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A Study on the Rationality of Land Use Change in the Dianchi Basin during the Last 40 Years under the Background of Lake Revolution

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Abstract: (1) Background: Dianchi Lake is the largest freshwater plateau lake in southwest China. Since the 1970s, with the large-scale lake reclamation and rapid urbanization, the land use/cover of the Dianchi Basin has changed dramatically, directly hindering the sustainable development of the watershed. It is urgent to study the rationality of land use change in order to promote the "win-win" of eco-environment protection and sustainable economic and social development in Dianchi Basin. (2) Methods: The rationality judgment criteria of land use change in Dianchi Basin was constructed from ecological values, land suitability, laws and regulations, and the rationality of land use change in the Dianchi Basin from 1980 to 2020 was evaluated. (3) Results: The rational degree of land use change in the Dianchi Basin was 71.76%, and the level of rationality was low rationality. The rational degree of change in cultivated land, woodland, grassland, water area and construction land was 74.41%, 69.11%, 77.11%, 3.07% and 98.26%, respectively. Among the irrational land changes, 86.59% of the land had changed to construction land. (4) Conclusions: The main problems of irrational land change in the Dianchi Basin are the massive reduction in high-quality cultivated land, the degradation of woodland, and the unordered expansion of construction land. In order to achieve sustainable development, it is important to protect cultivated land, woodland, grassland and lakes.

Keywords: Lake Revolution; land use change; rationality; Dianchi Basin

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1. Introduction

Lakes are some of the most important types of land use/cover, and it they are also a priceless resource for human survival. The health of lake ecosystems is essential for the preservation of the integrity of the Earth's ecosystems and the long-term sustainable development of human society. In 1995, the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP) jointly launched the Scientific Research Programme on Land Use/Land Cover Change (LUCC). At the same time, Biospheric Aspects of Hydrological Cycle (BAHC) were taken as the main subject of global water resources planning [1,2]. Since then, the relationship between land use change and hydrological cycle has become a hot topic in the study of global environmental change. As an integral part of the hydrological cycle, the land use change of lakes has attracted widespread attention.

China is dotted with thousands of lakes and has a long history of lake development. Since the 1970s, under the influence of China's rapid urbanization and industrialization, human activities around the lake have increased dramatically. The land cover in the basin gradually changed from natural vegetation to agricultural land and urban land. Urban sewage, industrial sewage and agricultural non-point source pollution have caused great damage to the health of lake ecosystems and the ecological environment of basins. China's lake governance is facing enormous challenges [3]. Scholars in related fields at home and abroad have undertaken a great deal of research and achieved a lot of results. For example, a series of studies were conducted on the spatio-temporal changes of land use in lake basins [4–13] and their driving factors [14–19], the impacts of land use change in lake basins [20–29] and the dynamic monitoring of lake areas [30–33]. These studies have laid an important theoretical foundation for the study of lake land use. However, most of these studies focused on land use. The research on the rationality of land use change is very rare. For example, Yang Zisheng, Wang Bin, Feng Jianmin and others studied the rationality of land use change driven by the project of "Returning Farmland to Forest" [34–37], and Wen Jie analyzed the rationality of land use structure using the TOPSIS method [38].

Dianchi Lake is the largest freshwater plateau lake in southwest China and is known as the "Plateau Pearl". The Dianchi Basin is the political, economic, cultural and transportation center of the province with its advantageous natural conditions and long history of development. In the 1960s and 1970s, the large-scale land reclamation from lakes greatly changed the land use type of the Dianchi Basin. Since the 1980s, with the rapid progress of urbanization and industrialization, the population of the watershed has grown significantly. Various land development and utilization activities became more and more frequent, and the intensity of development and utilization greatly increased. These changes have brought increasing pressure to the ecological environment of the watershed. Dianchi Lake has changed from the "Plateau Pearl" and the "Mother Lake" of the people of Kunming to a "sewage pond". The ecological problems caused by Dianchi Lake pollution have become the focus of the world's attention. In order to eliminate pollution of the Dianchi Lake, build a healthy ecosystem and promote the sustainable development of the basin's society and economy, it is necessary to strengthen the scientific management of land use in the basin.

On 27 September 2021, the Government of Yunnan Province issued the "Implementation Opinions on the Lake Revolution". The government's determination to lake protection is unprecedented. Under such a new background, this paper attempts to organically combine lake ecological environment protection with the rationality evaluation of land use change for the first time, construct the rationality judgment criterion of land use change, and take Dianchi Lake as the research area to carry out the rationality study of land use change. It is of great theoretical value for further enriching the research of rationality evaluation of land use change. At the same time, it is of practical significance to effectively restore the ecological environment of Dianchi Lake, realize the sustainable utilization of land resources in mountainous areas and enhance sustainable economic and social development.

2. Materials and Methods

2.1. Study Area

As shown in Figure 1, the Dianchi Basin is located in the center of the Yunnan Plateau, between 102°29′~103°01′ E and 24°29′~25°28′ N. The lake covers an area of 309.5 km^2 and consists of Waihai and Caohai. The normal water level of Waihai is 1887.5 m and Caohai is 1886.8 m. The area of the watershed is 2920 km^2, including 52 sub-district offices and 2 towns in the Wuhua, Panlong, Guandu, Xishan, Chenggong and Jinning districts of Kunming, with a population of more than 4 million. The average annual rainfall in the basin is 953 mm. The Dianchi Basin belongs to the northern subtropical monsoon climate. The dry season is from November to April, which is mainly controlled by the tropical continental air mass with clear and little clouds, abundant sunshine, strong total radiation, large evaporation and a warm and dry climate. From May to October, it is mainly affected by the southwest monsoon and enters the rainy season, with more precipitation and higher humidity. These characteristics are combined with high altitude and low latitude to form a climate characterized by warm winters and cool summers. The topography of the Dianchi Basin is high in the north and low in the south. Generally, it presents an asymmetric step-like landform pattern with Dianchi Lake as the center, wide in the south, north and east, and narrow in the west. Its unique geographical location and superior natural conditions have made the Dianchi Basin the political, economic, cultural and transportation center of the province. The semi-enclosed lake shape makes the water ecological environment of

Dianchi Lake very fragile, which cannot withstand the increasing population pressure and intensive land use. After suffering from environmental pollution and ecological damage, it is difficult to restore.

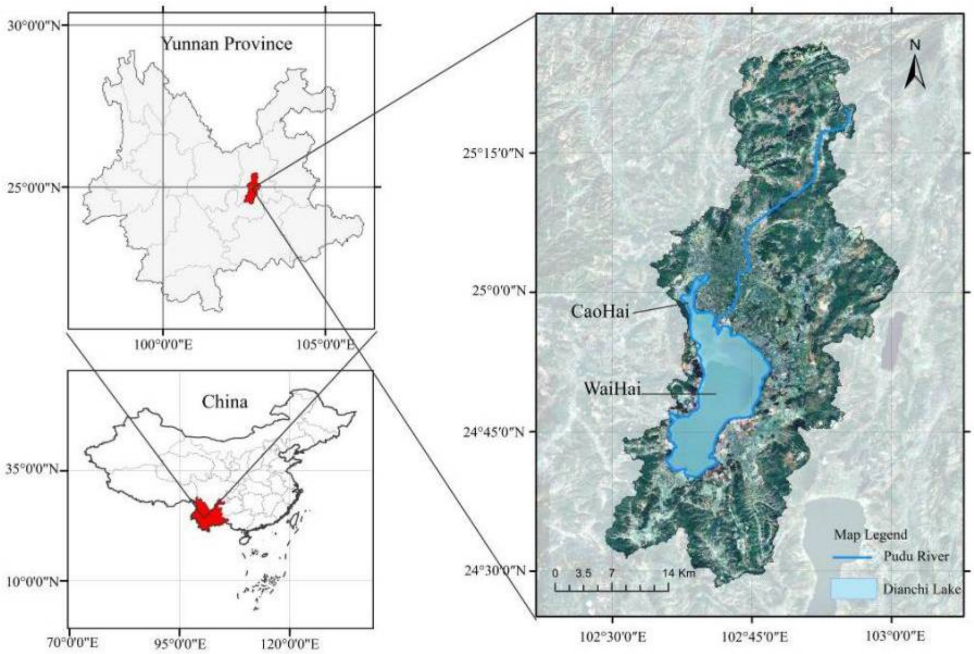

Figure 1. Location of Dianchi Lake.

As shown in Figure 2, a series of irrational land use activities in Dianchi Basin have brought about the problems of lake shrinkage, wetland disappearance and soil erosion and so on. For a long time, the irrational development and utilization of land has led to the continuous deterioration of the ecological environment of Dianchi Lake, and the ecosystem has been seriously damaged, which in turn has affected the long-term sustainable development of the economy. The obstructed economic development will prompt land developers to intensify land development and eventually form a vicious circle that impedes the sustainable development of the Dianchi Basin.

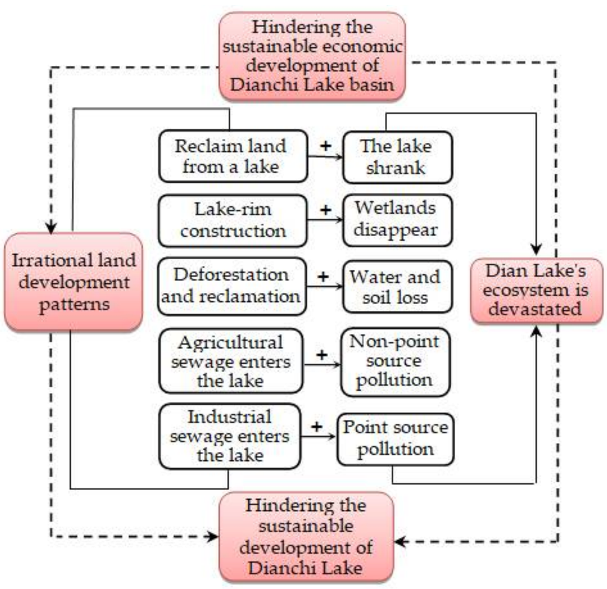

Figure 2. The vicious circle of irrational land use patterns in the Dianchi Basin.

However, it is not enough to know that the land use problems have led to ecological degradation and unsustainable development. What is the current extent of irrational land use changes in the Dianchi Basin? Are land changes causing serious ecological problems? How urgent is the scientific management and protection of the lake? Obviously, we cannot answer that. In this case, in order to clarify whether the land use change in the Dianchi Basin is rational and to what extent, and thus to find out the crux of the deterioration of the lake ecological environment, it is necessary to study the rationality of land use change in the Dianchi Basin.

2.2. Data Sources and Land Use Classification

Based on the land use classification data of the Dianchi Basin in 1980, 1990, 2000, 2010 and 2020, the rational degree of land use changes in the four periods of 1980–1990, 1990–2000, 2000–2010 and 2010–2020 was evaluated, respectively. The land use datasets were obtained from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (http://www.resdc.cn/, accessed on 14 June 2022). The raster data of 30 m spatial resolution digital elevation model image (DEM) were downloaded from the Geospatial Data Cloud website (http://www.gscloud.cn/, accessed on 18 March 2022). The raster data of soil type, soil organic carbon content in the topsoil 30 cm (T-OC), soil organic carbon content in the subsoil 100 cm (S-OC), soil pH in the topsoil 30 cm (T-pH) and soil pH in the subsoil 100 cm (S-pH) were all taken from the Harmonized World Soil Database (HWSD) [39], and the spatial resolution was 1 km. The spatial data of soil thickness were compiled from the soil profile data collected by the second Soil Survey of China, and the spatial resolution was 30 m. They are available on the Geographic Remote Sensing Ecological Network Platform (www.gisrs.cn, accessed on 9 July 2022).

Referring to the Multi-period Remote Sensing Monitoring Data Classification System of Land Use/Land Cover in China [40] and the Current land Use Classification of China (GB/T 21010-2017) [41], the land types in the study area were classified into 5 first-level categories and 15 second-level categories. The codes and names of the 5 first-level categories are 1—cultivated land, 2—woodland, 3—grassland, 4—water area, 5—construction land. Moreover, the 15 second-level categories are 11—paddy field, 12—dry land, 21—forest land, 22—shrub land, 23—open forest land, 24—other forest land, 31—high coverage grassland, 32—medium coverage grassland, 33—low coverage grassland, 42—lake, 43—reservoir and pond, 46—tidal flat, 51—urban land, 52—rural residential land, 53—other construction land. The classification accuracy of cultivated land, urban land and rural residential land was greater than 95% and the classification accuracy of other land categories was greater than 90%, which met the research needs.

2.3. Data Processing

In ArcGIS 10.2, the datasets were unified into the WGS1984 coordinate system using the tool of "data management tool-projection and transformation". "Spatial analysis tool-Surface analysis tool" was used to analyze DEM images to obtain slope data. By operating DEM images with "hydrological analysis tools", the boundary of the watershed was extracted. Then the land use classification data, slope data, altitude data, soil type data, soil thickness data, soil organic carbon content data and soil pH data were cut. By using the "intersect analysis" tool in ArcGIS, we obtained four land use change transfer layers. The changed land plots were taken as the unit of rationality evaluation. The data of slope, altitude, soil type, soil thickness, soil organic carbon content and soil pH were added to each changed land plot, which was used as the basis for the rationality judgment of land use change. The spatial data of altitude, slope, soil type, soil thickness, soil organic carbon content and soil pH of Dianchi watershed are shown in Figure 3.

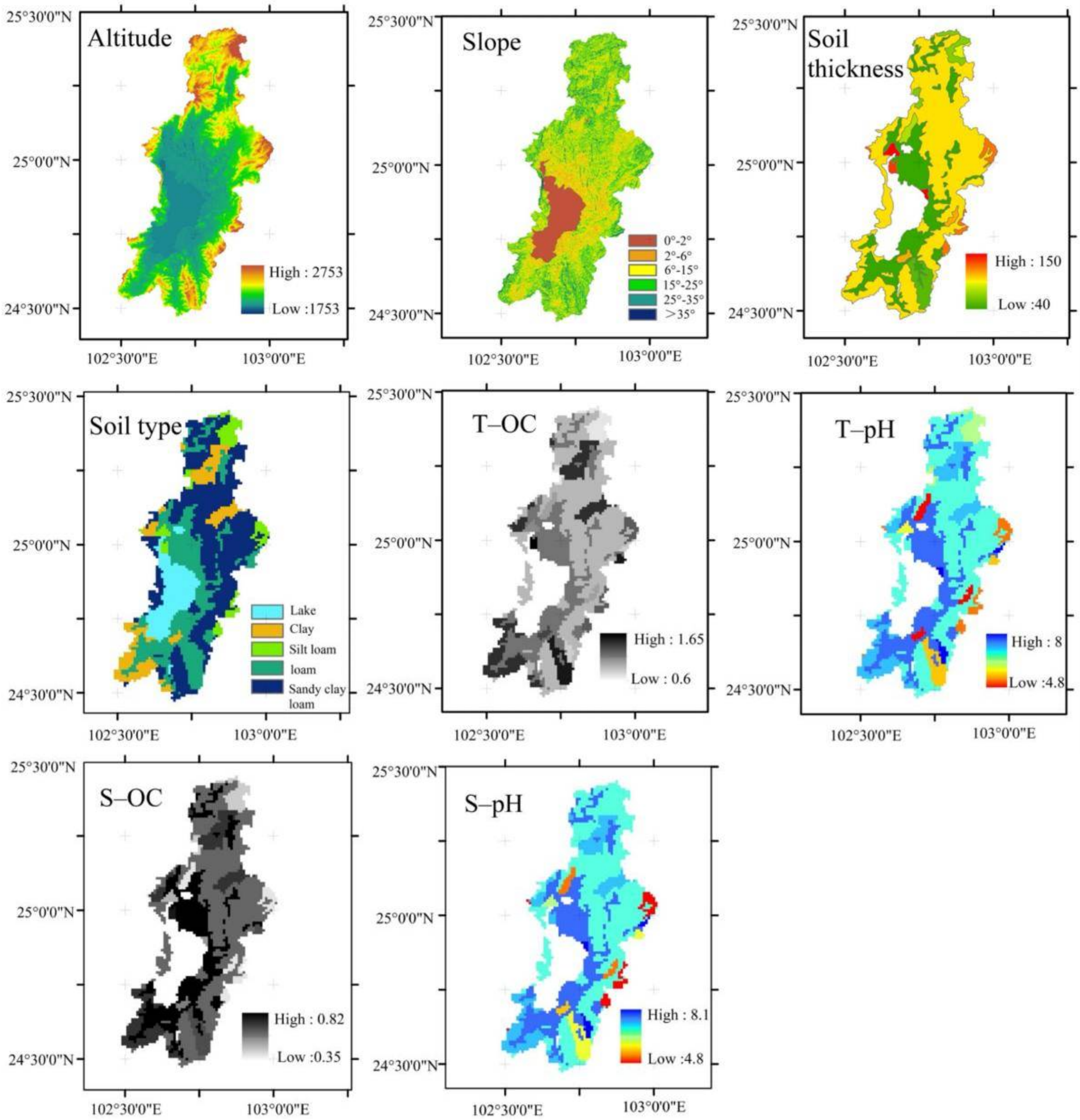

Figure 3. The spatial data of altitude, slope, soil type, soil thickness, soil organic carbon content and soil pH of the Dianchi Basin.

2.4. Rationality Evaluation Method of Land Use Change

2.4.1. Concept of Rationality of Land Use Change

The rational degree of land use change in this study refers to the concept proposed by Yang Zisheng [34]. It is equal to the proportion of rational land use change area to total change area in the study area. This paper first makes a scientific judgment on whether the land use change is rational, and then calculates the rational degree of the land use change in the study area. "Whether the land use change is rational" is for a specific plot of land, and "the rational degree of land use change" is for a certain study area. The detailed evaluation process is shown in Figure 4.

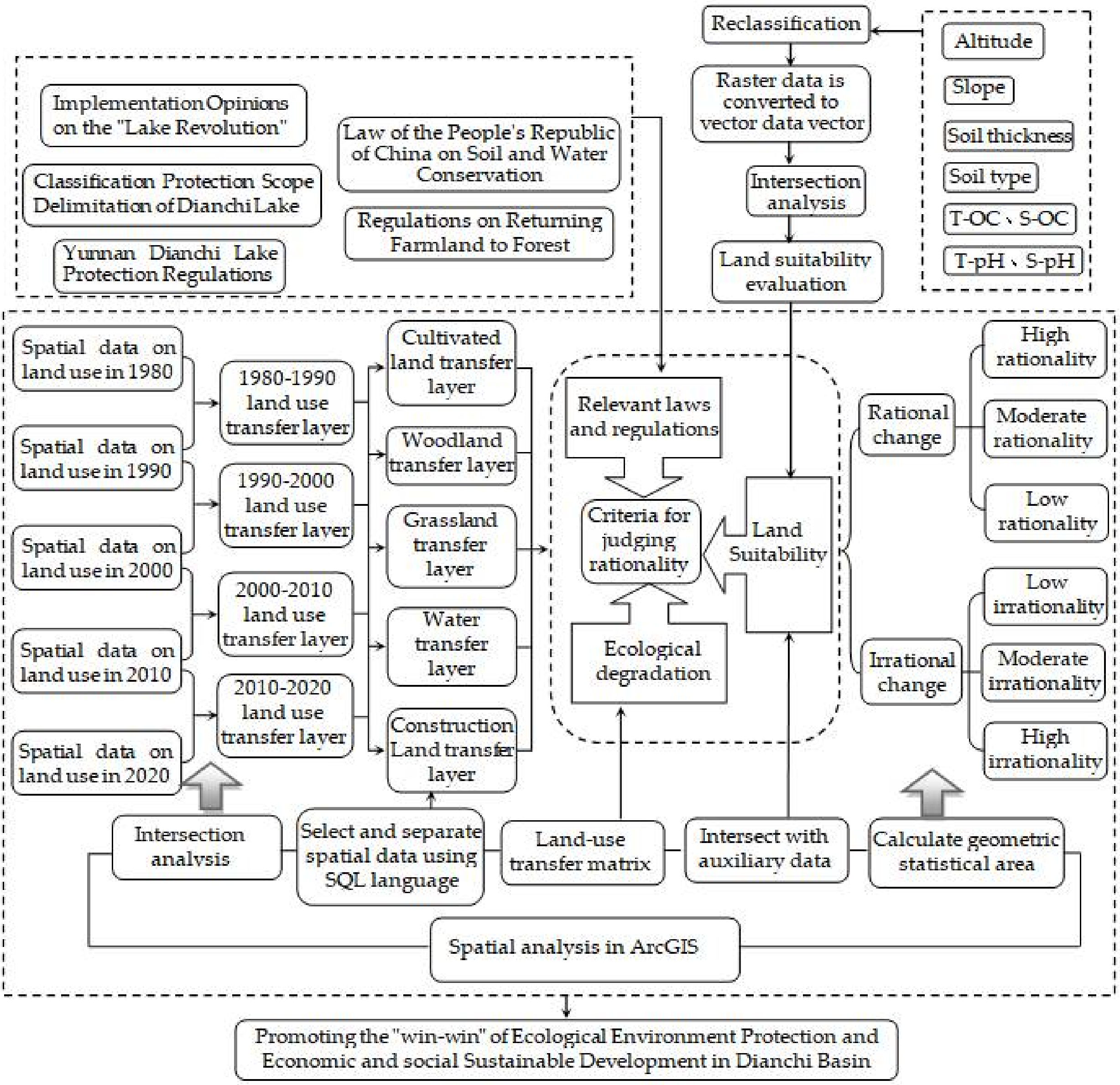

Figure 4. Technical roadmap for the rationality evaluation of land use change.

2.4.2. Establish Criteria for Judging the Rationality of Land Use Change

To calculate the rational degree of land use change, the rationality judgment criterion of land use change must first be established. Then we can count how much land has changed rationally and how much has changed irrationally. This section will describe which land use changes were rational and which were not. See Figure 5 for details.

The land use changes corresponding to the green grids in Figure 5 mainly take the ecological value as the basis of rationality judgment. The order of ecological value from small to large is 33—low coverage grassland, 32—medium coverage grassland, 31—high coverage grassland, 22—shrub land, 24—other forest land, 23—open forest land, 21—forest land. It is considered irrational to change from a land type with a high ecological value to a land type with a low ecological value, while it is rational on the contrary. According to the requirements of the Lake Revolution, the changes from other land types to lakes are conducive to the protection of lake ecology, which is regarded as rational.

	1	21	22	23	24	31	32	33	42	43	46	5
1		Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y	Y/N	Y/N	Y/N
21	N		N	N	N	N	N	N	Y	Y/N	Y/N	Y/N
22	Y/N	Y		Y	Y	N	N	N	Y	Y/N	Y/N	Y/N
23	Y/N	Y	N		N	N	N	N	Y	Y/N	Y/N	Y/N
24	Y/N	Y	N	Y		N	N	N	Y	Y/N	Y/N	Y/N
31	Y/N	Y	Y	Y	Y		N	N	Y	Y/N	Y/N	Y/N
32	Y/N	Y	Y	Y	Y	Y		N	Y	Y/N	Y/N	Y/N
33	Y/N	Y	Y	Y	Y	Y	Y		Y	Y/N	Y/N	Y/N
42	N	N	N	N	N	N	N	N				Y/N
43	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N				Y/N
46	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N				Y/N
5	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y	Y	Y	

Figure 5. Rationality judgment matrix of land use change. The number in the first column is the code of land use type before the change, and the number in the first row is the code of land type after the change. The code and name are 1—cultivated land, 21—forest land, 22—shrub land, 23—open forest land, 24—other forest land, 31—high coverage grassland, 32—medium coverage grassland, 33—low coverage grassland, 42—lake, 43—reservoir and pond, 46—tidal flat, 5—construction land. Each grid represents a type of land use change. The alphabetic "Y" in the grid means that the land use change is rational and the alphabetic "N" in the grid means that the land use change is irrational. "Y/N" means that evaluators need to comprehensively judge the rationality of changes by combining land use suitability, relevant national laws and regulations. Blank grids indicate no change, so they were not included in the rationality evaluation of land use change.

The rationality judgment of land use change corresponding to the blue grid in Figure 5 is relatively complex. It is mainly based on land use suitability and relevant national laws and regulations. Land suitability is evaluated by the limiting factor evaluation method based on the Cannikin Law. In the case of cultivated land, as long as one of the seven limit factors is satisfied, it is not suitable as a cultivated land. In other words, if the slope of a piece of land is greater than 25°, even if it has good condition in other aspects, we still consider that it is not suitable for farming unless there are very good soil and water conservation measures. Therefore, "slope > 25°" is one of the limits of suitable cultivated land, indicating that it is unsuitable for farming. See Table 1 for details. The slope limit was delineated according to the Regulations on Returning farmland to Forest and the Law of the People's Republic of China on Soil and Water Conservation. The altitude limit was divided in light of the actual situation of the Dianchi Basin. Soil type limit, thickness limit, pH limit were designated according to the usage instructions of Harmonized World Soil Database. When one land type changed to another, the suitability evaluation was carried out. If the evaluation result of the changed land is suitable, it shows that the land use change is rational. If the evaluation result of the changed land is unsuitable, it shows that the change is irrational.

Table 1. Main limit factors of suitable cultivated land, suitable woodland and suitable grassland in the Dianchi Basin.

Limit Factors	Cultivated Land	Woodland Land	Grassland
Slope limit	>25°	>35°	>35°
Altitude limit	>3000 m	>3000 m	>3000 m
Water limit	Severe drought and water shortage	Severe drought and water shortage	Severe drought and water shortage
Soil thickness limit	<40 cm	<20 cm	<10 cm
Soil type limit	Clay (heavy), sandy soil, silt (heavy), Gravel soil	Clay (heavy), sandy soil, Gravel soil	Clay (heavy), sandy soil, Gravel soil
T-OC/S-OC limit	T-OC < 0.6%	S-OC < 0.2%	T-OC < 0.2%
T-pH/S-pH limit	T-pH < 4.5 or T-pH > 8.5	S-pH < 4.5 or S-pH > 8.5	T-pH < 4.5 or T-pH > 8.5

The red grids in Figure 5 require special illustrations. The rationality judgment of the change from 1—cultivated land to 21—forest land is based on land suitability, but the change from 21—forest land to 1—cultivated land was regarded as irrational in this study. This is because deforestation and reclamation will further reduce the forest coverage rate in the Dianchi Basin, which will reduce the self-healing ability of the ecological environment of the Dianchi Lake. In addition to complying with land suitability, the change of construction land should conform to the regulations of Yunnan Dianchi Lake Protection Regulations and Classification Protection Scope Delimitation of Dianchi Lake. The changes that violate these two guidelines are irrational.

2.4.3. Quantitative Calculation Method of Rational Degree of Land Use Change

According to the concept of rational degree of land use change, the quantitative calculation formula of rational degree can be simply expressed by Formula (1).

$$\text{Rational degree of land use change} = \text{Land area with rational change}/\text{Total area of land use change} \times 100\% \quad (1)$$

After calculating the rational degree of land use change, we also graded the rationality of land use change in the Dianchi Basin. As shown in Table 2, level I means that the land use change is very rational. In this case, food security, ecological security and economic development are highly harmonized. Level II means that land use change is moderately rational, and has a small negative impact on ecological security, food security, economic development or some aspect of them, but the impact is not serious. Level III means that land use change is low rational, and has a large negative impact on ecological security, food security and economic development. It is necessary to find out the causes of the irrational land use change and control the change effectively. Level IV means that land use change is low irrational, which brings great difficulties to ensure ecological security, food security and sustainable economic development. Level V means that land use change is moderately irrational, and the irrational proportion of land use change exceeds the rational proportion, which brings serious problems of ecological security, food security and sustainable economic development. Level VI means that land use change is highly irrational, the ecological environment is seriously damaged, food security is seriously threatened and economic and social development is very unsustainable.

Table 2. Level of rationality.

Rational Level	Rational Degree
High rationality (I)	≥90%
Moderate rationality (II)	≥80% and <90%
Low rationality (III)	≥65% and <80%
Low irrationality (IV)	≥50% and <65%
Moderate irrationality (V)	≥25% and <50%
High irrationality (VI)	<25%

3. Results

3.1. Land Use Change in Dianchi Basin

Table 3 shows the change of the land use structure of the Dianchi Basin from 1980 to 2020. Over the past 40 years, great changes have taken place in the land use structure of the Dianchi Basin, with a sharp decrease in cultivated land and a rapid increase in construction land. In 1980, the ratio structure of cultivated land, woodland, grassland, water area and construction land was 1:1.39:0.70:0.49:0.54, and the land types in the basin were mainly cultivated land and woodland. By 2020, the ratio structure of cultivated land, woodland, grassland, water area and construction land was 1:1.89:0.86:0.69:1.36. The main land types in the basin were transformed into woodland, construction land and cultivated land.

Table 3. Land use structure of the Dianchi Basin from 1980 to 2020.

Land Type	1980		1990		2000		2010		2020		1980–2020	
	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)
Paddy field	382.01	13.79	364.69	13.16	329.09	11.88	282.10	10.18	228.35	8.24	153.65	5.55
Dry land	291.05	10.50	289.40	10.45	277.97	10.03	271.95	9.82	249.65	9.01	41.39	1.49
Forest land	184.87	6.67	184.45	6.66	185.36	6.69	185.84	6.71	188.48	6.80	−3.61	−0.13
Shrub land	492.93	17.79	493.74	17.82	493.77	17.82	491.37	17.73	460.44	16.62	32.49	1.17
Open forest land	247.31	8.93	246.64	8.90	245.09	8.85	247.61	8.94	244.93	8.84	2.37	0.09
Other forest land	7.31	0.26	7.38	0.27	7.38	0.27	9.99	0.36	8.96	0.32	−1.65	−0.06
High coverage grassland	285.76	10.31	286.58	10.34	284.76	10.28	278.32	10.05	260.39	9.40	25.37	0.92
Medium coverage grassland	183.68	6.63	183.74	6.63	182.08	6.57	170.03	6.14	149.72	5.40	33.96	1.23
Low coverage grassland	0.32	0.01	0.32	0.01	0.32	0.01	0.32	0.01	0.32	0.01	0.00	0.00
Lake	307.82	11.11	310.55	11.21	310.67	11.21	310.72	11.21	306.06	11.05	1.76	0.06
Reservoirs and ponds	19.54	0.71	20.72	0.75	20.61	0.74	19.94	0.72	19.58	0.71	−0.04	0.00
Tidal flat	2.61	0.09	4.69	0.17	4.71	0.17	4.71	0.17	2.69	0.10	−0.08	0.00
Urban land	199.96	7.22	210.22	7.59	258.02	9.31	320.24	11.56	448.00	16.17	−248.04	−8.95
Rural residential land	65.67	2.37	66.72	2.41	68.15	2.46	64.52	2.33	64.35	2.32	1.32	0.05
Other construction land	99.87	3.60	100.85	3.64	102.71	3.71	113.04	4.08	138.77	5.01	−38.90	−1.40

Figure 6 shows the spatio-temporal changes of land use in the Dianchi Basin from 1980 to 2020. The changes in woodland, grassland and water area are not obvious. The most obvious change is that the construction land around the Dianchi Lake has increased and gradually spread from north to east. In 1980, the construction land in the north of Dianchi Lake was relatively dispersed, but it was entirely covered by construction land by 2020. From the change of land use in space, it can be learned that the newly increased construction land in Dianchi Basin has occupied a large amount of cultivated land in the upper reaches of Dianchi Basin. Although the rapid increase in construction land has brought huge economic benefits to the Dianchi Basin, it has also posed huge risks to food security and ecological security. The fact that the water quality of Dianchi Lake continues to decline and the ecological environment is getting worse and worse proves to us that the high-intensity land development around Dianchi Lake has seriously exceeded the environmental carrying capacity of Dianchi Lake.

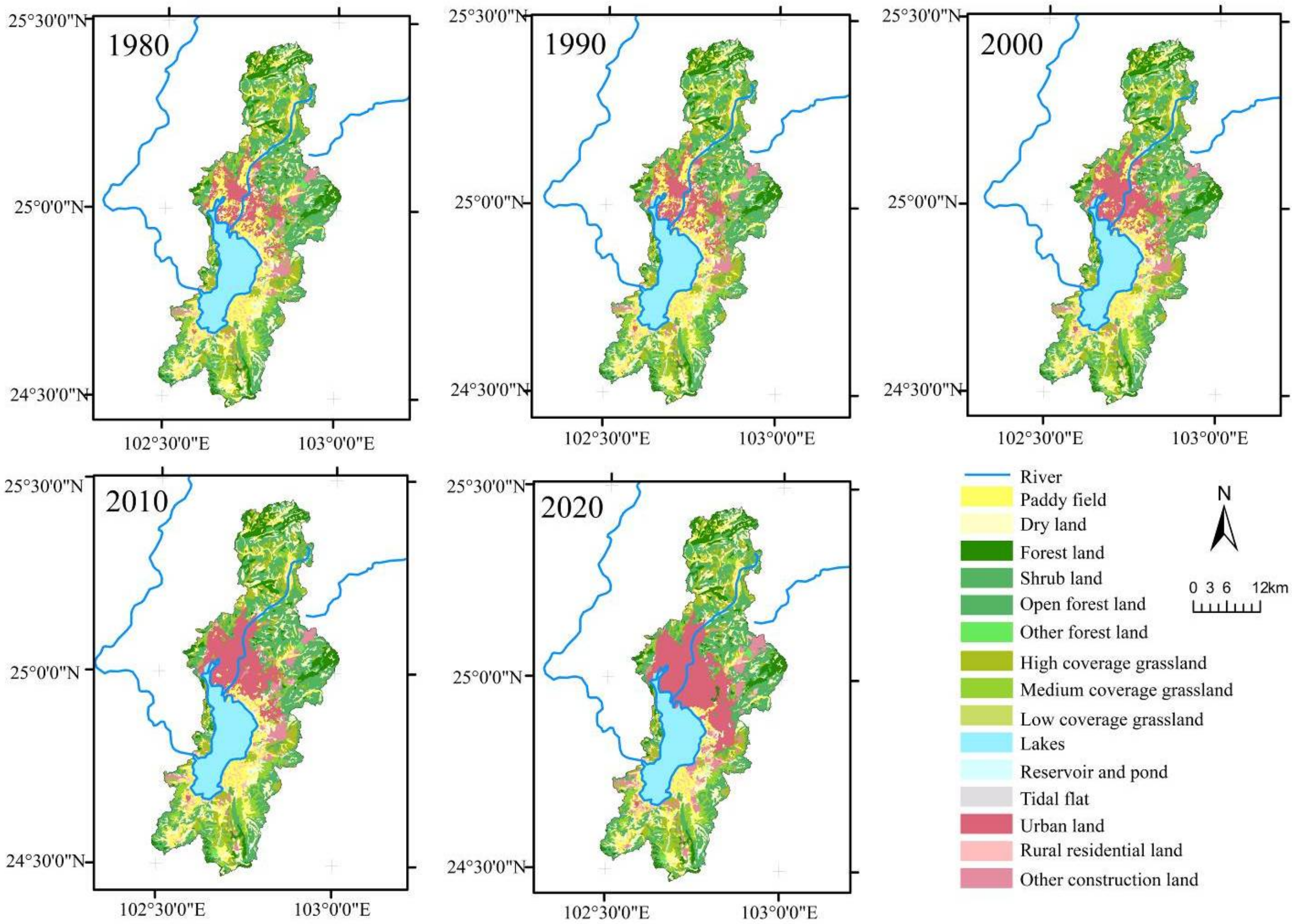

Figure 6. Spatial-temporal change of land use in Dianchi Basin from 1980 to 2020.

3.2. Rtionality of Land Use Change of Each Land Type

3.2.1. Rationality of Cultivated Land Change

It can be found in Table 4 that the rational degree of the change from cultivated land to woodland, grassland and water area in Dianchi Basin in the last 40 years was 58.13%, and the rational level was III. It is not hard to find that whether it was a paddy field or dry land; the rational degree of returning farmland to forest land and grassland was very low. Particularly in the first decade of implementation of "Returning Farmland to Forest", namely from 2000 to 2010, the rational degree went to the lowest level. This indicates that the implementation effect of the policy of "Returning Farmland to Forest" was very bad in the Dianchi Basin. As shown in column 14 of Table 4, the rational degree of the change from paddy field and dry land to construction land was relatively high. However, the land area of irrational change is also huge. The occupied cultivated land is distributed around the Dianchi Lake Nature Reserve. The irrational change has caused a great threat to the ecological security of the Dianchi Basin. It is worth noting that this study also calculated the proportion of suitable cultivated land changing to construction land. It can be found in Table 5 that a large amount of cultivated land with slopes below 25° and good soil conditions has been developed as construction land. In other words, the change of cultivated land has not only brought great pressure to the improvement of the ecological environment in the Dianchi Basin, but it has also made it difficult to maintain the bottom line and red line of cultivated land in Yunnan Province.

Table 4. Rational degree of cultivated land change.

		Change to Cultivated Land, Woodland, Grassland and Water Area					Change to Construction Land				Total Rationality			
Period	**Land Type**	**Changing Area (km²)**	**Rational Area (km²)**	**Irrational Area (km²)**	**Rational Degree (%)**	**Rational Level**	**Rational Area (km²)**	**Irrational Area (km²)**	**Rational Degree (%)**	**Rational Level**	**Rational Area (km²)**	**Irrational Area (km²)**	**Rational Degree (%)**	**Rational Level**
1980–1990	Paddy field	17.30	7.02	0.45	93.97	I	7.10	2.73	72.25	III	14.12	3.18	81.63	II
	Dry land	2.77	0.23	0.35	40.00	V	1.76	0.43	80.34	II	2.00	0.78	71.95	III
1990–2000	Paddy field	36.39	0.26	0.10	71.77	III	25.82	10.20	71.67	III	26.08	10.31	71.67	III
	Dry land	11.47	0.14	0.45	23.47	VI	9.40	1.48	86.36	II	9.54	1.93	83.17	II
2000–2010	Paddy field	47.01	0.19	1.34	12.26	VI	40.28	5.20	88.57	II	40.46	6.54	86.08	II
	Dry land	7.47	0.13	2.54	4.90	VI	4.56	0.24	95.10	I	4.70	2.77	62.88	IV
2010–2020	Paddy field	53.72	0.10	0.05	66.24	III	38.17	15.40	71.26	III	38.27	15.45	71.24	III
	Dry land	23.27	0.17	0.66	20.64	VI	13.03	9.41	58.07	IV	13.20	10.07	56.73	IV
	Total	199.39	8.24	5.94	58.13	IV	140.12	45.09	75.66	III	148.37	51.02	74.41	III

Table 5. Cultivated land changed to construction land from 1980 to 2020.

	1980–1990		1990–2000		2000–2010		2010–2020		Total	
	Area (km²)	**Proportion (%)**	**Area (km²)**	**Proportion (%)**	**Area (km²)**	**Proportion (%)**	**Area (km²)**	**Proportion (%)**	**Area (km²)**	**Proportion (%)**
Suitable paddy field changed to construction land	9.60	97.64	34.29	95.19	43.20	95.01	52.68	98.34	139.77	96.46
Unsuitable paddy field changed to construction land	0.23	2.36	1.73	4.81	2.27	4.99	0.89	1.66	5.13	3.54
Suitable dry land changed to construction land	2.13	96.82	10.33	94.92	4.17	86.97	21.40	95.37	38.03	94.33
Unsuitable dry land changed to construction land	0.07	3.18	0.55	5.08	0.63	13.03	1.04	4.63	2.29	5.67

3.2.2. Rationality of Woodland Change

The rational degree of woodland change was 69.11%; the level of rationality was III. In this paper, the rational degree of woodland change was divided into two parts, which are shown in the sixth and fourteenth columns of Table 6. In this way, the degree of woodland degradation can be figured out and the impact of construction land expansion on woodland can also be known.

From 1980 to 2020, although the change from woodland to cultivated land, woodland, grassland and water was small, it caused serious ecological problems that cannot be ignored. The changes from forest land to open forest land, shrub land and grassland were due to ecological degradation, which has made the watershed's ecological environment more fragile. At the same time, the change from woodland to steep dry land has exacerbated the soil erosion. The combination of the two has seriously damaged the stability of the Dianchi Lake ecosystem. In addition, in the past 10 years, the rational degree of the changes from open forest land and other forest land to construction land has dropped sharply, and even some land plots were located in the Dianchi Lake Nature Reserve. Although the ecological value of open forest land and other forest land is not as high as that of forest land, it can achieve the same ecological protection effect as forest land with a little improvement. However, they have changed to construction land, which is a great loss to the ecological protection of the Dianchi Basin. From the changes of woodland, we can find that the expansion of construction land has reached a very terrible stage. The disappearance of cultivated land can no longer meet the demand for the expansion of construction land. Woodland is also facing the threat of construction land expansion, even in the Dianchi Lake Nature Reserve.

3.2.3. Rationality of Grassland Change

It can be found in Table 7 that the changes in grassland mainly occurred between 1990 and 2020, and the grassland with high coverage and medium coverage changed greatly. The rational degree of grassland with high coverage decreased remarkably and the rational degree of grassland with medium coverage gradually increased. High coverage grassland can play a positive role in soil and water conservation in the Dianchi Basin, but its rational degree has dropped from 99.68% to 62.60%. It is very detrimental to the ecological environment of Dianchi Lake. Different from the high-coverage grassland, the changes of medium coverage grassland are gratifying. Most of them have changed rationally. For example, some of them changed to cultivated land to maintain food security. Some of them changed to construction land to ensure economic development. Others changed to woodland to enhance the self-healing ability of the ecosystem. All in all, the change of the medium coverage grassland is encouraging.

Table 6. Rational degree of woodland change.

		Change to Cultivated Land, Woodland, Grassland and Water Area					Change to Construction Land				Total Rationality			
Period	**Land Type**	**Changing Area (km^2)**	**Rational Area (km^2)**	**Irrational Area (km^2)**	**Rational Degree (%)**	**Rational Level**	**Rational Area (km^2)**	**Irrational Area (km^2)**	**Rational Degree (%)**	**Rational Level**	**Rational Area (km^2)**	**Irrational Area (km^2)**	**Rational Degree (%)**	**Rational Level**
1980–1990	Forest land	1.71	0.00	1.50	0.00	VI	0.21	0.00	100.00	I	0.21	1.50	12.37	VI
	Shrub land	0.00	0.00	0.00	/	/	0.00	0.00	/	/	0.00	0.00	/	/
	Open forest land	1.68	1.39	0.27	83.92	II	0.02	0.00	100.00	I	1.41	0.27	84.12	II
	Other forest land	0.00	0.00	0.00	/	/	0.00	0.00	/	/	0.00	0.00	/	/
1990–2000	Forest land	0.20	0.00	0.19	0.00	VI	0.00	0.01	0.00	VI	0.00	0.20	0.00	VI
	Shrub land	2.47	0.38	0.56	40.26	V	1.21	0.33	78.58	III	1.58	0.89	64.07	IV
	Open forest land	1.91	0.48	1.14	29.66	V	0.28	0.00	100.00	I	0.76	1.14	40.11	V
	Other forest land	0.00	0.00	0.00	/	/	0.00	0.00	/	/	0.00	0.00	/	/
2000–2010	Forest land	0.00	0.00	0.00	/	/	0.00	0.00	/	/	0.00	0.00	/	/
	Shrub land	3.11	0.21	0.02	92.54	I	1.30	1.59	45.10	V	1.51	1.60	48.51	V
	Open forest land	0.10	0.00	0.02	0.00	VI	0.08	0.00	100.00	I	0.08	0.02	82.03	II
	Other forest land	0.00	0.00	0.00	/	/	0.00	0.00	/	/	0.00	0.00	/	/
2010–2020	Forest land	2.01	0.07	1.16	5.47	VI	0.78	0.00	100.00	I	0.84	1.16	42.08	V
	Shrub land	31.54	5.02	0.38	92.88	I	20.25	5.88	77.50	III	25.27	6.27	80.13	II
	Open forest land	2.72	0.38	0.03	91.54	I	0.97	1.34	41.82	V	1.34	1.38	49.33	V
	Other forest land	1.07	0.00	0.00	/	VI	0.50	0.57	47.12	V	0.50	0.57	47.12	V
	Total	48.50	7.92	5.27	60.03	IV	25.60	9.71	72.50	III	33.52	14.98	69.11	III

Table 7. Rational degree of grassland change.

Period	Land Type	Changing Area (km^2)	Rational Area (km^2)	Irrational Area (km^2)	Rational Degree (%)	Rational Level
1980–1990	High coverage grassland	0.00	0.00	0.00	/	/
	Medium coverage grassland	0.00	0.00	0.00	/	/
	Low coverage grassland	0.00	0.00	0.00	/	/
1990–2000	High coverage grassland	2.66	2.65	0.01	99.68	I
	Medium coverage grassland	1.85	1.13	0.72	61.26	IV
	Low coverage grassland	0.00	0.00	0.00	/	/
2000–2010	High coverage grassland	7.96	5.59	2.37	70.25	III
	Medium coverage grassland	12.26	10.24	2.02	83.51	II
	Low coverage grassland	0.00	0.00	0.00	/	/
2010–2020	High coverage grassland	20.01	12.53	7.48	62.60	IV
	Medium coverage grassland	20.40	18.09	2.31	88.66	II
	Low coverage grassland	0.00	0.00	0.00	/	/
	Total	65.14	50.23	14.91	77.11	III

3.2.4. Rationality of Water and Construction Land Change

As shown in Table 8, the changes of lakes mainly occurred in 1980–1990 and 2010–2020. This is closely related to the lake reclamation in 1980–1990 and the rapid expansion of construction land in 2010–2020. Even though the lake area of irrational change is very small, it only accounts for 0.3% of the total area of Dianchi Lake. However, it is in this destruction that Dianchi Lake gradually changed from "Plateau Pearl" to "sewage pond". The shrinking of the lake should be given high attention.

Table 8. Rational degree of lake, reservoir and pond, tidal flat and construction land.

Period	Land Type	Changing Area (km^2)	Rational Area (km^2)	Irrational Area (km^2)	Rational Degree (%)	Rational Level
1980–1990	Lake	1.05	0.03	1.02	2.97	VI
	Reservoir and pond	0.15	0.15	0.00	100.00	I
	Tidal flat	0.00	0.00	0.00	/	/
	Construction land	0.00	0.00	0.00	/	/
1990–2000	Lake	0.00	0.00	0.00	/	/
	Reservoir and pond	0.31	0.00	0.31	0.00	VI
	Tidal flat	0.00	0.00	0.00	/	/
	Construction land	0.00	0.00	0.00	/	I
2000–2010	Lake	0.00	0.00	0.00	/	/
	Reservoir and pond	0.73	0.00	0.73	0.00	VI
	Tidal flat	0.00	0.00	0.00	/	/
	Construction land	0.00	0.00	0.00	/	I
2010–2020	Lake	5.12	0.17	4.95	3.25	VI
	Reservoir and pond	2.53	0.00	2.53	0.00	VI
	Tidal flat	1.52	0.01	1.51	0.42	VI
	Construction land	1.31	1.29	0.02	98.26	I
Total	Water	11.40	0.35	11.05	3.07	VI
	Construction land	1.32	1.29	0.02	98.27	I

The changes in the reservoirs and ponds are extremely irrational. The study found that most of the landfilled reservoirs and ponds in the Dianchi Basin are inextricably linked to the Dianchi ecosystem. They are distributed around the Dianchi Lake and play an important role in the virtuous cycle of the water ecosystem. Unfortunately, they have changed to construction land. The harm to the sustainable development of the Dianchi Basin is double.

Since the 1970s, the reclamation of tidal flat has been gradually banned, so the tidal flat in Dianchi Basin has not changed significantly from 1980 to 2010. However, from Table 8, we can find that the change of tidal flat in recent 10 years is very irrational. The changed tidal flats are distributed around the Caohai, and some are even close to the shoreline of Dianchi Lake. Such changes are obviously irrational. There are two reasons: First, tidal flat is located between the normal water level and the flood level, so building and producing on tidal flat will increase the risk of flooding. Second, the reclamation of the tidal flat will lead to the disappearance of wetland, which will aggravate the degradation of the ecological environment of Dianchi Lake.

The change of construction land is rational and mainly happened in the last 10 years. It can be found that most of the construction land has been reclaimed into high-quality cultivated land, woodland, grassland and water area. Only a very small part of them changed irrationally. Even so, compared with the conversion of a large amount of suitable cultivated land, suitable forest land and suitable grassland to construction land, the change of construction land is only a drop in the bucket.

3.3. The Rationality Analysis of the Land Use Change of Whole Region

Table 9 shows the total rational degree of land use change in the Dianchi Basin over the past 40 years. From the perspective of the whole watershed, the rational degree of land use change in Dianchi Basin shows a trend of first rising and then falling, and the level of rationality is low. However, rational degree is not enough to explain the rationality of land use changes in the Dianchi Basin. As can be found in Table 9, although the rational degree of land use change in the Dianchi Basin in the first 30 years was rising, the area of irrational change was also rising. It means that the reason for the increasing rational degree is that the land with rational change increases faster than the land with irrational change, rather than that the land with irrational change has decreased. From 2010 to 2020, the land area of irrational change in the Dianchi Basin was very large, up to 53.70 km^2, even more than the sum area of the irrational change in the previous 30 years, and the rational degree was lower than 70% for the first time in 40 years. Land use changes in Dianchi Basin are developing in an increasingly irrational direction, which will undoubtedly bring great difficulties to ecological protection and restoration of Dianchi Lake.

Table 9. Total rational degree of land use change in the Dianchi Basin.

Period	Rational Area (km^2)	Irrational Area (km^2)	Irrationally Changed to Construction Land (km^2)	Rational Degree (%)	Rational Level
1980–1990	17.92	6.74	3.16	72.68	III
1990–2000	41.74	15.50	13.05	72.92	III
2000–2010	62.58	16.05	12.06	79.59	III
2010–2020	111.51	53.70	51.37	67.49	III
Total	233.76	91.99	79.65	71.76	III

As a large amount of land in Dianchi Basin has changed to construction land, this study also counted the total area of the land that irrationally changed to construction land. It is displayed in the fourth column of Table 9. The results fully prove that the irrational changes brought by the rapid expansion of construction land in Dianchi Basin are the main reason for the continuous deterioration of the ecological environment in the past 40 years. If we turn a blind eye to this and allow the construction land to expand, the ecological environment of Dianchi Lake will be even worse.

4. Discussion

The rationality of land use change directly affects the sustainability of economic and social development. The painful lessons of the past have taught us that it is not feasible to follow the old way of first polluting and then treating. This study scientifically evaluated the rational degree of land use change in the Dianchi Basin in the past 40 years. The results showed that the rational degree of land use change in Dianchi Basin was 71.76%, which is low rationality. The large reduction in high-quality cultivated land, the ecological degradation of woodland, and the disorderly expansion of construction land have not only brought a great negative impact on food security and ecological security, but also affected the sustainability of economic and social development. Although the protection and management of Dianchi Lake has always been highly valued, measures such as "one lake, one measure", "relocation for ecological restoration" have played a certain role in the management and protection of Dianchi Lake. However, the fact is that the overall quality of the ecological environment has not been improved significantly, which is a common problem faced by most lakes in China. Under the background of the "Lake Revolution", we must pay great attention to the ecological damage caused by the irrational land use change and seek a more rational and sustainable land use pattern. Development should not be pursued at the expense of the ecological environment, but more sustainable development should be achieved on the basis of protecting the environment. The results of this study have important reference value for promoting the "win-win" of eco-environmental protection and sustainable economic and social development in the Dianchi Basin.

5. Conclusions

- The rapid reduction in high-quality cultivated land has added great difficulties for Yunnan province, which originally had "more mountains and less land", to maintain the bottom line of cultivated land and the red line of cultivated land. In the future land use management activities, the policy of "Returning Farmland to Forest" should be carried out scientifically. In order to protect cultivated land and prevent the further deterioration of the ecological environment, land remediation projects such as "replacing sloped cultivated land with terraced field" should be implemented carefully and effectively;
- In the past 10 years, the rational degree of changes in open forest land and other forest land has suddenly decreased, reflecting that the disorderly expansion of construction land has reached a very serious level. The disappearance of cultivated land has been unable to meet the demand for expansion of construction land. Woodland is facing the threat of being encroached on construction land, even the woodland in the Dianchi Lake Nature Reserve is no exception. Therefore, in order to facilitate the improvement of the regional ecological environment, planned afforestation is necessary. At the same time, we should make full use of 3S technology to strengthen the dynamic monitoring of land use. Real-time supervision should be performed in areas with important ecological protection functions to prevent the occurrence of irrational land changes from the root;
- The irrational expansion of construction land in the Dianchi Basin has brought a great threat to the ecological environment of the lake. In order to achieve more sustainable development, a strict construction land permit system must be established to control the increase in construction land in Dianchi Basin and prevent the pollution of Dianchi Lake from aggravating further. Industrial land and non-essential urban construction land that is harmful to the ecological environment should be relocated in a planned way. The legal system for prohibiting the illegal expansion of construction land is supposed to be completed as soon as possible.

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