accounting for 2.79%. The proportions of ecological cost in the early, middle, and late periods were 1.27%, 0.13%, and 1.39%, respectively. Each 1 billion yuan of fiscal land revenue produces 3.5 t of waste gas and dust, 241,000 m^3 of residual soil and stone, 9.1 plots of land transferred on average, and 32.2 hm^2 of urban expansion. The fragmentation degree of the transferred land is 29.0 plots/km^2, the average area of transferred land is 3.5 hm^2/plot, and the urban agglomeration degree of transferred land is 103.2%. As the national political, economic, and cultural center, this area leads the country in its level of urbanization, socioeconomic development, and education and cultural infrastructure. This infrastructure is constantly updated, and the level of urban greening is continuously improving to meet the needs of local development [76]. The population density is high, per capita land area is small, and state-owned land is fragmented. The tertiary industry (real estate and other service industries) is developed [77], land transfer prices are high, and the proportion of fiscal ecological land cost to fiscal land funds is extremely low.

Table 9. Cost of land finance funds per 1 billion yuan in each area from 2003 to 2017.

Project		Area I	Area II	Area III	Area IV	Area V
Land finance	Land transferred area (hm^2/billion yuan)	31.2	76.9	106.4	122.1	335.9
	Land fiscal fund (million yuan/billion yuan)	——	——	——	——	——
Early cost	Loss of cultivated land ecosystem service value (million yuan/billion yuan)	12.7	36.4	46.4	44.1	97.6
Middle cost	Energy costs (million yuan/billion yuan)	1.3	2.1	2.2	2.8	5.6
	Exhaust dust emission (t/billion yuan)	3.5	5.5	5.8	7.4	14.9
	Residual soil and stone (10,000 m^3/billion yuan)	24.1	32.2	33.7	41.8	84.5
	Heat island effect	——	——	——	——	——
	Number of land transfers (plot/billion yuan)	9.1	37.9	73.1	91.7	190.9
	Fragmentation degree of transferred land (plot/km^2)	——	——	——	——	——
	New urban built-up area (hm^2/billion yuan)	32.2	69.5	75.9	109.0	235.6
	Average area of transferred land (hm^2/plot)	——	——	——	——	——
	Degree of urban agglomeration of transferred land (%)	——	——	——	——	——
Late cost	Land reclamation fees (million yuan/billion yuan)	7.1	8.2	13.7	20.5	14.0
	New urban green space construction expenses (million yuan/billion yuan)	6.1	10.0	11.9	16.3	36.6
	City cleaning expenses (million yuan/billion yuan)	0.6	1.7	1.6	2.9	5.2
The total amount	Quantifiable cost (million yuan/billion yuan)	27.9	58.4	75.8	86.6	159.0

Area II (Highest Ecological Cost Area): This area is located on or near the eastern coast, and it witnessed rapid urbanization from 2003 to 2017. A total of 11,199,361.2 hm^2 of state-owned construction land was transferred, and the land finance fund was 15,601.2 billion yuan. The total fiscal ecological land cost is 910.6 billion yuan; 58.4 million yuan per billion yuan of land finance, accounting for 5.84% of land finance. The early, middle, and late stages accounted for 3.64%, 0.21%, and 1.99%, respectively. Each increase of 1 billion yuan of land finance funds will produce 5.5 t of waste gas dust, 322,000 m^3 of residual soil and stone, 37.9 plots of land transferred, and 69.5 hm^2 of urban expansion. The fragmentation degree of transferred land was 49.3 plots/km^2, the average area of transferred land was 2.0 hm^2/plot, and the urban agglomeration degree of transferred land was 90.5%. Area II has a superior geographical location, rapid economic development, and high openness to foreign trade, which is strongly supported by national policies. Flat terrain is conducive to urban infrastructure construction. The population growth rate is fast, the fragmentation degree of land transfer is high, and the area of land transfer is small. The urban greening level is high, and its later ecological cost is large.

Area III (Higher Ecological Cost Area): This area includes part of the central and eastern regions. During the 15 years from 2003 to 2017, the land transferred area was 1,382,043.8 hm^2, the land finance fund was 12,992.6 billion yuan, and the land fiscal ecological cost was 984.5 billion yuan, accounting for 7.58% of the land finance. The proportion of ecological costs to land fiscal scale in the early, middle, and late periods were 4.64%, 0.22%, and 2.71%, respectively. Each increase of 1 billion yuan of land finance funds will produce 5.8 t of waste gas dust, 337,000 m^3 of residual soil and stone, 73.1 plots of land transfer, and 75.9 hm^2 of urban expansion. The fragmentation degree of the transferred land in this region is 68.7 plots/km^2, the average area of transferred land is 1.5 hm^2, and the urban agglomeration degree of transferred land is 71.4%. This area mostly consists of China's major agricultural provinces, and cultivated land is the main land use type in this area [78]. The fiscal ecological land cost in the early stage is higher than in the other areas. Compared with Areas I and II, the urban agglomeration degree of the transferred land is lower, and secondary industry and towns develop faster. The population density is large, the fragmentation of state-owned land transfer is relatively high, and the transferred land area is small.

Area IV (Medium Ecological Cost Area): This area is mainly distributed in the central, western, and northeast regions. From 2003 to 2017, a total of 725,370.9 hm^2 of state-owned construction land was transferred, with total land finance funds of 5939.9 billion yuan and total fiscal ecological land costs of 514.6 billion yuan, accounting for 8.66% of the total land finance funds. Its land finance accounts for 4.41%, 0.28%, and 3.97% in the early, middle, and late periods, respectively. Each increase of 1 billion yuan of land finance funds will produce 7.4 t of waste gas dust, 418,000 m^2 of residual soil and stone, 91.7 plots of transferred land, and 109.0 hm^2 of urban expansion. The fragmentation degree of transferred land in this region is 75.1 plots/km^2, the average area of transferred land is 1.3 hm^2, and the urban agglomeration degree of transferred land is 89.3%. This area is mostly located on the second ladder of China, with large terrain fluctuations, including the Inner Mongolia Plateau and Loess Plateau in the north and the Yunnan–Guizhou Plateau in the south [79], and high fragmentation of transferred land and a small settlement area. The level of economic development is not as good as that in the central and eastern regions. Jilin and Heilongjiang have suffered serious population loss, and the development of urbanization has been hindered there.

Area V (Less Developed–Low Ecological Cost Area): This area is located in northwest China and the Qinghai–Tibet Plateau. From 2003 to 2017, a total of 225,713.4 hm^2 of state-owned construction land was transferred, with total land finance funding of 672.0 billion yuan. In the past 15 years, the total fiscal ecological cost of land was 106.8 billion yuan, accounting for 15.90% of the land finance funds: 9.76%, 0.56%, and 5.58% in the early, middle, and late periods in the land financial model, respectively. Each increase of 1 billion yuan of land finance funds will produce 14.9 t of waste gas and dust, 845,000 m^3 of residual soil and stone, 190.9 plots of land transfers, and 235.6 hm^2 of urban expansion. The fragmentation of transferred land is 56.8 plots/km^2, the average area of transferred land is 1.8 hm^2, and the urban agglomeration degree of transferred land is 70.1%. This area accounts for 42.8% of China's land area. It is characterized by a small population, low level of urbanization, relatively backward economic development, weak infrastructure, and a low level of industrial structure. The scale of land finance in this area is small, but the fiscal ecological land cost accounts for a large proportion of land finance revenue, which is much higher than the average level in China, due to the overall low economic development of this region.

6. Discussion

6.1. Innovations and Recommendations

At present, scholars are paying considerable attention to the social and economic impact of land finance, but only a few scholars are paying attention to the negative contribution of land finance to the amount of urban public green space and to the environmental effects, such as carbon emissions, in the process of land urbanization [80,81]. Moreover, the fiscal ecological land costs of this process are not considered. This study uses a variety of methods and formulates several indicators to quantify the ecological effects of the land finance model. Data from 31 provinces in China spanning a 15-year period are collected, sorted, and analyzed. Ecological land finance costs are calculated and compared, with the aim of contributing to the study of ecological issues related to land finance and the formulation of local government policies. According to the situation of each area, this study puts forward differentiated policy recommendations to reduce fiscal ecological land costs, as follows.

The core of reducing fiscal ecological land costs is to reduce the dependence of local governments on land finance. Specifically, we recommend the development of financial resources for local governments, such as levying property tax, incorporating ecological environmental performance into local government performance evaluation systems [82], and introducing a for-profit third-party organization to monitor the environmental performance of local governments [83].

Area I (Developed–Low Ecological Cost Area): The urbanization rate in this area has reached more than 80%, and the scale of land finance is large, but the ecological cost is small. The area of cultivated land in this area is small, as is the scale of ecological cost. The focus of reducing the fiscal ecological land cost can be placed in the middle and later stages. First, clean energy such as solar energy, wind energy, and biomass energy should be used to reduce exhaust gas and dust emissions in the infrastructure construction process of the development zone. Environmentally friendly materials with low albedo and good permeability should be developed and applied to pave roads to reduce the heat island effect. Second, urban land should be used efficiently and intensively in combination with national land space planning. Finally, mechanical cleaning methods, tree species with high survival rates, and mechanical maintenance methods for urban green space can be adopted to reduce later costs, and the experience of Hong Kong and Singapore can be used for reference in urban green space construction [70].

Area II (Highest Ecological Cost Area): The scale of land finance and land fiscal ecological costs are the highest in this area. We should refer to Area I to reduce the fiscal ecological land costs in the middle and later periods. In addition, we could strip and reuse the cultivated land resources occupied by the construction in the area and regularly assess rewards and punishments. This area should implement the transfer of cultivated land within the province, open the channel of land transfer, and increase the flexibility of land transfer to reduce early fiscal ecological land costs. The urban thermal environment can be improved through optimization of building layout, thus alleviating the heat island effect [84].

Area III (Higher Ecological Cost Area): The area is located in central and eastern China and is in a period of rapid urbanization. As China's main grain-producing areas, these provinces need to ensure that the quantity and quality of cultivated land do not decrease to safeguard national food security. The ecological service function of existing cultivated land can be increased through land consolidation and the transformation of low- and medium-yield fields. In the process of urbanization construction, we should draw lessons from the experience of Areas I and II to carry out urbanization construction in an intensive but cost-efficient way and avoid the old road of "development first and renovation later" [85].

Area IV (Medium Ecological Cost Area): The fiscal ecological costs of land in this area is lower than that in Areas I, II, and III. Southwest China and the Loess Plateau region have complex and difficult surface morphology; land transfer should be allocated around existing urban areas as much as possible, and old city reconstruction and redevelopment should be carried out to improve the degree of urban agglomeration. Inner Mongolia, Jilin, and Heilongjiang are suffering from serious population loss and have rich reserves of cultivable land resources. The abandoned and idle cultivated land in "hollow villages" should be reconstructed in a centralized manner, and large-scale and digital agriculture should be carried out, drawing on the experience of America and Europe [86].

Area V (Less Developed–Low Ecological Cost Area): The level of urbanization in this area is relatively backward, and the scale of land fiscal revenue is small, but ecological costs account for a relatively high proportion of it. The speed of land urbanization is much faster than the speed of population urbanization and industrial urbanization, and the development of urbanization is abnormal. It is necessary to avoid rapid urbanization development at the cost of wasting land and inefficient use of land [87]. Some advanced enterprises and industries should be introduced to create more sources of tax revenue for local governments.

6.2. Policy Implications

We put forward the concept of fiscal ecological cost of land and explain the formation mechanism of this cost, which is of great significance for reducing dependence on land finance and ensuring the healthy development of urbanization. Through the above discussion, we clearly recognize the important position of fiscal ecological costs of land in land fiscal revenue and the reasons for the formation of regional differences in the fiscal ecological cost of land. Based on the above findings, we put forward policy recommendations including balanced farmland occupation and replenishment, reclamation and reuse of farmland, use of clean energy, research and development of environmentally protective materials for road surfaces, construction of green land, and urban cleaning. Therefore, this study has theoretical and practical value for the rich research content of land finance and the transformation and optimization of land finance.

6.3. Limitations and Prospects

The following three points are worth exploring in the study of land fiscal ecological cost. (1) First, the data in this study are all national data; a follow-up study could further narrow the scope to provinces or cities; more in-depth results may be found. (2) Due to the availability of data and verified research methods, noise pollution in the process of urban development and the construction cost of urban water surfaces and other infrastructure in the later stage of the land finance model could not be effectively explored [88]. (3) Because of space limitations, we did not study the spatial–temporal pattern and driving mechanism of fiscal ecological land cost, which needs to be further discussed in subsequent studies. In addition, governments at all levels should try to reduce dependence on land finance and the scale of fiscal ecological land costs in the future.

7. Conclusions

By sorting out the process of land finance and developing a model, this study puts forward a definition of land fiscal ecological cost, explains the formation mechanism for fiscal ecological land cost, and scientifically estimates the scale of fiscal ecological cost of land across 31 provinces in China from 2003 to 2017. The results show that the fiscal eco-logical cost of land in China presents a spatial pattern of "higher in the east than in the west, higher in the south than in the north." Over the different stages of the land finance model, the quantified ecological cost of available funds is highest in the early stage, second in the later stage, and lowest in the middle stage. At the same time, it is necessary to also employ energy conservation and emissions reductions to reduce costs that cannot be quantified with capital, such as waste gas dust, residual soil and stone, heat island effects, and land fragmentation generated in the middle stage of the land finance model.

This study uses SPSS 22.0 statistical software to cluster and partition the fiscal ecological costs of land in 31 provinces and divides them into five regions. By comparison, it is found that the cost of each additional 1 billion yuan of land finance funds goes in the order Area I > Area II > Area III > Area IV > Area V, indicating that the ecological cost of land finance funds per unit cost is positively correlated with the degree of economic development. The degree of fragmentation of transferred land was in the order Area IV > Area III > Area V > Area II > Area I, and the average area of transferred land was in the order Area I > Area II > Area V > Area III > Area IV, indicating that the more complex the terrain, the higher the degree of fragmentation of transferred land and the smaller the land area to be transferred. The degree of fragmentation of transferred land is also related to industrial structure. The land fragmentation degree of the area dominated by primary industry is significantly higher than that of the region dominated by secondary and tertiary industries. Affected by the level of economic development and topography, the urban agglomeration degree of transferred land shows the rule of Area I > Area II > Area IV > Area III > Area V.

Finally, according to the scale of fiscal ecological cost of land in the five areas, policy recommendations are put forward as follows. Focusing on reducing dependence on land finance, cultivated land protection, cultivated land reclamation, and large-scale operations should be carried out in the early stage. In the medium term, we should use clean energy and develop environmentally friendly pavement materials. In the later stage, suit-able vegetation and cleaning methods should be selected.

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