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Construct the Framework for the Allocation of Resources Invested in Ecological Governance from the Urban–Rural Land Use Coupling

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Abstract: With the rapid development of urbanization, cities need more external resources to meet their ultimate demand, which leads to the transfer of land use function between urban and rural areas. How to measure the urban–rural land use coupling remains to be studied. In addition, due to the difficulty in evaluating the unequal development and coupling between urban and rural areas, resource-consuming regions often evade their responsibility for environmental pollution, resulting in unfair allocation of invested resources. Therefore, a framework for the allocation of resources invested in ecological governance was built from the perspective of urban–rural land use coupling. This framework made clear the urban–rural coupling and applied Gini coefficient to judge the overall imbalance in the region. According to the unbalanced structure of the region, the allocation framework based on the location quotient was used to redistribute the resources invested in ecological governance, and the attribution of responsibility was made clear, which can promote regional fairness. The main conclusions are: (I) Taiwan's overall urban–rural coupling is 8.3, that is, every hectare of land development in Taiwan requires 8.30 hectares of ecological land to meet development needs. The urban area needs to rely heavily on the ecological resources provided by the rural area. (II) The environmental problems of the urban area need to be solved by the urban area itself, while the rural area requires the urban area to be responsible for its ecological governance, and it needs to be responsible for the resource consumption of the external systems. This research provides a new perspective for the research on urban–rural coupling and resource allocation.

Keywords: urban–rural coupling; land use; ecological governance; resource allocation; attribution of responsibility

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1. Introduction

In order to meet the needs of socio-economic development and population growth, the expansion of global urban areas has reached an unprecedented rate [1]. According to the "World Urbanization Trends" in 2018, the global urbanization rate was 55% in 2018, and is expected to reach 66% by 2050. The rapid urbanization has led to the changes in the types of land use. It is generally believed that the transformation of land is permanent and usually irreversible. Land conversion has raised people's concerns about food security, loss of open space, protection of arable land, and environmental degradation [2,3]. In addition, cities rely heavily on external land resources and need a large quantity of resources to meet their final needs, not just the available areas within the boundary [4]. Therefore, land has become a kind of scarce resource, and the competition for land between different land uses has become increasingly intense. The measurement of the coupling between the land use of urban and external systems, especially the coupling between urban and rural land use systems, is an effective way to study the balance of land on a regional or global scale, and can also help to explore whether land resources can balance economic development under urbanization.

For a long time, urban and rural areas have been regarded as two independent systems with obvious differences, and their interrelationship is rarely considered. However, the relationship between urban and rural areas is the basic relationship of the development of human society [5]. The migration of the rural population to the cities has increased the urban population and promoted urbanization, and also made the rural areas rely more on the diversified supply from cities. The coupled and coordinated development of urbanization and rural land use has become a global strategic and scientific issue. A large number of theories have been applied to study the urban–rural coupling. For example, in 1989, Ebenezer Howard tried to explore the coordinated relationship between urban development and rural ecological environment from the perspective of rational planning, and proposed the concept of a "pastoral city" [6]. The "urban-rural linkage" proposed by Utopian socialists and Marxists focuses on the self-sufficient model of urban–rural land use. The "urban-rural dual structure" represented by the Lewis–Ranis–Fei model studied the issue of urban and rural independence [7]. Paolo Veneri et al. studied the benefits of distance between cities and villages from the perspective of population growth [8]. The urban–rural linkage and integration have received unprecedented attention. Therefore, exploring how urban and rural areas influence each other through land use is the basis for investigating urban–rural coupling.

Cities often suffer severe shortages of land resources, and their abilities of agricultural production and ecosystem services are insufficient to meet demand. This is the reason why cities rely heavily on the supplies from other regions. It is precisely the flow of people, capital, commodities, information and technology that has caused a close interconnection between urban and rural areas [9]. At the same time, population growth and urban expansion also require a large number of goods and services, which has led to the increasing dependence of cities on imported materials and goods (such as water, food and fuel) [10]. This also makes it inevitable that land and other factors will be transferred from rural areas to urban areas [11]. Land use does not exert a direct impact, but indirectly affects the land transfer between regions or between urban and rural areas, and the close regional relationship [12]. The lack of appropriate consideration of the coupling between urban and rural land may result in disastrous consequences, hindering urban development or the inefficient utilization of land resources. Therefore, research on the flow of land use resources has become increasingly important [13]. Furthermore, since the demand and supply of land use far exceed the coupling of urban–rural land use within each city, it is difficult to meet the growing demand for land through local land resources [14]. In this case, studying the utilization and allocation of land resources in urban and rural areas can directly and indirectly measure the balance between urban and rural land use and the overall spatial balance at multiple scales.

In traditional urbanization, blind pursuit of expansion and economic benefits makes it difficult to achieve sustainable development of urbanization. Additionally, focusing on rural development may lead to more land occupied for development. Therefore, whether the intensive development of urbanization or the expansion of urban and rural areas is more sustainable has become a problem that needs to be solved immediately. New urbanization needs to emphasize the coupling between urban and rural areas. The environmental quality will deteriorate with the economic development, and then gradually improve after the economy develops to a certain level [15,16]. It is known that when the urban population and land increase, rural residents' land use will decrease and forest resources will also recover. Additionally, the development of urbanization will provide more financial support for rural ecological and environmental protection. Although the influx of population has posed stress on the urban ecological environment, financial support has strengthened the concept of rural environmental protection and sustainable development [17]. The new urban–rural coupling regards urban and rural areas as a whole. Through the coupling between urban and rural land use, the overall development can be promoted, and the balance between urban and rural spaces can be achieved. Moreover, such a coupling relationship can also help us to view the urban development from an overall perspective to solve the fundamental problem in the development, instead of focusing only on the problems in urban and rural areas.

It is crucial to quantify the balance between two coupling systems. A large number of theoretical and case studies have been conducted on urban–rural coupling. First, most of the existing empirical studies measured and evaluated the spatial pattern of urbanization and rural areas, but failed to study the factors that affect urban–rural coupling and the mechanism [18]. Second, many studies have examined the relationship between urban and rural systems using a single environmental factor [19], such as carbon emissions and urban–rural heat island effects. Third, some studies focused more on the relationship between the construction land and population, and most of them regarded urban and rural areas as independent research objects. In terms of research framework, there is currently an urban–rural gradient framework to study the impact of cities on the ecosystem and ecological research related to social welfare [20]; the urban–rural integration model explores the integrated development of urban and rural areas from the perspective of labor, consumption patterns and economic development sequence; the regional network model explores the overall development of the region from urban spatial expansion, spatial structure and pattern changes [7]; the metacoupling framework uses quantitative methods to evaluate the efficiency of regional water transfer [21]. It can be seen that previous related studies and framework failed to make clear the coupling of urban–rural land use changes. Therefore, it is still necessary to incorporate the coupling between urban and rural land use into the sustainability evaluation framework [22]. By exploring the system of coupling between urban and rural land use, a theoretical basis can be provided for further resource investment in ecological governance. The so-called ecological governance emphasizes the governance of ecological damage and environmental degradation caused by land development.

Ecological governance is not only affected by territorial factors, but also influenced by the flow of land demand within the region. Severe land shortage will lead to a strong dependence on land resources in surrounding areas, and urban areas need to take more responsibility for resource utilization and related environmental issues [23]. However, due to the failure to quantify the coupling between urban and rural areas, there are often deviations in the investment of governance resources. For example, cities with a strong economic foundation may invest more resources to solve urban ecological issues, but for the villages that provide these cities with resources, there is often a lack of responsibility, which intensifies the contradiction between urban and rural development. For another example, some cities have invested abundant funds to improve the rural ecological environment, but this will increase the burden of urbanization [18]. Therefore, exploring urban and rural or global environmental governance from the perspective of land resource supply is of great importance for further solving the issue of urban and rural land use [4]. Through the overall analysis of the balance of land use in the region, feasible and fair allocation of the input resources for land ecological governance can be realized, so as to promote the implementation of sustainable development policies.

Coupling theory emphasizes the interconnection between two or more systems through various interactions and mutual influences [24]. This research explored the interaction and feedback in the urban–rural land use system, so as to better understand how the coupling of land use affects the supply of ecological resources. Therefore, this research quantified the coupling between urban and rural land use based on the coupling theory, and used the result as the basis for the input of ecological governance resources. The main purposes are (I) to establish an analysis framework for multi-scale evaluation of multiple types of land use, so as to provide a new perspective for the balanced structure and development of urban–rural land use; (II) to rationally allocate the resources for ecological governance according to the urban–rural coupling framework, so that a theoretical basis can be provided for the sustainable development of urban and rural areas.

2. Materials and Methods

2.1. Research Area and Data Source

This research explored the resources investment in ecological governance from the perspective of the coupling between urban–rural land use, thus, the most basic unit of analysis is a city. Since the development of cities often requires external systems to provide resources or provide resources to external systems to meet their own development needs, cities have become increasingly integrated [4]. Therefore, this research needs to be conducted on a national or regional scale to meet the research requirements. Taiwan is a relatively complete economy, and its internal land resources can meet the development demands of cities, including the demands for construction land and the land provided by the ecosystem service. In this research, Taiwan Island was selected as the research scope, involving 19 counties and cities in total.

In this study, the administrative boundary of "district or township" is used as the basic analysis unit, and the ratio of the developed land to the total area in the analysis unit is used as the basis for judging the division of urban areas and rural areas. The area with a density of construction land greater than 0.3 was regarded as the urban area, and the area with a density less than 0.3 was classified as the rural area (The urban area covered by its value includes more than 90% of construction land). The land use classification in this study comes from "Taiwan Land use survey results" [25]. The first-level system of land use survey divides land use into eight categories: construction use, public use, transportation use, recreation use, forest use, water use, agricultural use, and mineral and salt use. The specific land development type data comes from the results of Taiwan's land use survey in 2018, and each analysis unit counts the area of eight types of land use types. The specific research scope and the classification of urban and rural areas are shown in Figure 1.

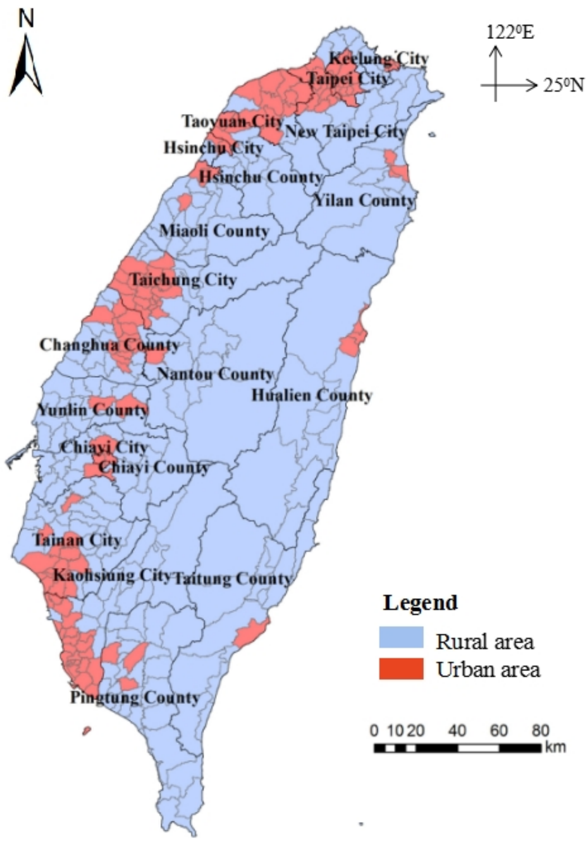

Figure 1. The research scope of ecological governance of urban–rural coupling.

2.2. Research Framework

This study aims to reallocate the ecological governance resources through land use types, and further solve the problem of unequal resource input caused by uneven regional development. Therefore, the research framework can be divided into the following two parts (Figure 2). The first part quantified the urban–rural coupling from the perspective of land use. First, according to the nature of the types of land use, the land was divided into construction land and ecological land, and based on the density of construction land, urban area and rural area were classified. Second, the ecosystem service value of ecological land was quantified, and the coupling between urban and rural land was quantified according to the coupling model (Formula (1)) constructed in this study. The analysis result can be used to judge the balance between urban and rural development, and is also a quantitative basis for the reallocation of ecological governance resources in the next step. The second part involves the redistribution of the resources invested in ecological governance. First, the location quotient theory and Gini coefficient were adopted to quantify regional inequality. Since the urban–rural coupling does not reflect the overall coupling in the country/region, the Gini coefficient can reflect the overall balance of the country/regional land development. An ecological governance resources allocation model was constructed based on the location quotient method. This model reflects the relationship of responsibility for ecological governance between urban and rural areas and the responsibility for other areas in the region. According to this model, the input resources for ecological governance can be divided into three parts: the ecological governance cost of the urban area, the rural area's ecological governance cost that should be borne by the urban area, and the cost of input or output of the urban area to other cities. The result quantified the specific responsibility that the urban area needs to take for ecological governance according to its own development needs. In this way, fair distribution of ecological governance resources can be realized and regional balance and sustainable development can be promoted. Figure 3 shows the urban–rural coupling relationship diagram of the ecological governance framework.

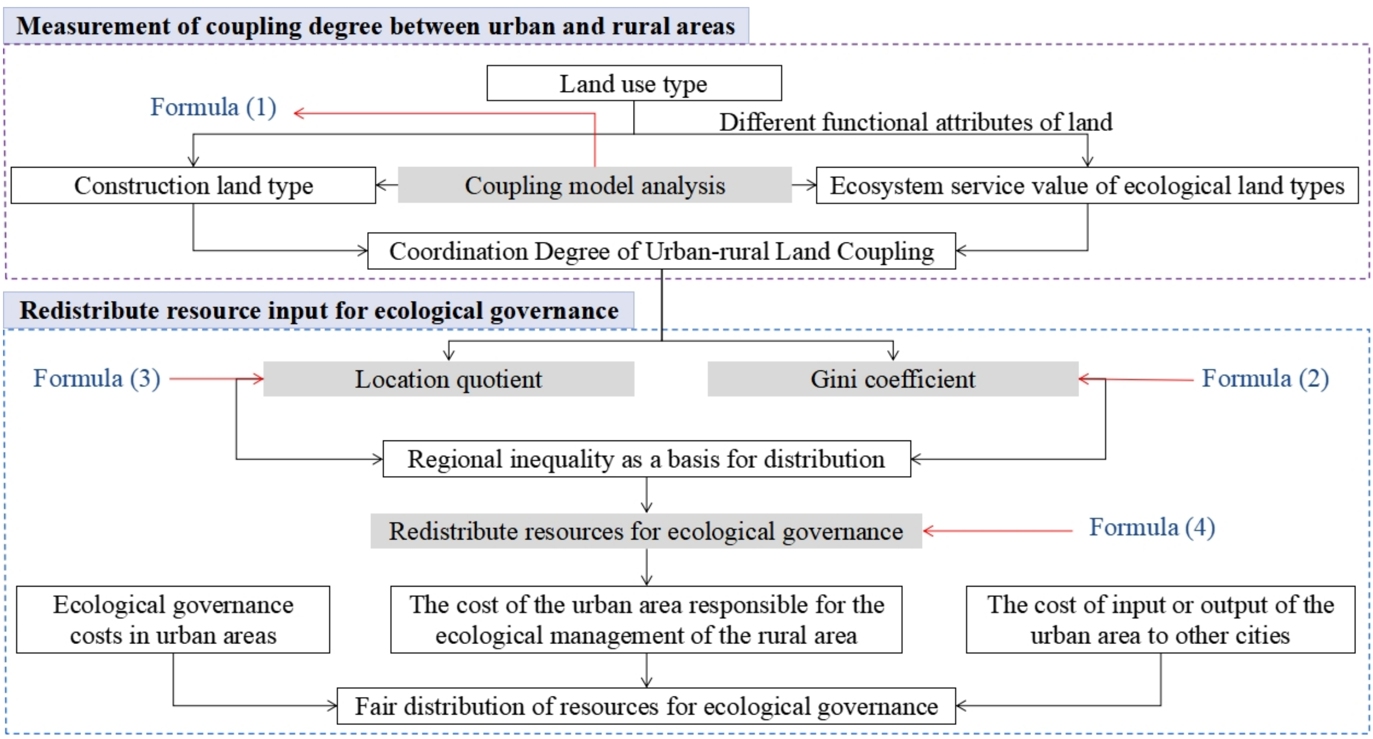

Figure 2. The research framework for the allocation of ecological governance resources.

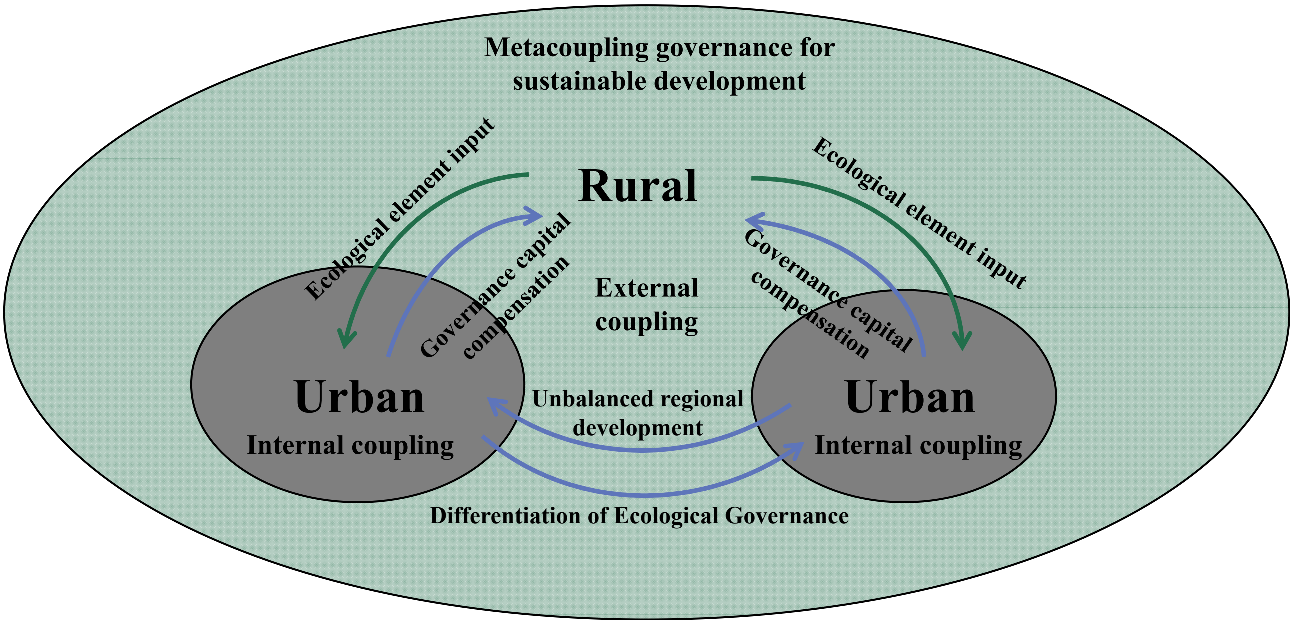

Figure 3. Urban–rural coupling relationship of ecological governance framework.

2.3. Method

2.3.1. The Method of Urban-Rural Coupling

Previous studies often used the coupling coordination degree (CCD) model to reflect the degree of coordination between two or more systems [26]. However, this method can only be used to judge the coupling state between the two systems, such as the unbalanced state or balanced state, and it cannot reflect the coupling situation where there is resource flow. For example, in this study, urbanization requires a large amount of ecological land to provide it with ecosystem service value, and the flow direction of such resources is often irreversible. Meanwhile, the more land used for ecosystem service, the more services that can be provided for urban development zones. The CCD model will judge that these two systems are in an unbalanced state. Therefore, this study established an urban–rural coupling model for land use, which can provide a basis for the resource input in the next stage.

The land use classification in this study comes from "Taiwan Land use survey results" [25]. The first-level system of land use survey divides land use into eight categories: construction use, public use, transportation use, recreation use, forest use, water use, agricultural use, and mineral and salt use. In this research, the land for transportation use, public use, construction use, and recreation use in urban development was used as the overall construction land. The main reason is that these types of land are the main land used for urbanization, population gathering and creating economic benefits. However, the construction land is often unable to create ecosystem service value. This study regarded the land for forest use, water use, agricultural use, and mineral and salt as ecological land. This type of land is mainly used to provide ecosystem services for urban system. In this study, the coupling between urban and rural areas was quantified based on the construction land and the ecosystem service value of ecological land. The specific coupling model is shown in Formula (1).

$$\begin{array}{c} \frac{y_{1j}}{x_{1j}}(a) \\ \frac{y_{2j}}{x_{2j}}(b) \\ \frac{y_{1j}+y_{2j}}{x_{1j}+x_{2j}}(c) \end{array} \tag{1}$$

Formula (a) represents the coupling relationship between the construction land and ecological land within the city; formula (b) is the coupling relationship between the construction land and ecological land within the rural area; formula (c) means the overall coupling between urban and rural areas. The larger the value, the higher the degree of coupling. y_{1j}, y_{2j}, respectively, represent urban and rural construction land; x_{1j}, x_{2j} denote the ecosystem service value provided by ecological land, respectively.

The data on construction land were expressed by the land area in each city. The ecosystem service value provided by ecological land is complicated. Ecological land has various functions, such as providing services (including food production and raw material provision), regulating services (including gas regulation, climate regulation, hydrological regulation and waste treatment), supporting services (including soil maintenance and biodiversity maintenance) and cultural services (providing aesthetic landscapes) [27]. Costanza et al. [28] provided the principles and methods for estimating the global ecosystem service value. This method mainly uses the relative value per unit of arable land in the current year to quantify the value of other services, and it has been widely used. This study uses this theory and the average food price per hectare of 14,801 yuan per hectare in Taiwan in 2019 as a measure of the service value of ecological land [29]. See Table 1 for details.

Table 1. Ecosystem service value provided by various types of land use.

	Forest Use	Agricultural Use	Water Use	Mineral and Salt Use
Providing	5721	2403	1036	2765
Regulating	24,547	6654	75,711	0
Supporting	14,745	4304	9818	35
Cultural	3595	294	8107	0
Total	48,609	13,655	94,672	2800

After the urban–rural coupling in each city was quantified, the Gini coefficient was adopted to evaluate the overall regional inequality. The Gini coefficient is a classic method widely applied in inequality assessment [30]. In this study, the urban–rural coupling in 19 counties and cities in Taiwan was used to evaluate the overall coordination and imbalance of land use coupling in Taiwan. The specific Formula (2) is shown as follows.

$$G = \frac{1}{2n^2\mu} \sum_{j=1}^{n} \sum_{i=1}^{n} \left| T_j - T_i \right| \quad (2)$$

where G is the Gini coefficient; n is the number of cities; μ is the mean of the analysis parameter; and T_j, T_i are the value of the urban–rural coupling in the city. The value of G is between 0 and 1; 0 means complete equality, and there is no inequality in land coupling within the region; 1 means complete inequality. This value can be used to judge the extent to which regional inequality needs to be considered when resources are invested in ecological governance.

2.3.2. Location Quotient Method

In this study, the location quotient (LQ) method was used to quantify the proportion of resources invested in ecological governance. Location quotient can be applied to determine the degree of specialization of a region's resource input relative to that of the reference region [31], which can be expressed by Formula (3).

$$LQ = \frac{e_i}{e} / \frac{E_i}{E} \quad (3)$$

when $LQ < 1$, it means that the input of i types of resources in the region cannot meet the needs of the region, and resources from other regions are needed to meet the requirement for resource input of the region; when $LQ > 1$, it indicates excessive input of i types of resources in the region, and resources can be provided for other regions; when $LQ = 1$, it means that the region can just achieve self-sufficiency. Based on the location quotient theory and the results of the coupling method, an allocation model for the input resources of ecological governance was built, as shown in Formula (4). The input resource for ecological governance mainly refers to the financial input for land governance [32].

$$Q_j = q_j \times \left(\frac{y_{1j}}{x_{1j}} / \frac{y_{1j} + y_{2j}}{x_{1j} + x_{2j}}\right) + q_j \times \left(1 - \frac{y_{1j}}{x_{1j}} / \frac{y_{1j} + y_{2j}}{x_{1j} + x_{2j}}\right) + \left| q_j \times \left(\frac{y_{1j} + y_{2j}}{x_{1j} + x_{2j}} / \frac{\sum y_{ij}}{\sum x_{ij}} - 1\right)\right| \quad (4)$$

where Q_j represents the expected cost of ecological governance in the city; q_j is the actual cost of ecological governance; $q_j \times \left(\frac{y_{1j}}{x_{1j}} / \frac{y_{1j}+y_{2j}}{x_{1j}+x_{2j}}\right)$ denotes the corresponding ecological governance cost of the urban area; $q_j \times \left(1 - \frac{y_{1j}}{x_{1j}} / \frac{y_{1j}+y_{2j}}{x_{1j}+x_{2j}}\right)$ is the corresponding ecological governance cost of rural area; $q_j \times \left(\frac{y_{1j}+y_{2j}}{x_{1j}+x_{2j}} / \frac{\sum y_{ij}}{\sum x_{ij}} - 1\right)$ is the ecological governance cost that the city obtains from other cities or the ecological governance cost that needs to be borne by the city for other cities. Through Formula (4), redistribution of financial investment in land governance was realized, so that regional inequality can be promoted and a more equitable distribution of resources can be achieved.

3. Results

3.1. Urban–Rural Land Use Coupling

With the accelerated economic and market integration, coordinated development between urban and rural areas has become increasingly important. The coupling between urban and rural land use can be obtained by Formula (1), as shown in Table 2. In general, assume that Taiwan as a whole is in a regional balance state, then the score of the overall coupling between construction land and ecological land in the region is 8.30, indicating that the development of 1 hectare of land requires 8.30 hectares of ecological land to achieve the balance of ecosystem services in the region.

Table 2. Coupling between urban and rural land use.

	Coupling of Urban Area	Coupling of Rural Area	Coupling of Urban-Rural
Kaohsiung city	0.71	20.64	5.46
Hualien county	1.27	55.54	33.50
Keelung city	1.46	5.24	3.37
Chiayi county	2.80	11.93	9.82
Miaoli county	1.65	14.59	10.72
Nantou county	2.33	28.01	24.53
Pingtung county	1.72	13.61	10.24
Taitung county	2.32	51.76	35.48
Tainan city	1.49	8.16	4.34
Taichung city	1.04	15.01	4.34
Taoyuan city	1.27	10.42	2.54
Taipei city	0.88	12.67	5.99
Hsinchu city	0.49	2.36	1.05
Hsinchu county	1.49	16.25	9.47
Yilan county	1.53	23.87	17.89
Yunlin county	2.35	5.65	4.99
Changhua county	1.85	5.42	3.46
Taipei city	1.10	0.00	1.10
Chiayi city	0.82	0.00	0.82
Average coupling score	1.50	15.85	8.30

From the perspective of the coupling of the urban area, the score of the coupling of the urban area is between 0.7 and 2.8, which is far smaller than the overall coupling of Taiwan. Therefore, the urban area relies heavily on the ecosystem service provided by the rural area or other external systems. Kaohsiung city has the smallest coupling of urban area, with only 0.71, indicating that the urban area has a high construction density, with a severe insufficiency of ecological land. Failure to effectively coordinate with the rural area will result in poor environmental quality in the urban area. The coupling of urban area in Chiayi County is 2.8, which is the highest level among all counties and cities in Taiwan, suggesting that the city pays more attention to urban greening and has more land use to provide ecosystem services. The per capita GDP of Chiayi County is at the low level in Taiwan, which shows that the degree of coupling of urban area is high, and the area may face the problem of low urban–rural efficiency. However, in the areas with high per capita GDP, such as Kaohsiung city, Taipei city, and Hsinchu city, the degree of land use coupling in the urban area is not high, and the urban area relies heavily on the rural area and external systems. It can be seen that urban–rural coupling plays a role in stimulating economic development.

From the perspective of the coupling of rural area, Taipei city and Chiayi city are completely in the urban development zone, thus the coupling of their rural area is 0, and the ecological land needs to be provided by the external systems, which indirectly reflects their need to share responsibility for external ecological governance. The degree of land coupling in Changhua county, Yunlin county, Hsinchu city and Keelung city is also less than the overall coupling in the region, indicating that there is more land development in the rural area, and the urban area has been extensively developed. A lack of reasonable planning for urban–rural land use types has led to inefficient utilization of land use resources. However, generally speaking, most of the scores of couplings of rural area are greater than 10. This shows that rural area still mainly provides ecosystem service for urban area. The score of coupling of rural area in Hualien county and Taitung county is 55.54 and 51.76, respectively, indicating that the cities have a large amount of ecological land, which can provide ecosystem services for its urban area, and can also export a large number of ecosystem services to external systems. Therefore, the external systems need capital investment to be responsible for the ecological governance in its consumption area.

From the perspective of urban–rural coupling, the degree of coupling in each city is quite different, revealing severe imbalanced regional development, and the investment in ecological governance needs to be re-examined. The degree of urban–rural coupling in 11 counties and cities is less than the overall coupling degree in the region, and the urban–rural coupling degree in only eight counties and cities is greater than the overall coupling degree in the region. It shows that most counties and cities need external systems to provide ecosystem services to meet the needs for ecosystem services, especially Chiayi city, Taipei city and Hsinchu city. The urban–rural coupling in Hualien County, Taitung County, and Nantou County is far greater than the overall coupling in the region, indicating that these counties and cities play a key role in balancing the ecosystem service and require a large amount of external funds for ecological governance. If large-scale land development is conducted, it may lead to an unbalanced supply of ecosystem services.

3.2. Regional Unbalanced Development

According to the result of urban–rural coupling and Formula (2), the overall Gini coefficient of regional land use can be obtained. The results showed that the overall Gini coefficient of land use coupling in Taiwan is 0.51, suggesting unbalanced land development in cities in Taiwan, and many cities need ecological land support from other cities to meet their own development needs. The large value of the Gini coefficient means that when resources are invested in ecological governance, attention should be paid to the overall regional governance. Whoever consumes ecological land resources needs to be responsible for the governance of the environment. The Gini coefficient can well reflect the unfair resource input, and this value can be used as the basis for the redistribution of the government's resources.

3.3. Analysis of Input Resources for Ecological Governance

It can be seen from the Gini coefficient and the results of urban–rural coupling that there exists unbalanced development in the region and the flow of land supply to external systems. Therefore, it is necessary to reallocate the resources invested in ecological governance. According to Formula (4), the ecological governance cost of the urban area, the ecological governance cost of the rural area that should be borne by the urban area, and the input or output cost of the urban area can be obtained. The details are shown in Table 3. Generally, the urban area not only needs to solve its own environmental problems, but also needs to be responsible for the ecological governance of the rural area. In addition, for the areas outside the cities, whether the city needs to be responsible for its external systems should be judged based on the flow direction of ecological land resources.

Table 3. Distribution of urban area's cost of ecological governance.

	Cost of Ecological Governance (Million Yuan)		
	Urban Area	**Rural Area**	**External System**
Kaohsiung city	935.20	6222.30	−2446.87
Hualien county	17.84	451.31	1424.85
Keelung city	461.15	604.02	−632.95
Chiayi county	29.62	74.10	19.06
Miaoli county	73.68	404.81	139.74
Nantou county	29.96	285.96	618.05
Pingtung county	256.78	1268.64	357.23
Taitung county	14.32	204.50	716.79
Tainan city	1002.70	1926.29	−1397.42
Taichung city	1855.27	5851.48	−3678.22
Taoyuan city	2756.53	2773.45	−3834.12
Taipei city	2053.63	11,983.93	−3901.26
Hsinchu city	585.16	676.37	−1101.78
Hsinchu county	213.57	1143.44	191.43
Yilan county	35.76	382.53	483.47
Yunlin county	216.91	242.96	−183.36
Changhua county	157.09	136.82	−171.20
Taipei city	9884.01	0.00	−8572.96
Chiayi city	635.20	0.00	−572.23

Note: "−" indicates the amount of capital investment for the external systems.

From the perspective of the external systems, a negative value indicates that a part of the urban ecological governance cost needs to flow out to the ecological governance of the external systems. The area with the largest outflow of cost is Taipei city (8572.96 million yuan). The city needs external systems to provide ecosystem services to achieve ecological balance. Therefore, the governance cost in the past needs to be adjusted accordingly to provide financial support for the external systems. The areas with large outflow of cost include Kaohsiung city, Tainan city, Taichung city, Taoyuan city and Taipei city. Only through the redistribution of resources can these cities improve environmental quality in other areas, thereby realizing the balanced urban and rural development, and promoting regional coordinated development. It can be seen from Table 3 that the goal of redistributing ecological resources has been achieved, and the ecological governance funds that need to be shared by urban area for different regions were acquired. This can provide a quantitative basis and analytical framework for the government to redistribute resources in the next step. It also offers a fiscal revenue source of ecological governance for the government, which is conducive to promoting fair and balanced regional development.

4. Discussion

With the rapid urbanization, a large amount of ecological land in cities has been consumed [33]. Such transformation of land use is usually irreversible, and urban development further affects the changes in rural land use [34], which leads to the coupling between urban and rural land use. The continuous pressure brought by urban expansion and the ecological advancement in rural areas will be a favorable support for sustainable development in the future. Economic development increases income and social welfare, but it inevitably promotes the migration of rural population to cities, so that rural construction land that used to be inefficient can be converted into ecological land. However, the growth of urban areas may intensify citizens' concerns about the environment [35]. Our research showed that the ecological service of urban areas is mainly provided by the ecological land in rural areas. Therefore, the view on urban–rural coupling in this research can support the coordinated development between urban and rural areas, and it can stimulate people to pay attention to the environmental protection in rural areas.

Land use is defined as the demand for direct and indirect production of final goods/ services [36]. The area of urban land use is often small; thus, cities rely heavily on external land resources to meet their ultimate development needs. This is the reason why there is an overall imbalance in land use in a relatively small range. It can be seen that the demand and supply of land use are driven by forces far beyond the scope of each city. However, it is generally believed that the circulation of land is usually balanced on a global or regional scale, that is, the inflow from and outflow to various cities are in a cycle. Our research showed that each hectare of land development requires 8.30 hectares of ecological land to achieve the balance of ecosystem services in the region. The coupling between urban construction land and ecological land is only 1.5, revealing that the urban area needs external supply of ecosystem service. The coupling score of rural area is 15.85, which means that rural area can provide a large number of ecosystem services for external systems. The research on urban–rural coupling can help to achieve the balance between urban and rural spaces, so that the coordinated management of urban and rural land can play a central role in the economic growth and sustainable development.

Regarding the sharing of the responsibility for ecological governance, due to the difficulty in assessing the impact, resource-consuming regions often evade their responsibility for environmental pollution, leading to unfair resource investment in ecological governance. Based on the flow of land resources, a close relationship has been established between urban and rural areas, and the direction of flow has become an important basis for sharing the responsibility for ecological governance. The coupling between urban and rural land use in this study provides a quantitative basis for the resources invested in ecological governance. It was found that the urban area not only needs to be responsible for the ecological governance of the rural area, but also needs to be responsible for the ecological governance of the external systems. According to the coupling relationship, this study divided the urban input in ecological governance into three parts: the urban area's ecological governance cost, the rural area's ecological governance cost that should be shared by urban area, and the urban area's cost of input or output to other cities. This result made clear the attribution of the responsibility for ecological governance and avoids blind pursuit of urban environment improvement while ignoring the governance of rural areas, which makes it difficult to achieve sustainable development of urbanization.

The urban–rural coupling framework is a powerful tool for analyzing the impact of urban development on the ecosystem, realizing the coordinated development of urban and rural areas, and achieving the balance of regional land use. Based on the theory of urban–rural coupling, a framework for the allocation of resources invested in ecological governance was built, which can fill the gaps in the research on the coordinated development of urban and rural areas. Most of the existing studies measured and evaluated the level and spatial pattern of the coupled development between urbanization and the ecological environment, but failed to study the factors that affect such coupled development and the impact mechanism. In addition, less attention has been paid to how the integration of land use system promotes the coordinated development of urban and rural areas [18,19]. The framework of this research made clear the urban–rural coupling relationship, effectively evaluated the balance of urban land use from a specific perspective, and applied the Gini coefficient to judge the overall imbalance in the region. Then, based on the unbalanced regional structure, the attribution of the responsibility for ecological governance was made clear, so that feasible and fair methods of input resource allocation can be formulated. This framework plays a vital role in balancing urban and rural development. Importantly, it allows local government agencies to determine the environmental governance cost that they need to bear when developing land.

Urban–rural coupling can be a very effective method for evaluating ecological costs in the process of urban peripheralization. It can provide a quantitative reference for research on the relationship between urban and rural areas, landscape urbanization, and the impact of urban peripheralization on ecosystem services. In developing countries in Asia, structural changes in urbanization and industrialization are encouraged. In this process, urban and rural areas are transforming from isolated areas to strong interconnected wholes [2]. Therefore, the urban–rural coupling model can play an important role in exploring future land use scenarios [37]. It can be used to detect the balance between urban and rural development in cities, regions, or globally, and it can also be used to review the sustainability of different types of development (such as landscape urbanization, compact cities, etc.).

Although this research has made a certain contribution to the research on urban–rural coupling, this paper proposes further improvement directions for the existing problems in the future. (I) The increase in international trade makes the area of this study not a real balance of land use. The global resource flow is also an important factor affecting the balance of land supply and demand. Therefore, the impact of globalization can be added to subsequent studies to quantify the impact on the urban–rural coupling. (II) The classification of urban and rural boundaries in this study is mainly based on administrative boundaries. Since government data statistics are often based on administrative regions, the division of urban and rural areas is mainly based on administrative boundaries [38]. Therefore, there is a certain error in defining the scope of urban and rural areas. If there are more specific data on urban and rural land and resource input, more accurate analysis results can be obtained.

5. Conclusions

The land use model plays an important role in exploring future land use. It provides support for the integrated urban and rural development, thereby exerting a significant impact on the ecological coupling between urban and rural areas. Additionally, the balance between economic growth and environmental protection has always been a key issue for sustainable urban and rural development. In this research, with 19 cities in Taiwan used for case analysis, the urban–rural land use coupling was explored, and the resources invested in ecological governance were redistributed. The conclusions can be summarized as follows:

(I) This study constructed a framework for the allocation of the resources invested in ecological governance from the perspective of the coupling relationship between urban and rural land use. The framework first applied the coupling model to quantify the urban–rural coupling relationship, and incorporated the Gini coefficient to judge the degree of inequality in urban ecological supply. Then, the allocation framework based on location quotient was used to redistribute the resources input in ecological governance, and the attribution of the responsibilities was made clear, which promoted regional fairness.

(II) From the perspective of coupling, Taiwan's overall urban–rural coupling is 8.3, which means that every hectare of land development in Taiwan requires 8.30 hectares of ecological land to meet development need. Additionally, the land use coupling in the urban area is only 1.5, while the coupling in the rural area is 15.85. This reflects that the urban area needs to heavily rely on the ecological resources provided by the rural area.

(III) From the perspective of resource allocation, the urban area not only needs to solve the environmental problems in the urban area itself, but also needs to be responsible for the ecological governance of rural area, as well as the resource consumption of the external systems. The area with the largest outflow of funds to the external system is Taipei city. The results made clear the funds that the urban area needs to share for the ecological governance in different regions, realizing the purpose of resource redistribution and promoting the balanced development of the region.

Urban–rural coupling is a dynamic process. The expansion of cities stimulates the flow of material, energy and information between urban and rural areas. In general, the spatial transfer of land use functions is an inevitable result of urban development. From the perspective of land use, this research explored the coupling relationship between land development and ecological protection, which facilitates the understanding of the coupling system between humans and the environment. However, urban–rural coupling involves various aspects such as spatial development, economic balance, and social equity [39], and there is still a long way to go to achieve the sustainable development of urban and rural areas.

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