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Article

Ecosystem Service Value Assessment and Contribution Factor Analysis of Land Use Change in Miyun County, China

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Abstract: Unreasonable land use planning can reduce ecosystem service value and result in unsustainable land use. In this paper, the changes of ecosystem service value were investigated by using the GIS and dynamic simulation model of land use in Miyun of Beijing, China, based on the land use at four time points including 1991, 2006, 2021 and one improved scenario, respectively. The results showed the total ecosystem service value of Miyun was about 2968.34 million Yuan in 1991, 3304.72 million Yuan in 2006, 3106.48 million Yuan in 2021, and 3759.77 million Yuan in the improved scenario. In terms of ecosystem service function, the functions of water supply and soil formation and retention accounted for the largest proportion, which were 19.99% and 14.58% respectively; whereas the functions of food supply and recreation and culture were only 1.83% and 5.99%, respectively. Coefficients of sensitivity for forest cover, water bodies and arable land were relatively large, which were 0.73, 0.28 and 0.14, respectively. The contribution factors of total ecosystem service value with the land use change during different periods were mainly the unused land to forest cover and arable land, which respectively accounted for more than 63% and 21% of the contribution rate. These results suggested that sustainable land use planning should be undertaken with emphasis on vegetation restoration and protection of water bodies.

Keywords: land use change; ecosystem service value; coefficient of sensitivity; spatial analysis; drinking water sources

1. Introduction

Land is the basis of human existence and the most intense interaction between human and nature generally proceeds on and beneath it. Land use change is a major cause of global environmental change [1,2] and sustainable development puzzles including regional economic stability [3], environmental quality [4], biodiversity [5] and ecosystem services [6]. Land use change can alter the structure, process and function of ecosystems, and thus affect the ecosystem service value [7]. As is well known, simple land use for the purpose of economic growth is not a sustainable pathway. Therefore, the ecosystem service value of land use decisions must be introduced to promote the rational exploitation of natural resources for sustainable use of land. From this perspective, the study of ecosystem service value of land use change has much significance [8].

As the earth life support system, the ecological system is the material base of human survival and development. Ecosystem services refer to the formation of ecosystems and ecological processes, which can maintain the natural environment and the effectiveness of human existence [9]. It not only offers necessary products to human production and living but also provides necessary natural conditions and utilities for the life system, thus creating the Earth life support system [10,11]. For a long time, people only consider the economic value of the environment and natural resources, but ignore their potential ecological, social and environmental values [12,13]. This short-sighted behavior causes irrational exploitation of natural resources and even serious damage to ecosystem service, which reduces human welfare income and endangers human sustainability in the biosphere [14,15]. Most services provided by ecosystems have a public characteristic of no market-oriented value, which are prone to be consumed excessively. In order to improve the ecological environment and realize sustainable development of mankind, it is necessary to carry out an assessment of the value of ecosystem services and to build bridges between the market value of ecosystem services and ecological systems [16,17]. With the in-depth study of sustainable development mechanisms, it is found that it is the basis for sustainable development to maintain and conserve the ecological services. Therefore, quantitative assessment of the value of ecosystem services has become one of the hottest international sustainable development topics. It is currently at the intersection of ecology, ecological economics, environmental science, resource economics, environmental economics and management science [18–20].

Ecosystem services can be described, measured and evaluated according to the relationship between ecosystem services and ecosystem functions. Ecosystem service value for different purposes can be divided into different categories [21–23]. Generally, the ecosystem service function comprises two parts, *i.e.*, use value and non-market value. The research about assessment of the value of ecosystem services can be grouped into four areas, including global or regional ecosystem service value assessment, watershed-scale ecosystem price, single ecosystem evaluation, and evaluation of species and the conservation of biological diversity [24,25]. Costanza *et al.* [7] put forward the principles and evaluation methods of the ecosystem service value in 1998, and since then quantitative assessment of the ecosystem service value has become a single hot topic in international sustainable development, ecology and environmental economics. The ecosystem services can be divided into nine categories, including gas regulation, climate regulation, water supply, soil formation and retention, waste treatment, biodiversity protection, food, raw material, and recreation and culture. Kreuter *et al.* [21] analyzed the change in ecosystem service value in the San Antonio area, Texas. Hein *et al.* [26] estimated and examined the spatial scales of ecosystem services, and analyzed how stakeholders at different spatial scales attached value to different ecosystem services. Yang *et al.* [27] analyzed the ecosystem service value of constructed wetland in Hangzhou, China. Li *et al.* [28] assessed the variations of ecosystem service value in response to land use change in Shenzhen. Estoque *et al.* [29] estimated the landscape pattern and ecosystem service value changes for sustainability of the Philippines. Nevertheless, this study mainly aims to evaluate the effects of different historical land use changes on ecosystem service values, without considering the natural, social and economic drivers, and application of a land use temporal and spatial dynamic simulation model and evaluation of different future land use scenarios for ecosystem service value, to provide scientific reference for sustainable land use planning. Miyun County is the largest single source for drinking water of Beijing, China, which undertakes the important task of supplying water for industrial and agricultural production and living to Beijing and Tianjin. Gao *et al.* [30] calculated the ecological value of forest for conservation of water supply. Zhang *et al.* [31] estimated the water conservation of the forest ecosystem and its value. However, few studies have been carried out to investigate the impact of optimizing land use scenario on the value of ecosystem services, and relevant analysis of major contributor factors of the ecosystem service value is relatively rare. Besides, the estimation of the value of domestic and foreign ecosystem services related to ecosystem types and spatial and temporal differences in the quality status is yet to be examined, so it is difficult to estimate the results that reflect the value of ecosystem services in the spatial distribution in a real scenario. The main objective of this study is to estimate variations in ecosystem service value in response to different land use changes by using GIS and land use dynamic simulation models. Meanwhile, the coefficient of sensitivity and the main contributing factors are analyzed. It is believed that our work can provide useful information and advice for policy-making for sustainable use of land resources and drinking water source protection.

2. Study Area

Miyun County, which is located in the northeast of Beijing (116°65′E–117°5′E, 40°2′N–40°8′N), is the largest county in Beijing, China (Figure 1). The area of Miyun is 2229.45 km^2, accounting for 13% of the area of Beijing. Its average annual precipitation is 661.3 mm, with an average annual temperature of 10.8 ℃. It is an important source of drinking water and ecological conservation area of Beijing. As the biggest reservoir in north China, Miyun reservoir was built in 1958–1960, and is located in the middle of Miyun County. Its forestry ecological coverage rate reaches 62.3% of county, and the wet index and water density rank the top of the city. By the end of 2012, it had a population of 0.47 million people.

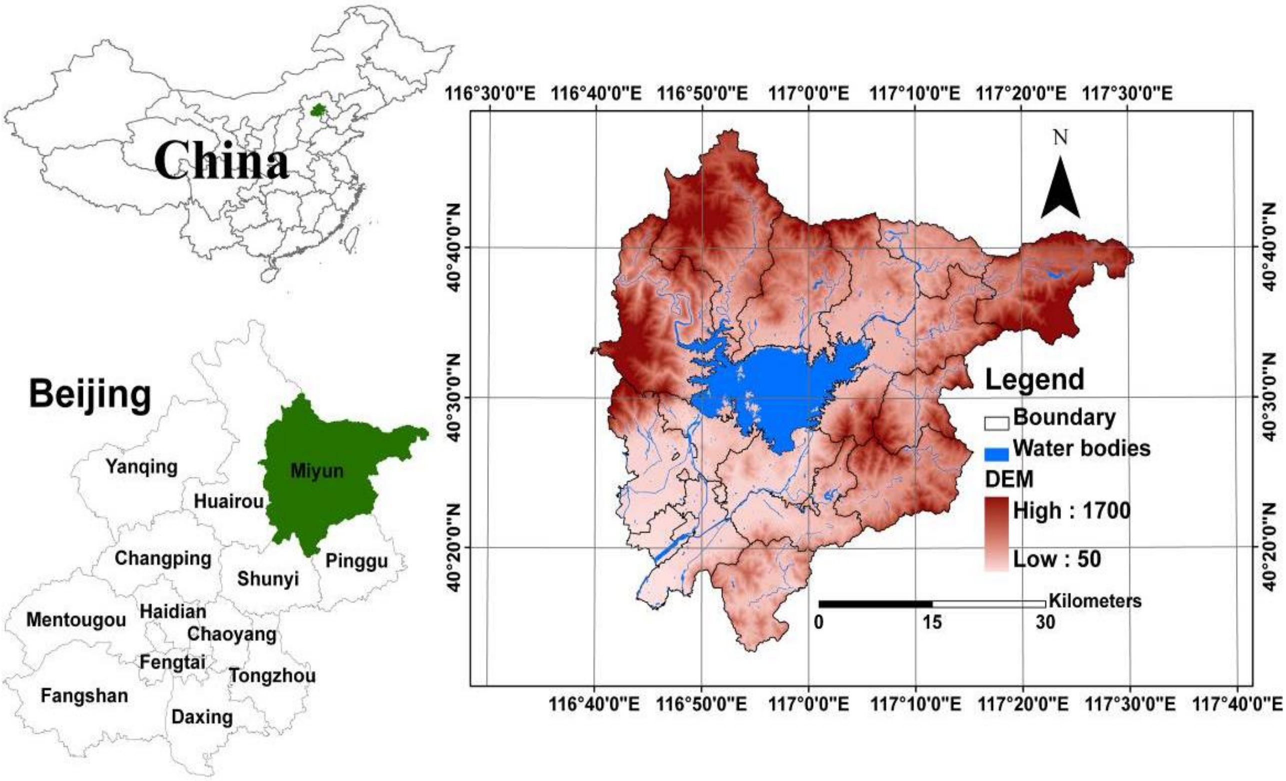


Figure 1. The study area of Miyun County in Beijing, China.

3. Materials and Methods

3.1. Establishment of Land Use Scenarios

3.1.1. Land Use Scenario in 2021

Land use simulation models are established according to the dynamic simulation model CLUE-S of Wageningen University in the Netherlands [32]. CLUE-S model includes three modules: the land demand module, spatial analysis module and spatial distribution module [33,34]. Many scholars use the model to set land use scenarios, as well as different scenarios of various types of land total control simulation [35]. According to existing economic and social trends, it is assumed that the major land transformation process in Miyun County does not change. Each land area accords with the land use change during 1991–2006, and the land structure of 2021 can be forecasted by using the BP neural network model.

3.1.2. Improved Scenario of Land Use for Enhancing the Value of Ecosystem Services

Miyun County is the only water source area of Beijing. Therefore, the focus is on considering water protection and vegetation restoration measures. To enhance the ecosystem service value of drinking water sources, the improved scenario of land use is established by vegetation buffer strip construction, including riparian buffer zone construction (riparian buffered by forest), conversion of cropland to forest with a slope of more than 25°, and reforestation on bare land. In addition, the adjustment elastic variable is in main file and the land use demand is in demand file of the CLUE-S model, making the conversion between the various types of land use more reasonable.

The arable land increases by 25,062.5 ha, accounting for 56.10% of the total area; the construction land increases by 8350 ha, accounting for 87.49%; and the unused area is reduced by 46,118.75 ha, accounting for 89.74%. These results indicate the main trend for the expansion of construction and agricultural land and the reuse of unused land from 1991–2021. In contrast, the woodland increases by 40,293.75 ha, accounting for 42.31% of the total area; and the water bodies increases by 987.5 ha, accounting for 4.93% under an improved scenario (Figure 2). These results show that land use change gives priority to vegetation restoration and protection of water bodies.

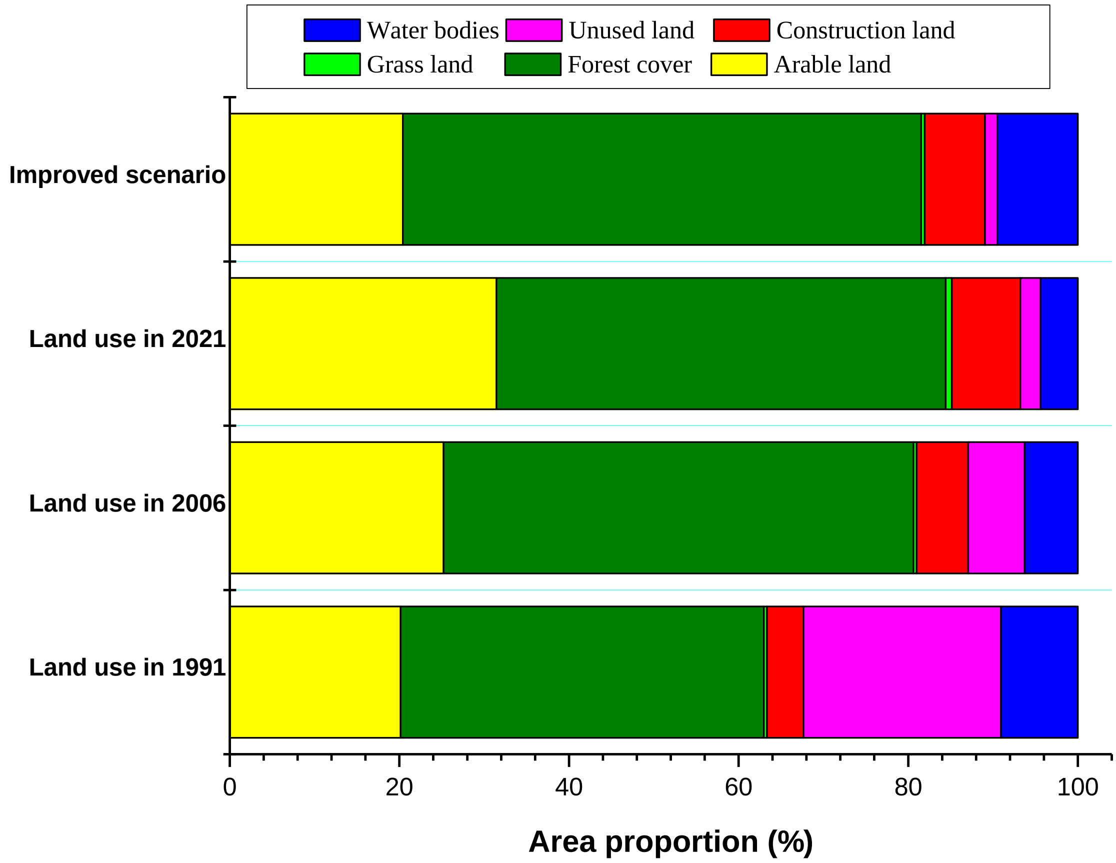


Figure 2. The proportions of different land use areas in 1991, 2006, 2021 and under an improved scenario.

3.2. Assignment of Ecosystem Service Value

According to Costanza *et al.* [7], the estimation of ecological service value should be made on a global scale in order to reduce the error caused by application of terrestrial ecosystems in China. Based on the results of Costanza *et al.* and Xie *et al.* [11,36,37], considering the actual situation of China, different land use types per unit area ecosystem service value can be determined. In this study, the value of ecosystem services' evaluation system by Xie *et al.* is adopted (Table 1).

Table 1. Ecosystem service value of per unit area of different land use types in Miyun (Yuan ha^{-1} a^{-1}).

	Arable Land	Forest Cover	Grass Land	Unused Land	Water Bodies
Gas regulation	442.40	3097.00	707.90	0.00	0.00
Climate regulation	787.50	2389.10	796.40	0.00	407.00
Water supply	530.90	2831.50	707.90	26.50	18,033.20
Soil formation and retention	1291.90	3450.90	1725.50	17.70	8.80
Waste treatment	1451.20	1159.20	1159.20	8.80	16,086.60
Biodiversity protection	628.20	2884.60	964.50	300.80	2203.30
Food	884.90	88.50	265.50	8.80	88.50
Raw material	88.50	2300.60	44.20	0.00	8.80
Recreation and culture	8.80	1132.60	35.40	8.80	3840.20
Total	6114.30	19,334.00	6406.50	371.40	40,676.40

3.3. Calculation of Ecosystem Service Value

Regional ecological service value calculated by the following formula:

$$ESV_k = \sum_f A_k \times VC_{kf} \tag{1}$$

$$ESV_f = \sum_k A_k \times VC_{kf} \tag{2}$$

$$ESV = \sum_k \sum_f A_k \times VC_{kf} \tag{3}$$

where ESV_k, ESV_f and ESV denote ecosystem service value of land use type k, ecosystem service value of function type f, and total ecosystem service value, respectively; A_k represents the area (ha) for land use type (k); VC_{kf} is the ecosystem service function value index for land use type (k) and ecosystem service function (f).

3.4. Analysis of Coefficient of Sensitivity and Main Contribution Factors for Ecosystem Service Value

To reflect the dependence of ecosystem service value on the ecosystem service value index over time, the elasticity coefficient of economics is selected to calculate the sensitivity index [21]:

$$CS = \left| \frac{(ESV_j - ESV_i)/ESV_i}{(VC_{jk} - VC_{ik})/VC_{ik}} \right| \tag{4}$$

where ESV represents the total ecosystem service value; VC is the value coefficient; i and j represent the initial and adjusted values, respectively; k is the land use type; and CS is coefficient of sensitivity.

Adjust the value coefficient of each land use type by 50%, respectively, and then measure the change of ecosystem service value. If $CS > 1$, the ESV for VC is flexible; if $CS < 1$, the ESV for VC is lack of elasticity; $CS = 1$ means a complete elasticity; $CS = 0$ indicates a complete inelasticity. The greater the ratio is, the more important it is to the accuracy of the ecosystem service function value index.

The main contribution factor can be calculated by the following formula:

$$ESV_{t+1,t} = \sum_f (VC_{t+1,f} - VC_{t,f}) \times A_{t+1,t} \tag{5}$$

where *ESV* refers to the total ecosystem service value; *VC* represents the value coefficient; *A* is the area of different land use types; *f* is the ecosystem service function; *t* and *t* + 1 refer to the time point before and after the period.

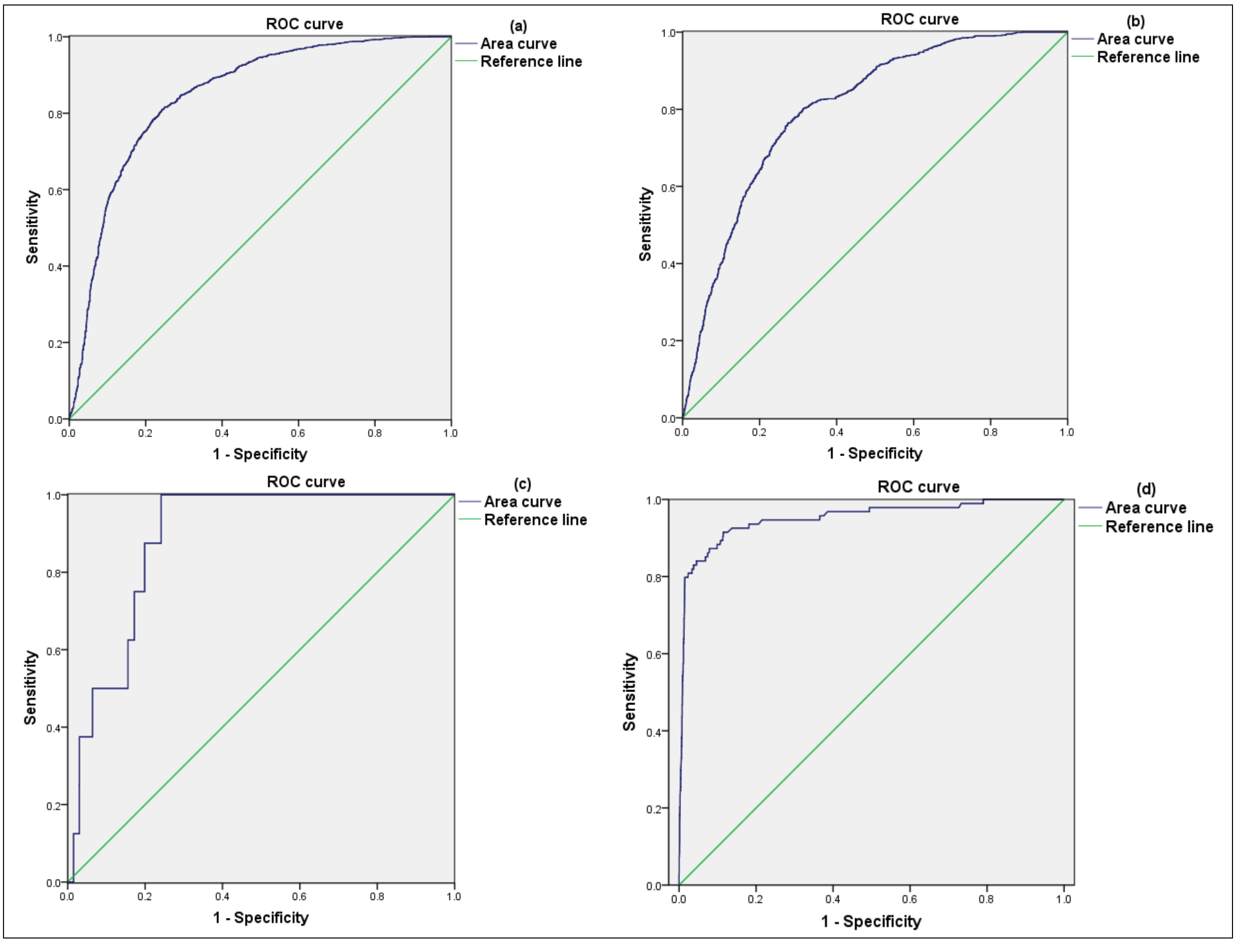
3.5. Data Collection

The research data include traffic maps, digital elevation model (DEM, 1:50,000), water system map, slope map, and administrative boundary map, social and economic data. Land use during 1991–2006 (1:10,000) is divided into six categories, including arable land, forest cover, construction land, water bodies, grass land and unused land.

4. Results and Analysis

4.1. Validation of CLUE-S Model

This research adopts the binary logistic regression analysis, evaluation of various driving factors on the impact of land use change. The results showed that the ROC value of various land use types are as follows: water bodies, construction land, grass land, arable land, forest cover and unused land respectively, the ROC values were 0.995, 0.951, 0.886, 0.847, 0.802 and 0.754. The ROC values are greater than 0.7, indicating the selected drive factor has high explanatory power (Figure 3).



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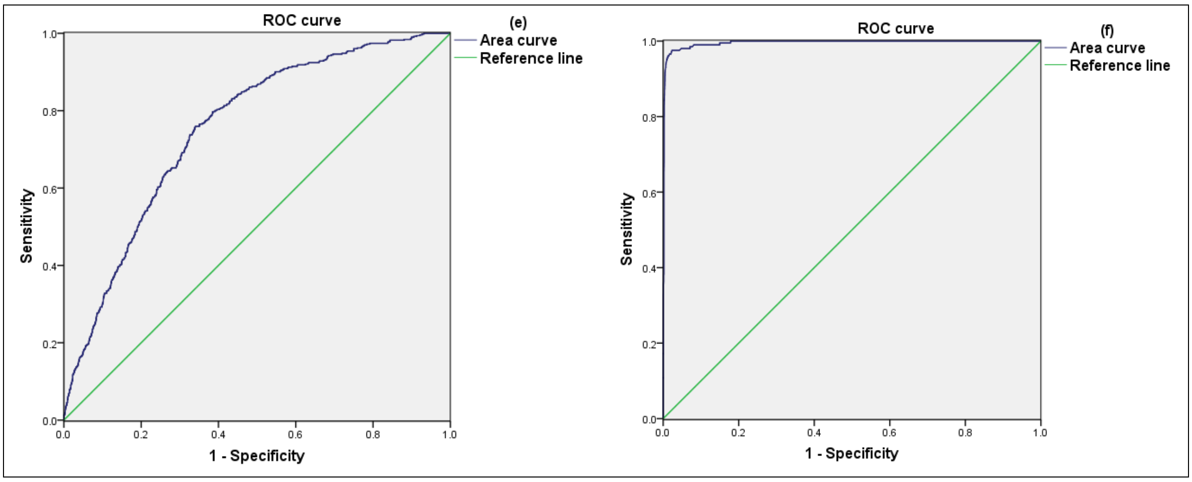


Figure 3. ROC value of each land use type. (**a**) Arable land; (**b**) Forest cover; (**c**) Grass land; (**d**) Construction land; (**e**) Unused land; (**f**) Water bodies.

In this study, the accuracy of the model is quantitatively calculated by Kappa coefficient, and the accuracy of the model is evaluated. Take actual land use and driving factors in 1991 as the input of the model, simulating the spatial distribution of land use in 2006. As is shown in Figure 4, spatial distribution of simulated and real forest in 2006 showed a higher consistency, and the overall kappa coefficient is 0.76, indicating that the CLUE-S model can be used to simulate land use change of Miyun County.

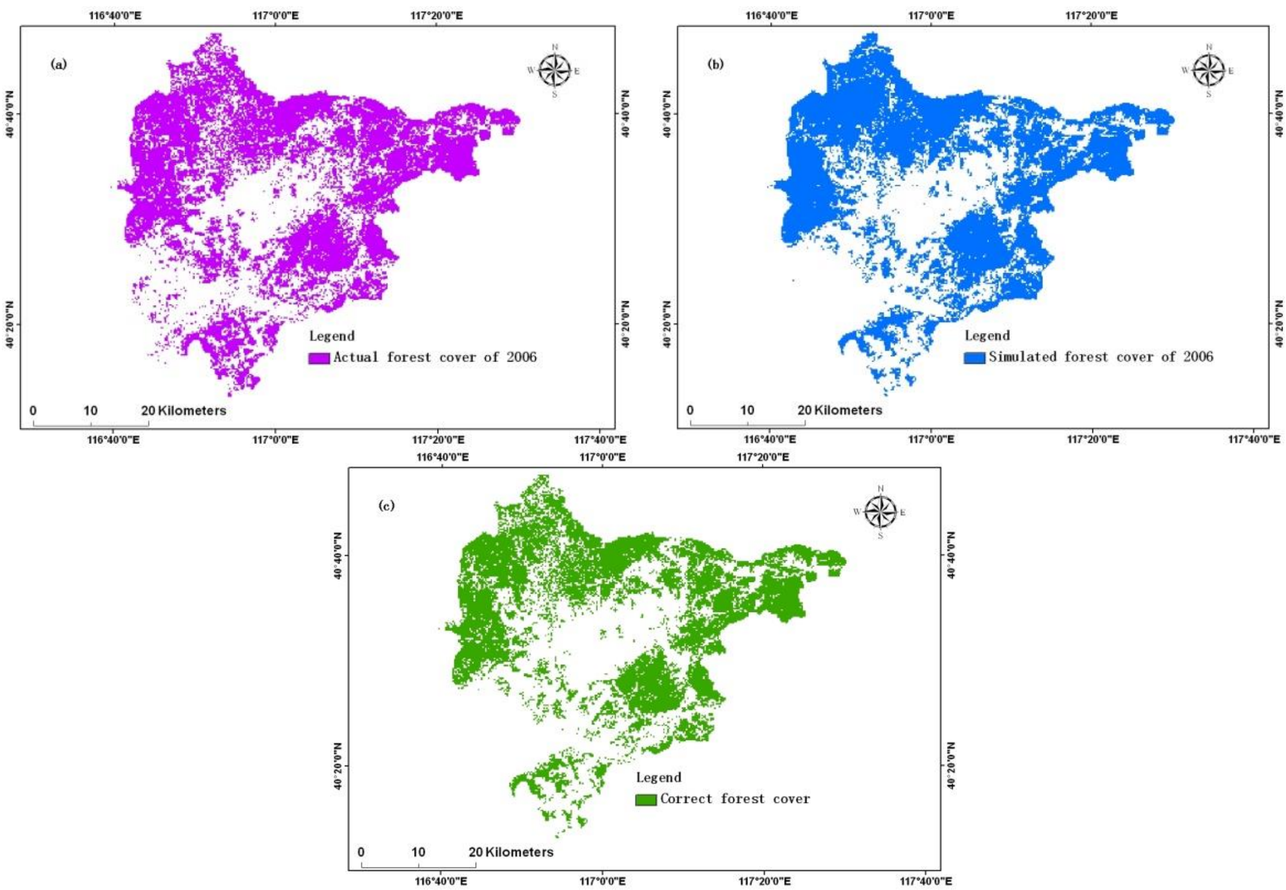


Figure 4. CLUE-S model validation (In forest cover, for example). (**a**) Actual forest cover of 2006; (**b**) simulated forest cover of 2006; (**c**) correct forest cover.

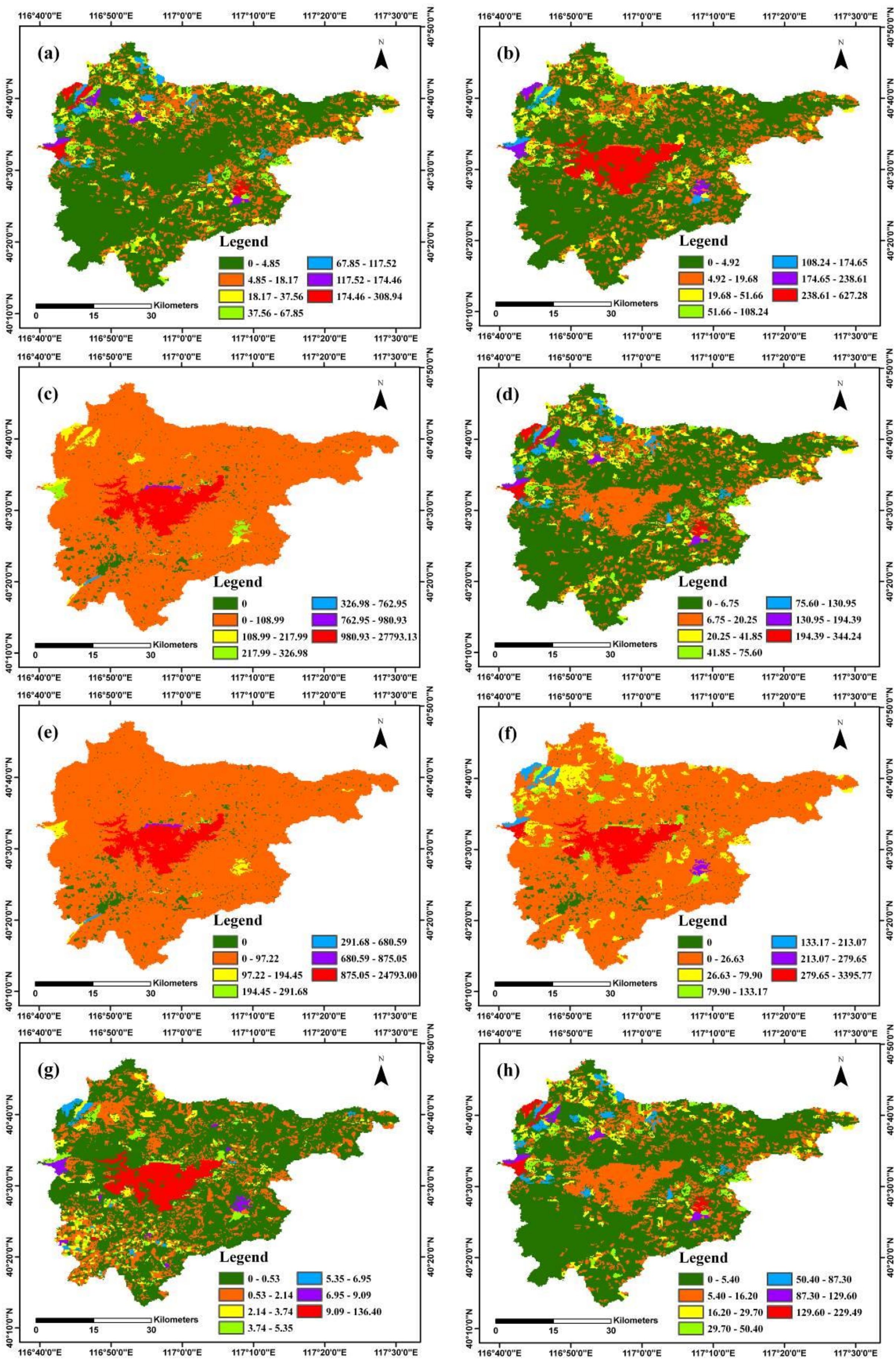
4.2. Overall Analysis of the Ecosystem Service Value

The total ecosystem service value of Miyun is about 2968.34 million Yuan in 1991, 3304.72 million Yuan in 2006, 3106.49 million Yuan in 2021, and 3759.77 million Yuan in the improved scenario (Table 2). From 1991–2006, the ecosystem service value increases by 336.38 million Yuan (11.33%), primarily due to the increase of forest area and the decrease of the unutilized area. However, the total ecosystem service value decreases by 198.24 million Yuan (6.00%) from 2006–2021, mainly due to the decrease in forest cover and the expansion of construction land. Comparatively speaking, the total ecological service value increases by 455.05 million Yuan (13.77%) from 2006 to the improved scenario, which can mainly be attributed to the vegetation restoration of drinking water source and protection of water bodies.

Table 2. Ecosystem service value in Miyun in 1991, 2006, 2021 and the improved scenario.

	1991		**2006**		**2021**		**Improved Scenario**	
	ESV (10^4 Yuan/a)	**Proportion (%)**	**ESV (10^4 Yuan/a)**	**Proportion (%)**	**ESV (10^4 Yuan/a)**	**Proportion (%)**	**ESV (10^4 Yuan/a)**	**Proportion (%)**
Gas regulation	31,635.21	10.66	40,718.54	12.32	39,571.50	12.74	44,043.03	11.71
Climate regulation	27,251.77	9.18	34,503.20	10.44	34,076.57	10.97	36,874.35	9.81
Water supply	66,070.46	22.26	63,141.17	19.11	54,689.60	17.60	78,779.74	20.95
Soil formation and retention	39,026.27	13.15	49,969.80	15.12	49,836.37	16.04	52,803.99	14.04
Waste treatment	50,239.41	16.93	44,984.34	13.61	39,632.67	12.76	56,221.50	14.95
Biodiversity protection	36,475.82	12.29	42,683.45	12.92	40,724.51	13.11	46,761.35	12.44
Food	5067.36	1.71	6213.90	1.88	7344.91	2.36	5416.90	1.44
Raw material	22,399.49	7.55	28,872.87	8.74	27,650.68	8.90	31,603.41	8.41
Recreation and culture	18,668.53	6.29	19,385.18	5.87	17,121.77	5.51	23,472.76	6.24
Total	296,834.32	100.00	33,0472.46	100.00	310,648.58	100.00	375,977.03	100.00

From the spatial distribution of total ecosystem service value (Figures 5–8), 0–245.85 10^4 Yuan/a is distributed in most regions in 1991, 0–31.71 10^4 Yuan/a is mainly distributed in the eastern and southwestern regions in 2006, 0–809.28 10^4 Yuan/a is mainly distributed in the northeast and south in 2021, and 0–1667.79 10^4 Yuan/a is distributed in most regions under the improved scenario.



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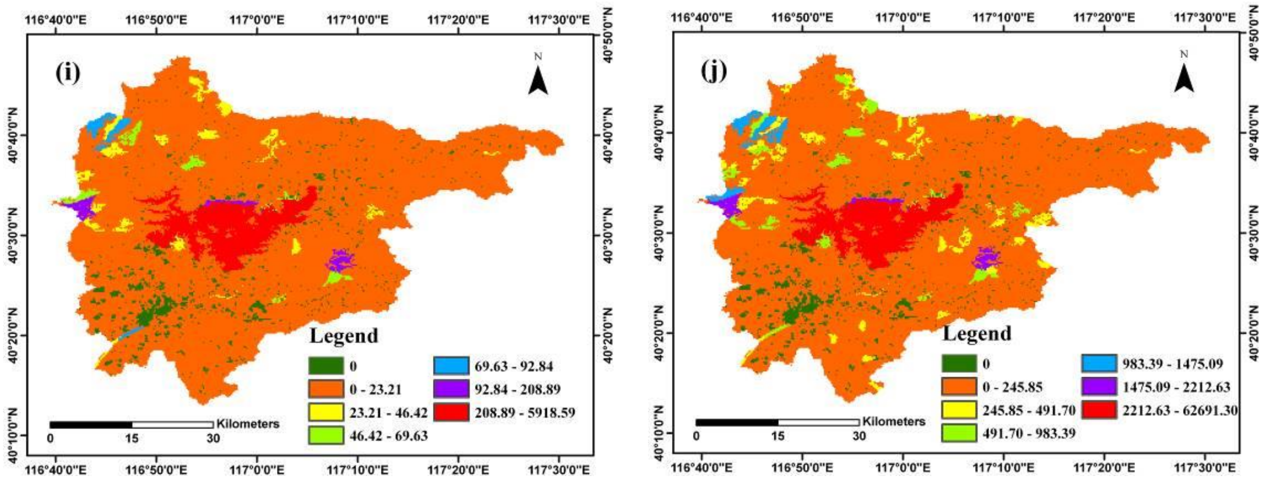
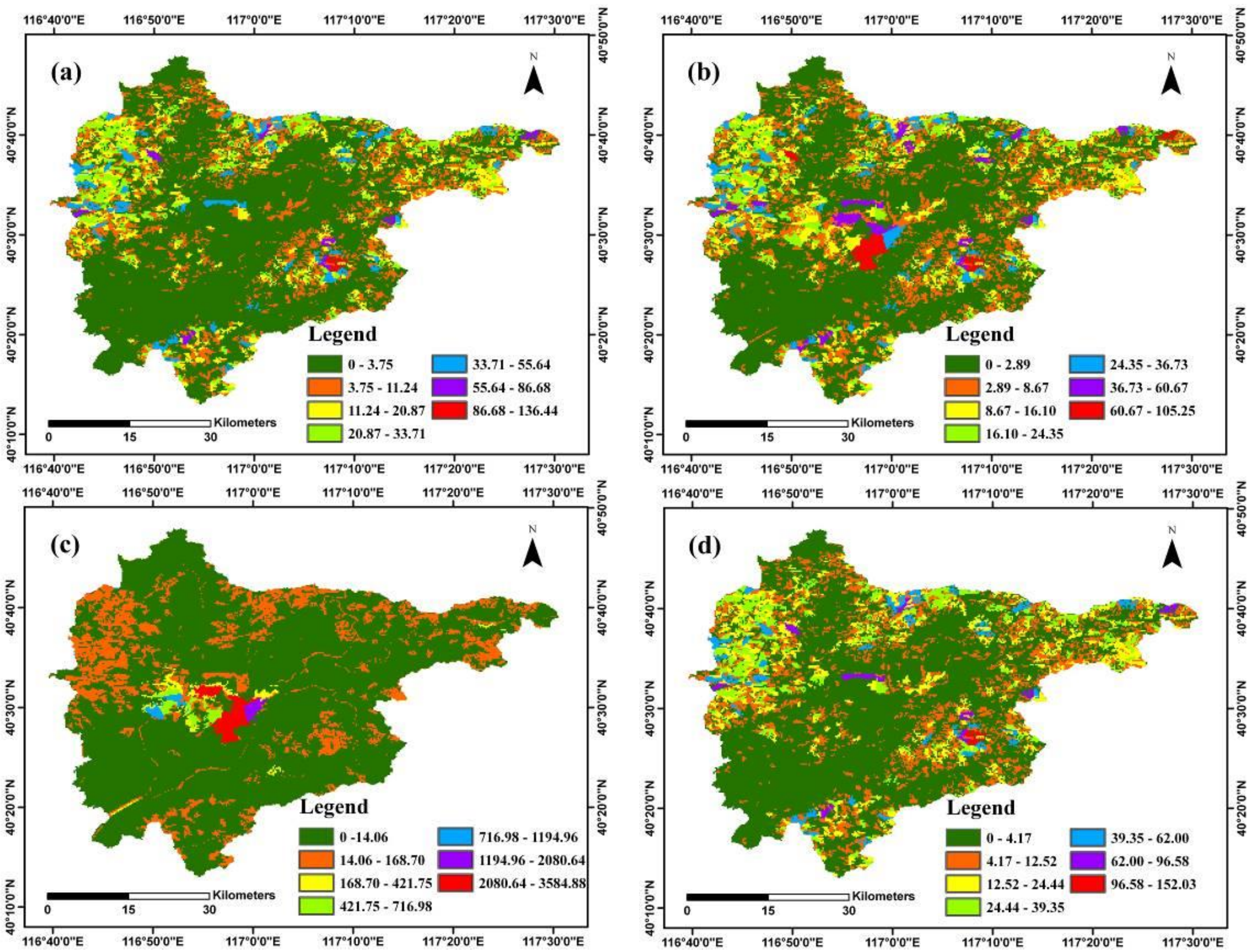


Figure 5. Spatial distribution of the ecosystem service value in Miyun in 1991 (10^4 Yuan/a). (**a**) Gas regulation; (**b**) Climate regulation; (**c**) Water supply; (**d**) Soil formation and retention; (**e**) Waste treatment; (**f**) Biodiversity protection; (**g**) Food; (**h**) Raw material; (**i**) Recreation and culture; (**j**) Total ESV.



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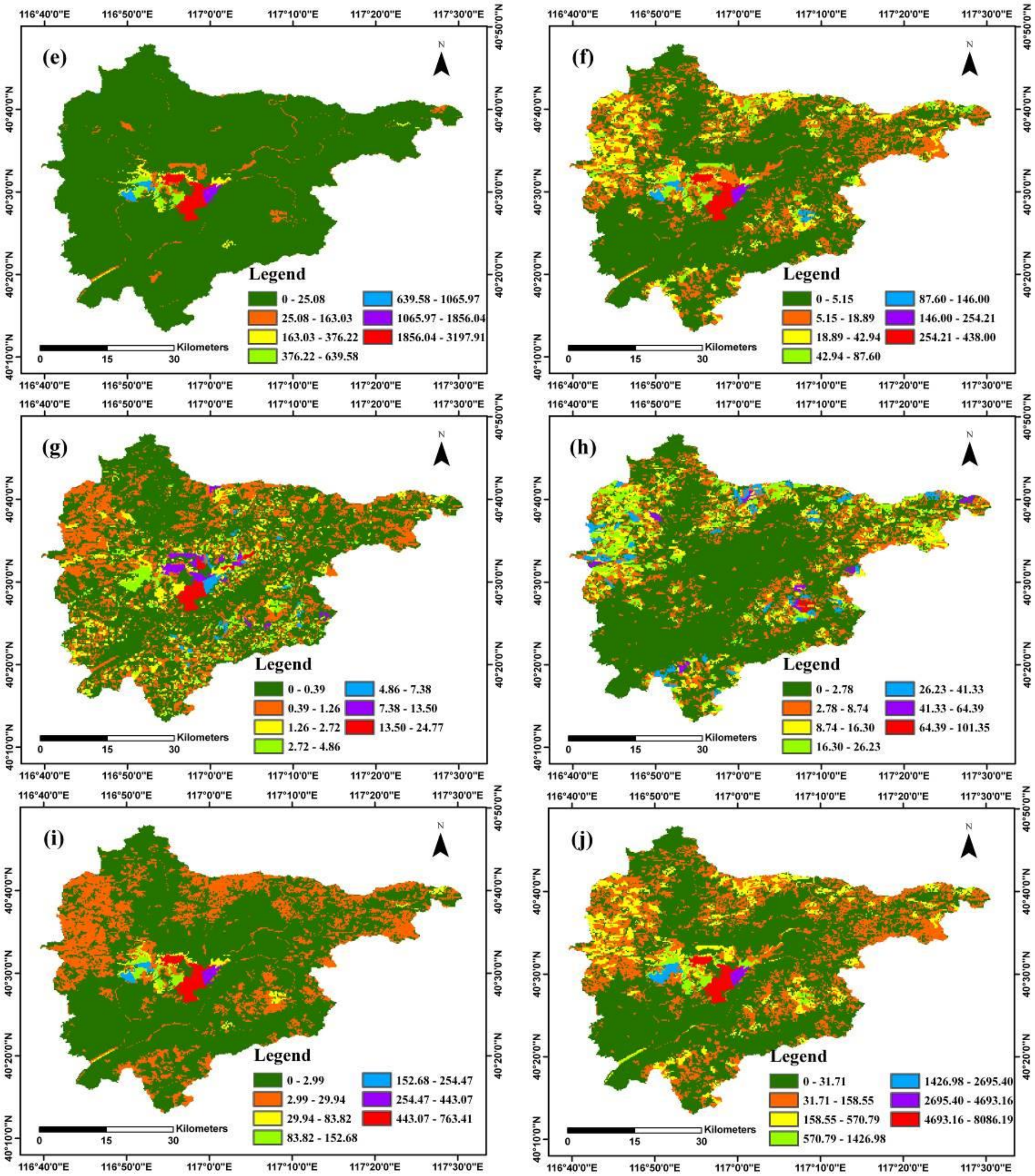
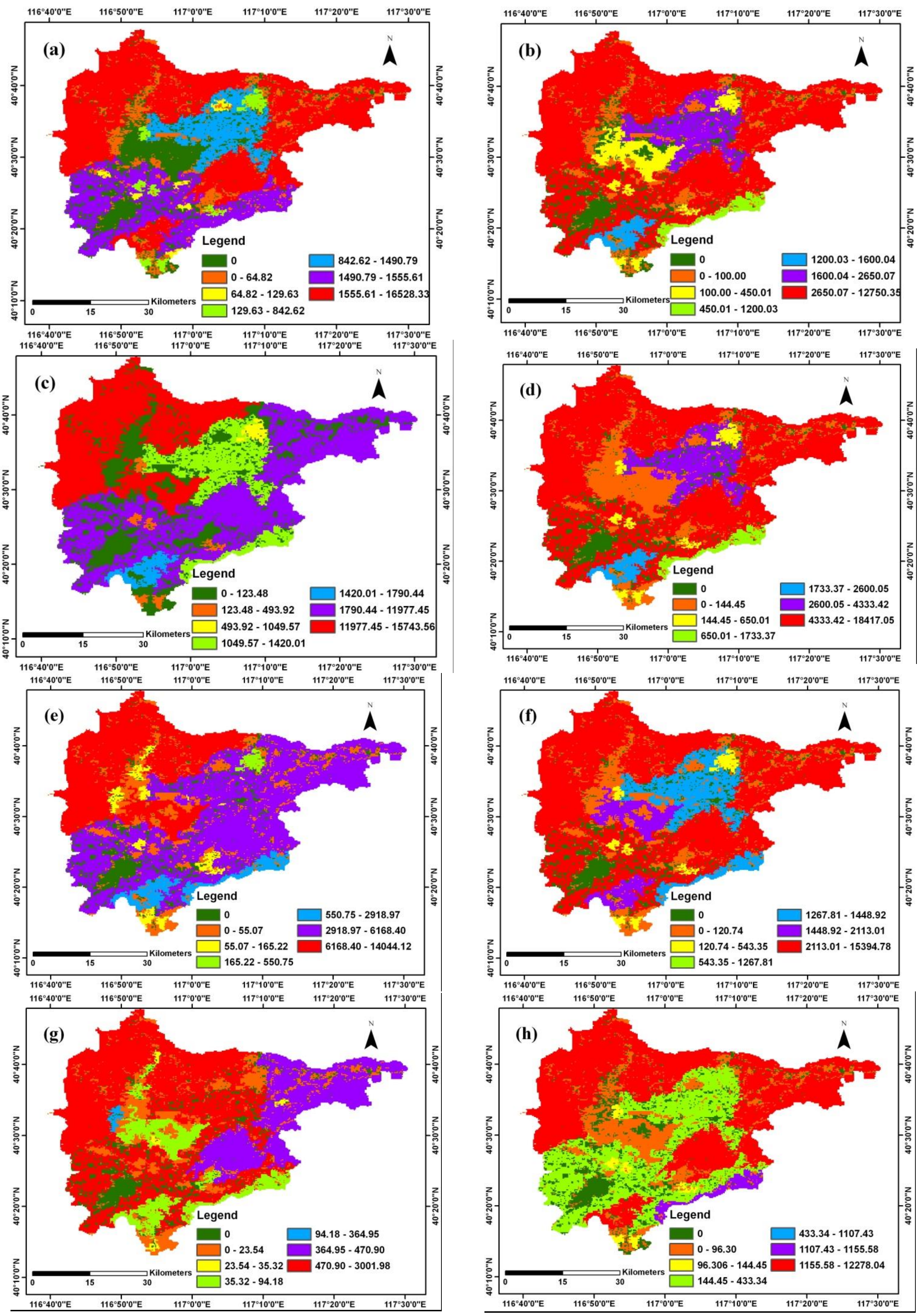


Figure 6. Spatial distribution of the ecosystem service value in Miyun in 2006 (10^4 Yuan/a). (**a**) Gas regulation; (**b**) Climate regulation; (**c**) Water supply; (**d**) Soil formation and retention; (**e**) Waste treatment; (**f**) Biodiversity protection; (**g**) Food; (**h**) Raw material; (**i**) Recreation and culture; (**j**) Total ESV.



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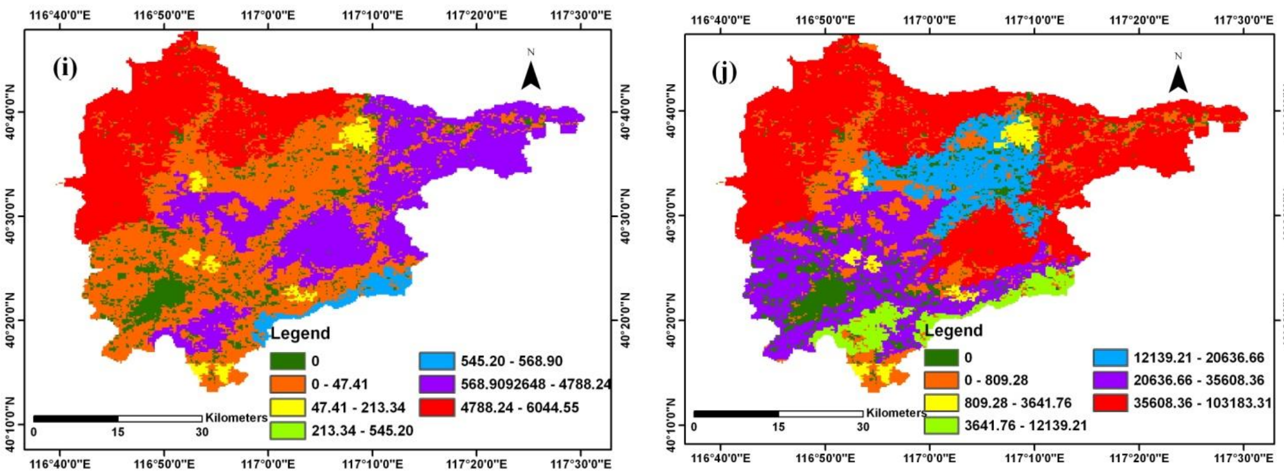
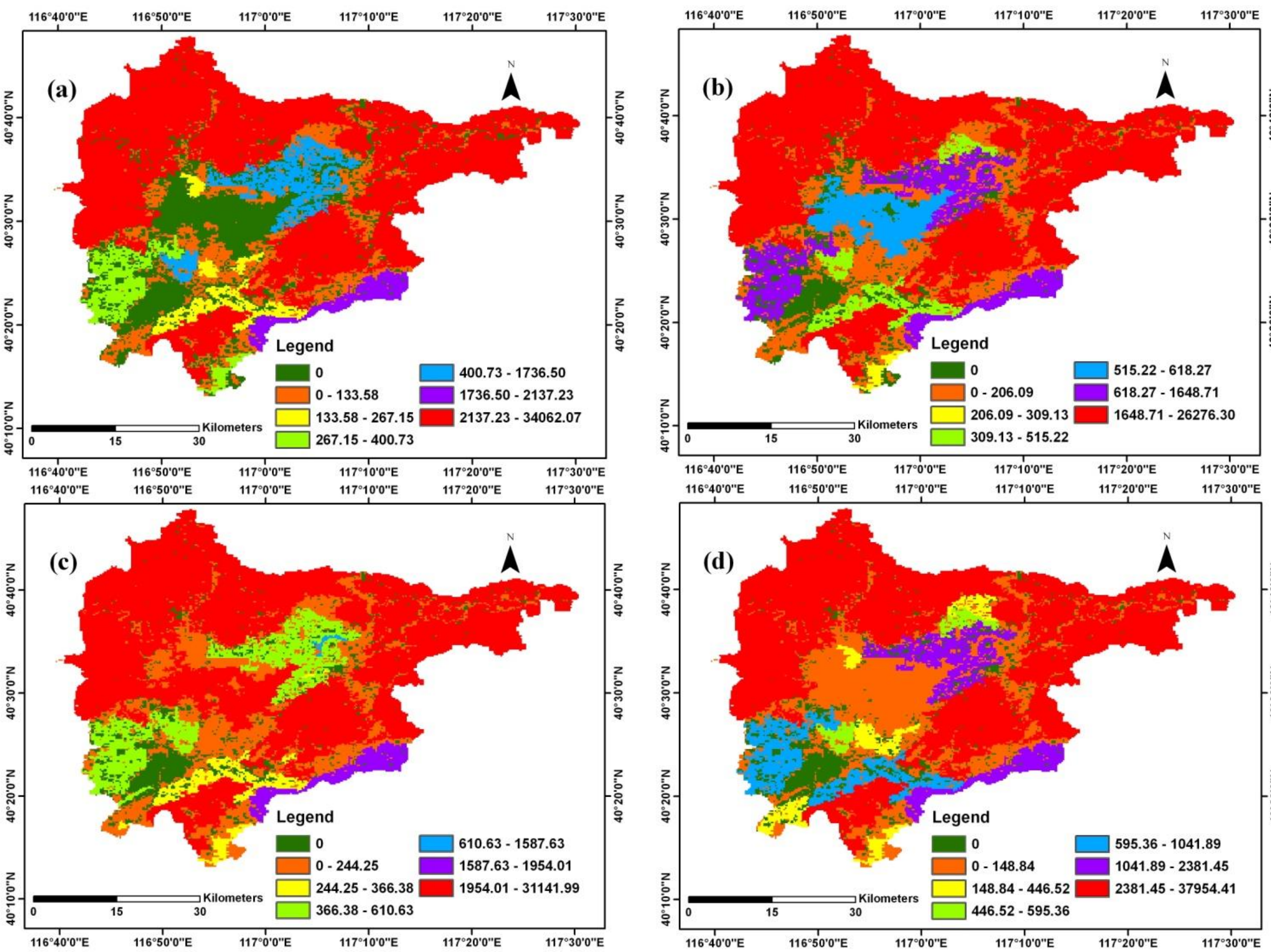


Figure 7. Spatial distribution of the ecosystem service value in Miyun in 2021 (10^4 Yuan/a). (**a**) Gas regulation; (**b**) Climate regulation; (**c**) Water supply; (**d**) Soil formation and retention; (**e**) Waste treatment; (**f**) Biodiversity protection; (**g**) Food; (**h**) Raw material; (**i**) Recreation and culture; (**j**) Total ESV.



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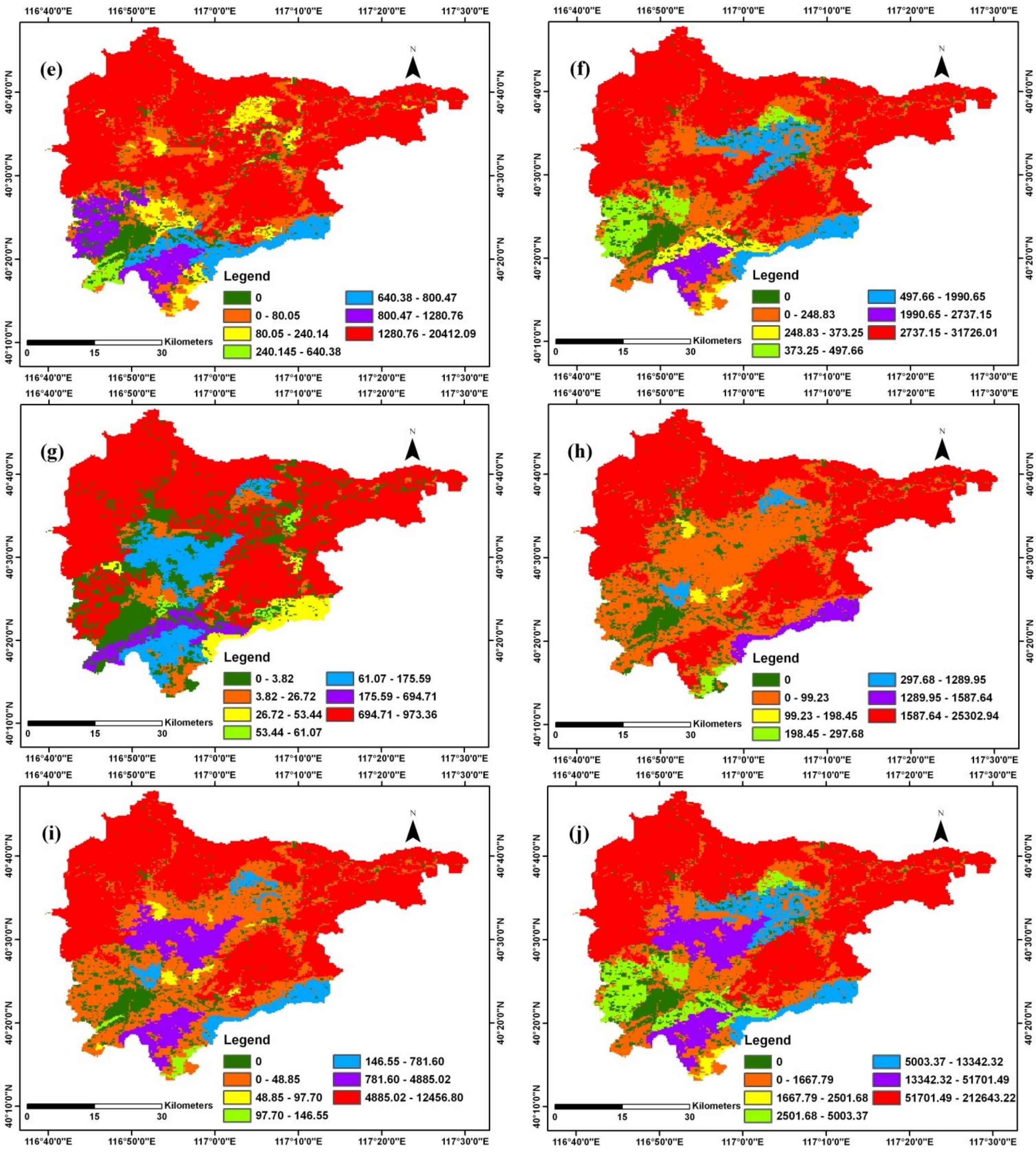

Figure 8. Spatial distribution of the ecosystem service value in Miyun in the improved scenario (10^4 Yuan/a). (**a**) Gas regulation; (**b**) Climate regulation; (**c**) Water supply; (**d**) Soil formation and retention; (**e**) Waste treatment; (**f**) Biodiversity protection; (**g**) Food; (**h**) Raw material; (**i**) Recreation and culture; (**j**) Total ESV.

4.3. Ecosystem Service Function Assessment

Figures 5–8 and Table 2 show different functions of ecosystem services in Miyun County. Water supply and soil formation and retention account for 19.99% and 14.58%, respectively, indicating a high value of ecosystem services. In contrast, food and recreation and culture account for only 1.83% and

5.99%, respectively, indicating a lower value of ecosystem services. Based on their contributions, the overall rank order for each ecosystem function can be described from high to low as follows: water supply, soil formation and retention, waste treatment, biodiversity protection, gas regulation, climate regulation, raw material, recreation and culture, food.

4.4. Spatial Analysis of Ecosystem Service Function for Different Administrative Regions

Figures 9–12 show the different ecosystem service functions for different administrative regions. In 1991, the highest proportions of ecosystem service value are 15.54% and 9.59% in Shicheng and Fengjiayu, respectively, and the main ecosystem service function is water supply, which is located in the west and northwest of the study area; the lowest proportion is 0.03% and 0.04% in Tanying and Shougang, respectively, which is located in the south of the study area. In 2006, the highest value ratio of ecological service is 10.36% and 12.28% in Shicheng and Miyun Reservoir, respectively, and the main ecosystem service function is also water supply, which is located in the western and middle part of the study area; the lowest ratio is 0.06% and 0.23% in Tanying and Kaifaqu, respectively, and the main ecosystem service function is soil formation and retention, which is located in the south and southwest of that the study area.

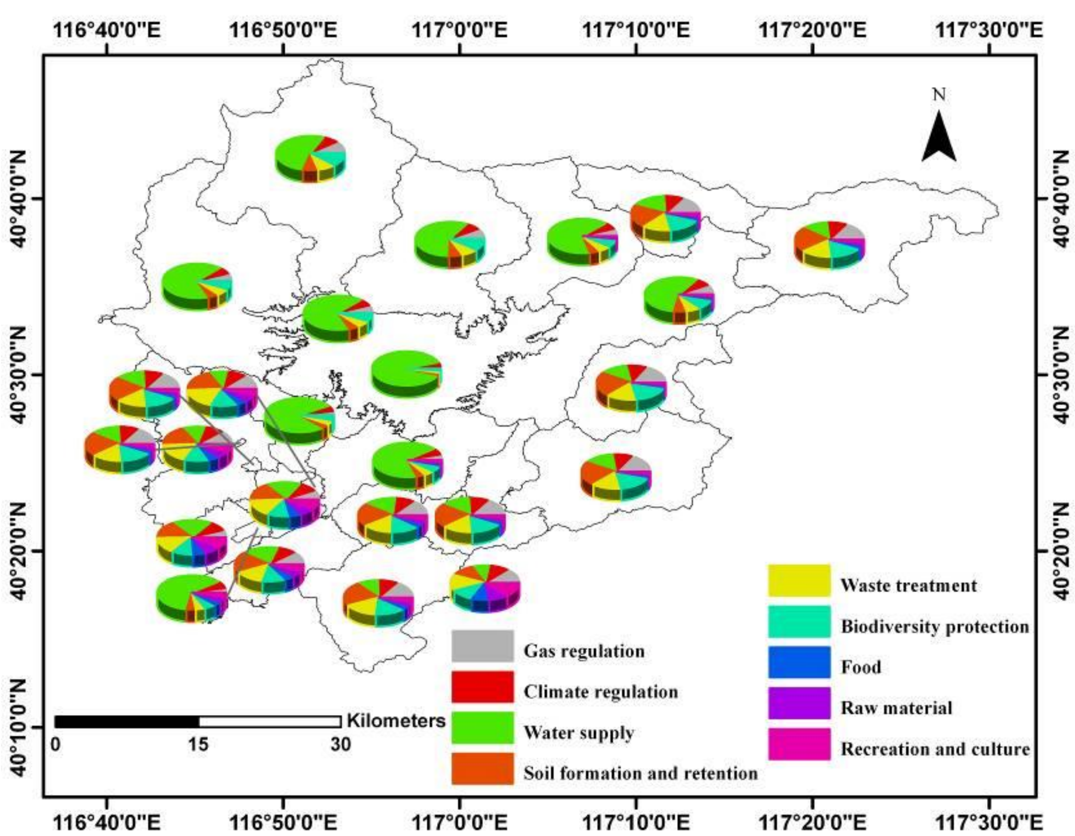

Figure 9. Spatial distribution of ecosystem service function in 1991.

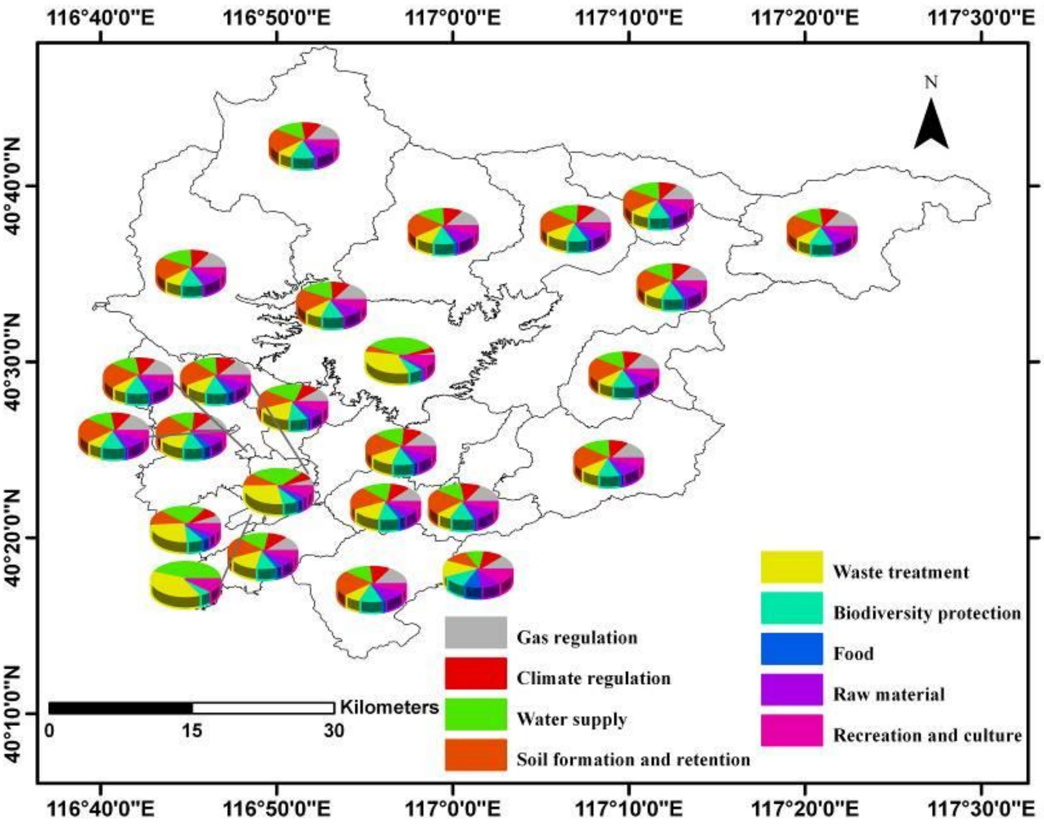

Figure 10. Spatial distribution of ecosystem service function in 2006.

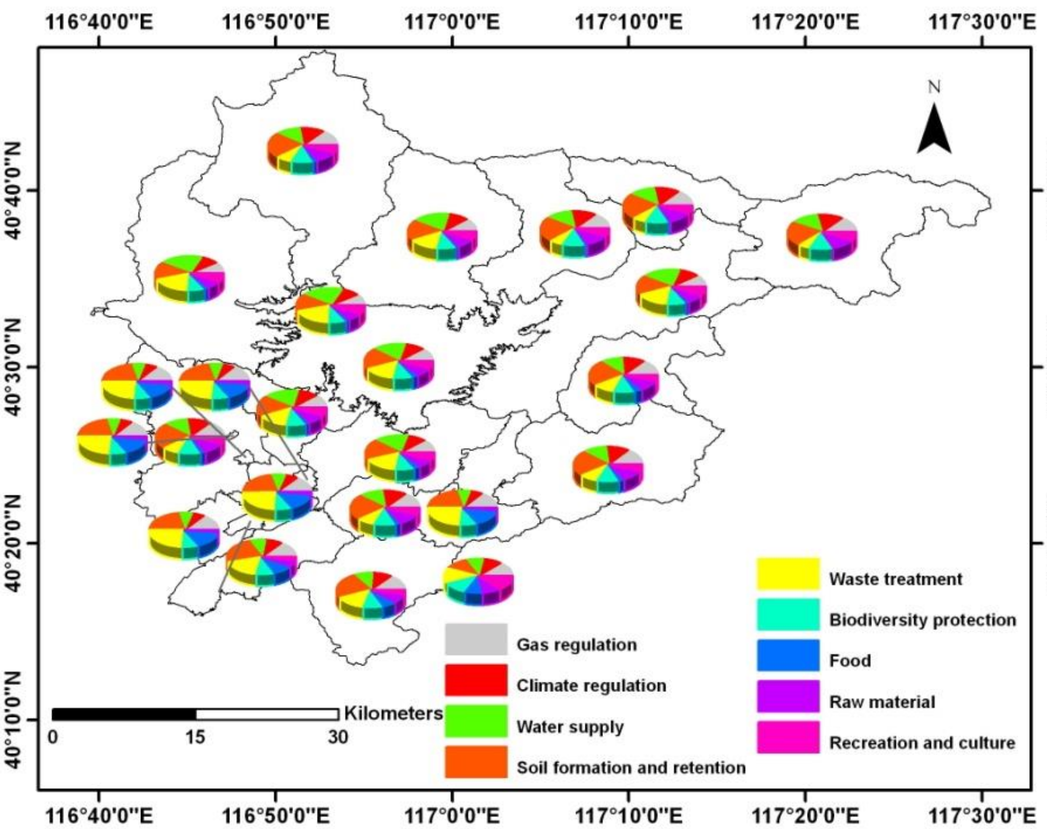

Figure 11. Spatial distribution of ecosystem service function in 2021.

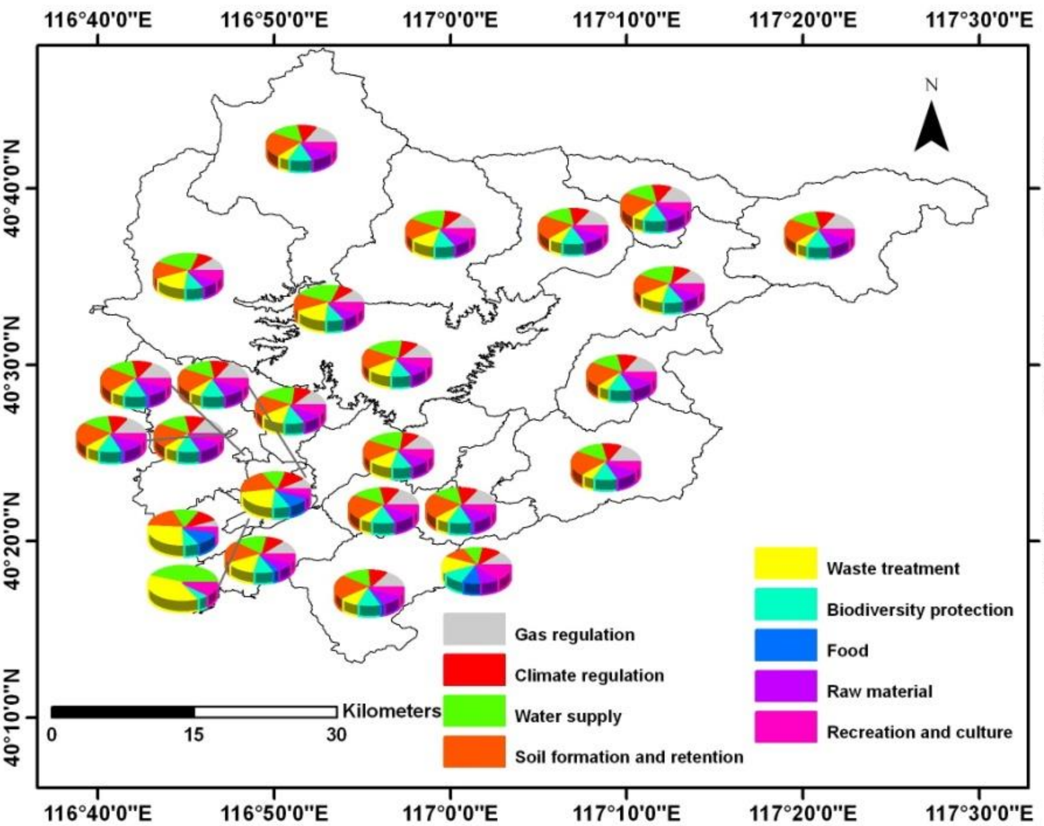

Figure 12. Spatial distribution of ecosystem service function under the improved scenario.

In contrast, in 2021, the highest proportions of ecosystem service value are 7.83% and 7.79% in Gaoling and Gubeikou, respectively, and the main ecosystem service function is soil formation and retention, which is located in the west and northwest of the study area; the lowest proportion is 0.82% and 0.81% in Tanying and Shilibao, respectively, which is located in the south of the study area. Under the improved scenario, the highest value ratios of ecological service are 7.01% and 2.60% in Shicheng and Miyun Reservoir, respectively, and the main ecosystem service function is water supply, which is located in the western and central section of the study area; the lowest ratios are 0.07% and 0.03% in Tanying and Kaifaqu, respectively, and the main ecosystem service functions are soil formation and retention and water supply, which is located in the south of the study area.

4.5. Sensitivity Analysis of Ecosystem Service Value Coefficient

Table 3 shows the changes in the proportion of total ecosystem service value, and the coefficient of sensitivity resulting from a 50% adjustment of the coefficient of ecosystem service value can be calculated by using Formula (4).

Overall, the total ecosystem service value of different land use types with respect to the coefficient of sensitivity changes of ecosystem service value is less than 1, which indicates that the total ecosystem service value is relatively inelastic. Coefficients of sensitivity for forest cover, water bodies and arable land are relatively larger, of which the coefficient of sensitivity for forest land is the highest, *i.e.*, 0.62 in 1991, 0.72 in 2006, 0.73 in 2021 and 0.70 under the improved scenario, due to the large area and high ecosystem service value coefficient. Besides, the coefficient of sensitivity for water bodies is the second largest, *i.e.*, 0.28 in 1991, 0.17 in 2006, 0.14 in 2021 for arable land and 0.12 in the improved scenario for unused land; while that for unused land is the least, *i.e.*, 0.01 in 1991, 0.00 in 2006, and 0.00 in 2021 for grass land, and 0.00 under the improved scenario for grass land, due to the low ecosystem service value.

Table 3. Changes in total ecosystem service value and coefficient of sensitivity resulting from adjustment of coefficient.

Change of Ecosystem Service Value Coefficient	1991		2006		2021		Improved Scenario	
	%	***CS***	**%**	***CS***	**%**	***CS***	**%**	***CS***
Arable land *VC* ±50%	4.63	0.09	5.19	0.10	6.86	0.14	3.68	0.07
Forest cover *VC* ±50%	31.12	0.62	36.06	0.72	36.55	0.73	34.85	0.70
Grass land *VC* ±50%	0.09	0.00	0.08	0.00	0.16	0.00	0.08	0.00
Construction land *VC* ±50%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unused land *VC* ±50%	0.00	0.01	0.08	0.00	4.59	0.09	5.93	0.12
Water bodies *VC* ±50%	13.84	0.28	8.59	0.17	1.47	0.03	4.76	0.10

The proportion of the total ecosystem service value increases from 31.12%–36.06% during 1991–2006 mainly due to the increase of forest cover area, but decreases from 8.59% to 1.47% during 2006–2021 mainly due to decrease in water bodies area. From 2006 to under the improved scenario, the proportion of the total ecosystem service value increases from 0.08%–5.93%, mainly due to the decrease of unused land area and the high ecosystem service value coefficient.

4.6. Analysis of Contribution Factors

Figure 13 shows the contribution factors of total ecosystem service value with land use change during different periods, which can be calculated by using Formula (5).

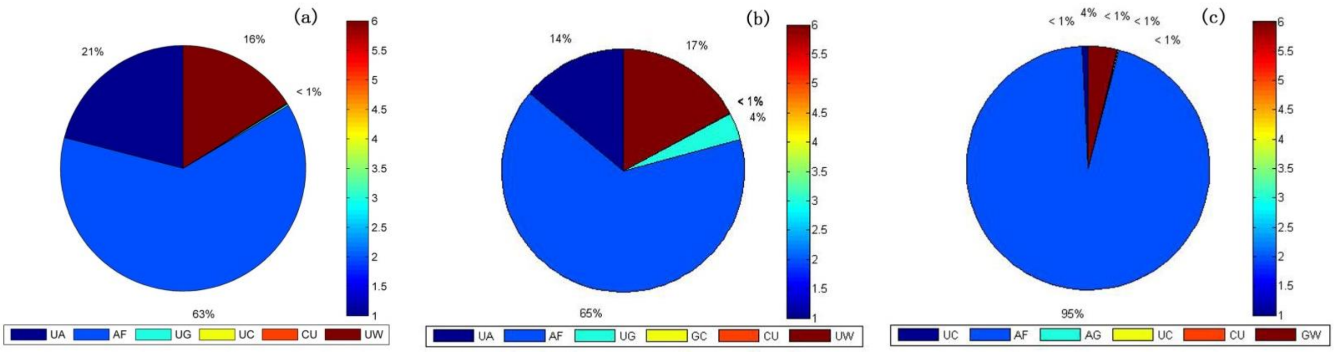

Figure 13. Contributing factors of land use change with respect to the ecosystem service value during different periods: (**a**) 1991–2006; (**b**) 2006–2021; (**c**) 2006–under the improved scenario.

From 1991–2006, the total ecosystem service value increases mainly due to land use change from arable land to forest cover, and the corresponding contribution rate reaches 63%. In contrast, from 2006–2021, the contribution rate of the same land use change accounts for 65%. For both the two periods, the contribution rate of land use change from construction land to unused land just accounts for 0.006%. Furthermore, from 2006 to under the improved scenario, the total ecosystem service value increases mainly due to land use change from arable land to forest cover, and the contribution rate reaches 95%.

The results show that the contribution factor of land use change mainly lies in the vegetation restoration during different periods.

The capital letter W denotes water bodies, U denotes unused land, C denotes construction land, G denotes grass land, F denotes forest cover, and A denotes arable land. UA refers to land use change from unused land to arable land, AF refers to land use change from arable land to forest cover, and so on.

5. Conclusions

This paper investigates the changes in ecosystem service value by using the GIS and dynamic simulation model of land use based on land use change in Miyun of Beijing, China, at four time points including 1991, 2006, 2021 and under an improved scenario. Some conclusions can be drawn, as follows:

(1) The total ecosystem service value of Miyun is about 2968.34 million Yuan in 1991, 3304.72 million Yuan in 2006, 3106.48 million Yuan in 2021, and 3759.77 million Yuan under the improved scenario. The ecosystem service value increases by 336.38 million due to the increase of forest area and the decrease of the unused area from 1991–2006. However, from 2006–2021, the total ecosystem service value decreases by 198.24 million Yuan due to the decrease of forest cover and the expansion of construction land. In contrast, due to the buffer strip construction of the drinking water source, vegetation restoration, and protection of water bodies, the total ecological service value increases by 455.05 (13.77%) from 2006 to under the improved scenario.

(2) In terms of ecosystem service function, water supply and soil formation and retention account for 19.99% and 14.58%, respectively, which are the largest proportions. However, food and recreation and culture account for only 1.83% and 5.99%, respectively, which are the least. The overall order for each ecosystem function based on their contributions can be ranked from high to low as follows: water supply, soil formation and retention, waste treatment, biodiversity protection, gas regulation, climate regulation, raw material, recreation and culture, and food.

(3) The total ecosystem service value is relatively inelastic. Coefficients of sensitivity for forest cover, water bodies and arable land are relatively larger, of which that for forest land is the highest due to the large area and the high ecosystem service value coefficient.

(4) The contribution factor of land use change during different periods mainly lies in the vegetation restoration from unused land or arable land to forest cover, especially land use change from arable land to forest cover, which has a high contribution rate of 95%.

6. Discussion

Miyun County is the only drinking water source of Beijing, China. It is meaningful to enhance ecosystem service value in response to land use change and conduct relevant research on ecosystem service value assessment, which can provide an important basis for sustainable land use and a feasible protection strategy for drinking water sources for decision-makers. However, according to current trends of land use, necessary measures should be taken to reduce the risk of ecosystem service value and improve the land use scenario. By constructing a buffer zone of drinking water sources, implementing vegetation restoration, and protection of water bodies, the ecosystem service value can be effectively improved by 455.05 million Yuan (13.77%).

The ecological service value coefficient of different land use types is dynamic and complicated, which not only relates to land use type, biodiversity and environment, but has a close relation with resource scarcity, regional conditions and so on [14,38–40]. Accurate assignment to regional ecological systems must be based on a long period of field investigations and long-term experiments. Meanwhile, it is necessary to accurately quantify the change in the regional ecological service value [23,41–44] in a monetary form.

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Author Contributions

Ping Zhang, Yunhui Liu and Zhenrong Yu conceived and designed the experiment. Ping Zhang, Liang He and Peishu Huo collected the data. Ping Zhang, Xin Fan and Tao Zhang analyzed the data. Liang He, Xin Fan and Ying Pan contributed materials/analysis tools. Ping Zhang wrote the paper, and Yunhui Liu revised the paper.

Conflicts of Interest

The authors declare no conflict of interest.

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