Research Paper

Research on the Delimitation of Urban Development Boundary based on Geodesign

Take the Kunming Yangzonghai Scenic Spot,China as an example

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Abstract

The delineation of urban development boundary is an effective means to prevent the blind expansion and disorderly spread of cities, as well as an important way to promote the healthy development of cities. The current methods of urban development boundary delineation lack the comparative analysis of multiple development scenarios and the immediate evaluation of boundary delineation results, and the geodesign methodology can just make up for this deficiency. Based on the traditional delineation process of urban development boundary, this paper constructs a geodesign framework for delineation of urban development boundary. Taking Yangzonghai Scenic Spot as an example, under this framework, the current situation of the study area is firstly analyzed, and several possible development scenarios are proposed; then the possible development scenarios are simulated by using geographic information technology; Finally, from the perspective of ecosystem service value and urban intensive and economical development, evaluation factors are selected to comprehensively evaluate the multi-scenario land use simulation results. The evaluation results show that the group development model under the high ecological security and the moderately loose basic farmland policy have the highest comprehensive benefits, and use this as the basis for the delineation of urban development boundary.

Keywords

urban development boundary, geodesign, cellular automata-markov model, Kunming Yangzonghai Scenic spot

1. Introduction

Over the past 40 years of reform and opening up, China's urbanization process has been accelerating. The urbanization rate announced by the government exceeded 50% for the first time in 2011, and reached 53.73% in 2013, indicating that China's urbanization process is entering a critical period of transformation and development(Mao, Q.Z.,2015). The seventh national census shows that China's urbanization rate in 2020 reached 63.89%(National Bureau of Statistics,2021). Although rapid urbanization has promoted rapid economic development and greatly improved people's living standards, it has also leaded to many problems. Among them, the two most prominent and acute problems are the deterioration of the ecological environment and the serious imbalance between the supply and demand of land resources. The fundamental reasons are the disorderly spread and rapid expansion of cities. These two problems pose serious challenges to the development of healthy urbanization, and scientific and reasonable Delineating urban development boundary is the most targeted coping strategy to solve the above problems (Li,Y.H.,2015;Zhou,R. et al.,2014). Although the current urban development boundary delimitation methods are relatively rich and mature, there is a lack of comparative analysis of multiple development scenarios and immediate evaluation of the results of urban development boundary delimitation. Geodesign can just make up for this deficiency.

The geodesign framework is the core content of geodesign, a decision support methodology that closely integrates planning and design activities with real-time (or quasi-real-time) GIS-based dynamic environmental impact simulations. In a new perspective, it is an effective means to solve the humanities and environmental problems of modern society through the organic integration of traditional disciplines and the help of information technology. It is the result of years of multi-disciplinary and industry development, social and environmental needs and technological progress, and provides an effective methodology for us to solve many problems such as resource shortage in modern society, population urbanization, environmental degradation, and climate change(Ma,J.R.,2013). Based on the traditional delineation process of urban development boundary, this paper constructs a geodesign framework for delineation of urban development boundary. The framework has three loop iterations. Under this framework, this study takes Kunming Yangzonghai Scenic Spot as an example, and completes the delineation of urban development boundary through three iterations.

2. Methods

2.1. Urban development boundary delimitation

Many scholars have made in-depth discussions on how China can learn from and use the relevant theories of urban development boundary to solve the practical problems faced by China's urban development from the theoretical and practical levels(Tan.R.H.et al.,2020;Zhang,B.et al.,2018;Yang,X.,Yang,J.,He,L.C.,2019;Zhao,Z.F. et al.,2017;Lin,J.,Liu,W.L.,2014). In terms of the method of delimiting the urban development boundary, there are mainly three types: the growth method, the exclusion method and the comprehensive method.(Wang,Y.,Gu,C.L.,Li,X.J.,2014). The growth method regards urban construction land as an ever-growing organism, simulates urban growth with models and delimits urban development boundary with reference to the simulation results, and is mainly used for the delineation of elastic development boundary. For example, the urban agglomeration of Thiruvananthapuram in India has delineated urban development boundaries based on remote sensing, artificial neural networks and cellular automata models(Vishal Chettry and Meenal Surawar,2021); the exclusion method is to exclude the unsuitable land for construction due to limited construction

conditions or sensitive ecological environment, and identify the possible range of urban construction land. The maximum value is mainly used for the delineation of rigid development boundary. For example, Claire Jantz et al.(2003) designed three scenarios with 45m spatial resolution data in the Washington-Baltimore metropolitan area. In each scenario, parks, wetlands, beaches, forests, agriculture, waters The protection intensity of other protected areas is different, the scope of growth management area, whether new planned roads and sites are included, and the intensity of slope restrictions are also different. By excluding undeveloped areas, the urban development boundary under different ecological security requirements is delineated; The comprehensive method integrates the prediction of growth trends on the basis of considering the limiting factors of urban growth, and is mainly used for the delineation of elastic development boundary. Diana Mitsova, William Shuster, etc.(2011) developed a cellular automaton for land cover change-Markov.The chain model integrates the protection of environmentally sensitive areas into the prediction of urban development at the regional scale, which improves the connectivity between open spaces and helps to protect the ecological environment while achieving economic development.

This research adopts the technical route in the "Guidelines for the Delineation of Urban Development Boundary" (for trial implementation, draft for comments) issued by the Ministry of Natural Resources in June 2019 to delineate the urban development boundary. First of all, carry out various evaluation studies. On the basis of evaluation, carry out the research on the current situation of urban development, the research on urban development orientation, the research on the scale of urban development and the research on urban development pattern. The results of the planning shall be linked with various types of statutory planning land, and the final plan shall be coordinated and improved.

2.2. Geodesign

Geodesign framework has a process of multiple iterative loops and feedback possibilities(Steinitz C.,2012). Professor Carl Steinitz summarized the core of the geodesign framework as four types of people, six models and three cycles. Based on Carl Steinitz's geodesign framework, he has carried out corresponding practice in many fields of urban planning and landscape planning, and developed a series of application-oriented geodesign frameworks, such as Michael Goodchild's marine ecological protection geodesign Framework, the Singapore Urban Redevelopment Authority takes the geodesign framework as the principle, selects a series of evaluation indicators in the overall urban planning and design, integrates the elements of land use, infrastructure, ecology, culture, landscape, etc., and completes the planning well. With the established goals, AECOM's low-carbon ecological planning evaluation tool has achieved good results by simulation and systematic evaluation of the results of different planning schemes (Yang,Y.S.,Li,D.H.,2013;Dang,A.R.,Li,J.,Chen,J.S.,2014).

The research and application of geodesign in China is also gradually deepening. For example, Professor Zhou Wensheng of Tsinghua University(2014) constructed a GIS-based urban and rural planning support system-Tsinghua geodesign platform according to the concept of geodesign, which can be used in the whole process of planning and design, that is, from the current data Collection, status analysis, planning scheme design, planning scheme evaluation, simulation, planning scheme display to planning results output. Jin Xianfeng, Luo Lingjun and others(2014) combined the geodesign framework with the existing urban and rural planning system, and established the urban and rural planning geodesign framework on the basis of the original framework to improve the scientificity and practicability of planning. Niu Qiang(2015) combined the planning quantitative analysis work with the geodesign framework, and proposed a set of planning quantitative analysis framework, so that all kinds of quantitative analysis in planning can better serve the planning objectives.

In recent years, the development of geographic information technology has vigorously promoted the practice of delimitation of urban development boundary, and the use of new technologies and methods in boundary delimitation has gradually increased. Geodesign is a research method of multidisciplinary cooperation. Geographic information technology is used to simulate the current and future development status and conduct real-time evaluation, so as to maximize the benefits of research results and minimize the risks. Therefore, from the perspective of research methods, the concept of geodesign fits well with the delineation of urban development boundary.

2.3. Establishment of Geodesign Framework for Urban Development Boundary Delimitation

The core of geodesign is a circular design process consisting of "scenario simulation" and "instant evaluation". Traditional designers often use pencil and tracing paper to sketch the scheme on the map, but it is difficult for their opinions to get timely feedback during the design, and the impact and consequences of the scheme can not be fully evaluated until the design is completed. Geodesign is based on spatial analysis, bringing geographic analysis into the design process, considering key factors in advance, rather than analyzing the potential impacts and consequences of proposed projects after the design is complete, helping to shorten design cycle times, to improve the quality of the results(Li,L.,Yuan,C.,2011). Based on the methods of "scenario simulation" and "real-time evaluation", the core of geodesign, this paper introduces corresponding models in the analysis of the current situation of the study area, multi-scenario simulation and real-time evaluation of simulation results. Complete the delineation of urban development boundary. The geodesign framework of the urban development boundary delimitation is shown in Figure 1.

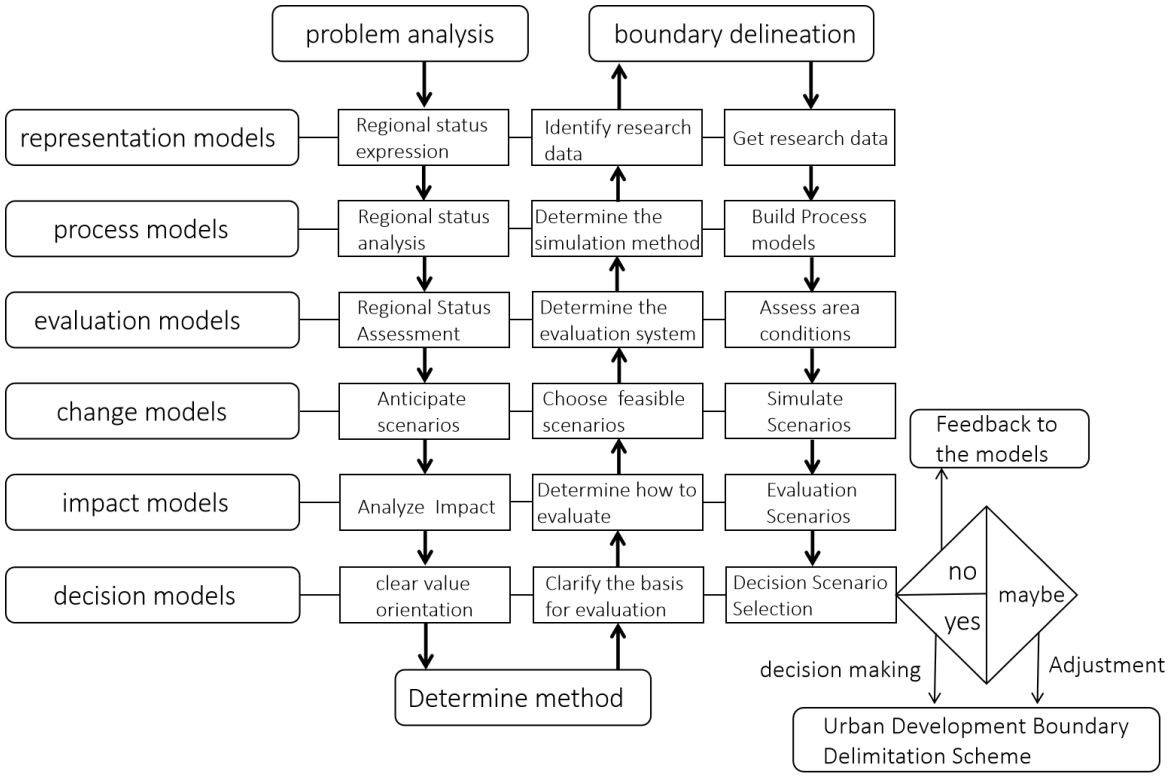


Figure 1. Geodesign framework for the delineation of urban development boundary. Source: the authors.

3. Result

3.1. The first cycle: clarifying the value orientation of urban development boundary delimitation

3.1.1.Current Situation Assessment and Issue Summary

Yangzonghai Scenic Spot is located in the southeast of Kunming City, adjacent to the main urban area of Kunming City. It has jurisdiction over 3 towns (streets), Qidian Street, Tangchi Street and Yangzong Town, with a total area of 546 square kilometers. Yangzonghai in the area is one of the nine plateau lakes in Yunnan Province and is a natural freshwater lake. The Yangzonghai district is located at the administrative junction of the original two cities and three counties. The development of the district lags behind the surrounding districts. Except for the initial industrial development in the Qidian Street, Yangzong Town and Tangchi Street have not yet formed industrial development. Compared with the other two Streets, the contradiction between people and land in Yangzong Town is more prominent. The proportion of basic farmland in Yangzong Town has reached 95%. The residential sites of residents in the dam area are surrounded by basic farmland. It hindered the development of Yangzong Town. This study summarizes the requirements of relevant laws and policies of Yunnan Province for the protection and development of Yangzonghai area, as shown in Table 1.

Table 1. Summary of relevant regulatory and policy requirements.Source:the authors.

Regulation and Policy Name	specific requirements
"Land and Spatial Planning of Yunnan Province (2021-2035) (Draft for Comment)"	The proportion of basic farmland in the dam area should be kept above 80%, and the key dam area should be kept above 85%; the per capita urban construction land area should be controlled at about 100 square meters per person
"Implementation Opinions of the CPC Yunnan Provincial Committee and the Yunnan Provincial People's Government on Winning the Tough Battle of the "Lake Revolution" (Draft for Comments)"	The urban spatial layout should adopt a moderately centralized layout or a group layout.
"Yangzonghai Ecological Corridor Line and Lake Ring Road Line in Yunnan Province" "Two Lines" Demarcation Scheme 》	The "two-line" control measures require the complete withdrawal of villages, population, buildings, industries and facilities unrelated to protection and governance within the ecological corridor line, except for shipping, public law enforcement, comprehensive transportation infrastructure, cultural relics, historical buildings, and historical villages. Various types of construction land within the lake highway line should be reserved or not according to the actual situation.
"Technical Guidelines for Compilation of State (City) Territorial Space Overall Planning in Yunnan	Adhere to the principle of ecological priority and green development, promote multi-center, multi-

Province (Trial)"	level, multi-node, group-type, networked development, and prevent the disorderly spread of cities.

3.1.2.Regional multi-scenario development possibilities

According to the current situation assessment and problem summary of Yangzonghai area, the land use in Yangzonghai area can be regulated from three directions: spatial development mode, farmland land protection policy, and ecological security mode, as shown in Table 2.

Table 2. Multi-scenario land use regulation modes and measures.Source: the authors.

regulation mode	Control measures
space development model	Moderately centralized layout dominated by three town centers
	A cluster-style layout dominated by three town centers and other suitable mountainous areas adjacent to large settlements
Farmland Protection Policy	The basic farmland in Yangzong Town is reduced from 95% to 85%, which meets the upper-level planning and sets aside the construction land index (appropriately adjusts the basic farmland)
	Implement strict protection measures for basic farmland, and the number of basic farmland is not allowed to be reduced (strict protection of basic farmland)
Ecological safety model	All construction land in the "two lines" will be withdrawn (high ecological security)
	All the construction land within the ecological corridor line will be withdrawn, and the construction land outside the ecological corridor line and within the road around the lake will be reserved (low ecological safety)

Combining the above three development models, the following nine development scenarios are finally obtained:

Scenario 1: Baseline Scenario Continuing the Status Quo

Scenario 2: Moderately centralized layout/strict protection of basic farmland/high ecological security

Scenario 3: Group layout/strict protection of basic farmland/high ecological security

Scenario 4: Moderately centralized layout / Moderate adjustment of basic farmland / High ecological security

Scenario 5: Group layout / Moderate adjustment of basic farmland / High ecological security

Scenario 6: Moderately centralized layout / Moderate adjustment of basic farmland / Low ecological security

Scenario 7: Group layout / Moderate adjustment of basic farmland / Low ecological security

Scenario 8: Moderately centralized layout/strict protection of basic farmland/low ecological security

Scenario 9: Group layout/strict protection of basic farmland/low ecological security

3.1.3.Value Orientation of Multi-scenario Evaluation of Urban Development Boundaries

From the perspective of current situation assessment and problem summary, the biggest problem of Yangzonghai Scenic Spot at this stage is the contradiction between regional ecological protection and economic development. Combined with the requirements of various normative documents and policy documents, the Yangzonghai Scenic Spot can be clearly defined. The main value orientation of the delimitation of urban development boundary is ecological priority, implementing the concept of green development, and promoting the intensive and economical development of cities. Therefore, whether it has improved ecological benefits and promoted urban intensive and economical development (economic benefits) should be used as the basis for evaluating whether the delineation results of urban development boundary is scientific and effective.

3.2.The second cycle: selecting and clearly defining research methods

The main goal of the second cycle is to determine the specific research methods for each part of the framework. The method choices involved in this case include the method of multi-scenario simulation of urban development boundary and the method of evaluation of simulation results.

3.2.1.Multi-scenario simulation method of urban development boundary

In recent years, a variety of dynamic simulation models of land use change have emerged, including system dynamics (SD), cellular automata, Markov, CLUE, CLUE-S, SLEUTH, agent-based models, spatial Logistic Wait. The cellular automata-Markov (CA-Markov) model combines the advantages of the long-term prediction of the Markov model and the ability of cellular automata to simulate the spatial changes of complex systems, which not only improves the prediction accuracy of land use type conversion, but also effectively simulating spatial changes in land use patterns(He,D.et al.,2014). In view of the characteristics of high prediction accuracy and relatively low data requirements of the CA-Markov model, this model was finally selected for the multi-scenario simulation of urban development boundary in the Yangzonghai district.

3.2.2. Evaluation method of multi-scenario simulation results of urban development boundary

At present, the related research on ecological benefits in academic circles mainly cuts in from two perspe ctives: landscape pattern optimization and ecosystem service value assessment(Luo,T.,Lin,Y.C.,Fan,H.Q.,2 022). Considering that the evaluation of ecosystem service value is relatively intuitive and the calculation process is relatively convenient, the ecosystem service value is selected as the index to evaluate the ecolo gical benefits of urban development boundary delimitation results, and the equivalent factor method is u sed as the calculation method. Finally, the calculated ecosystem service value is divided into 5 categories according to the natural breakpoint method, with a score of 1 to 5.

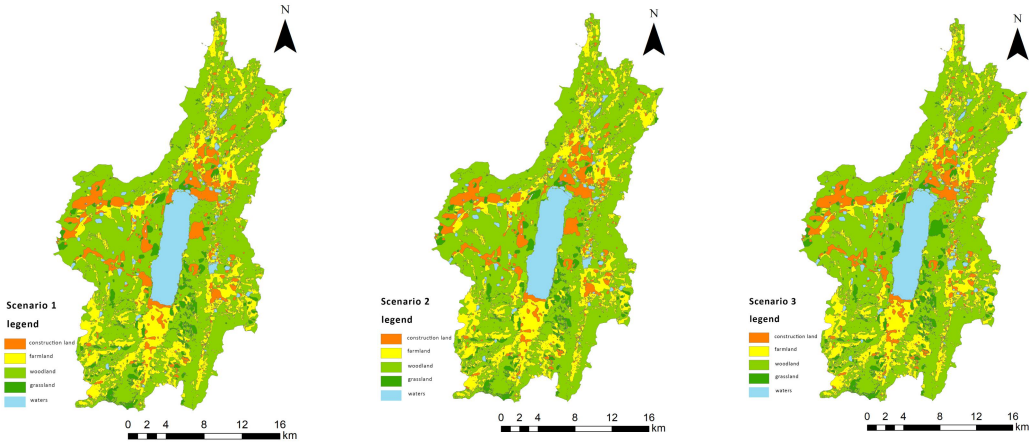
This study uses the per capita urban construction land area to reflect the effect of urban intensive and economical development. Based on the actual situation of the three towns in Yangzonghai Scenic Spot, the author divides the per capita urban construction land area into the following grades: 5 points: 95-105 square meters per person; 4 points: 85-95 square meters per person ,105-115 square meters/person; 3

points: 75-85 square meters/person, 115-125 square meters/person; 2 points: 65-75 square meters/person, 125-135 square meters/person; 1 point: Less than 65 square meters / person, more than 135 square meters / person. Calculate the per capita urban construction land area of the three towns to get the corresponding scores, and then calculate the average as the urban intensive and economical development (economic benefits) score of this scenario.

3.3.The third cycle: complete the delineation of urban development boundary

3.3.1.Multi-scenario simulation of urban development boundary

This study uses globeland30 data in 2000 and 2010 as land use data to create a CA-Markov model. According to the principles of improving ecological benefits and promoting the intensive and economical development of the city determined in the first cycle, combined with the actual situation of Yangzonghai Spot, the basic farmland protection area, ecological protection red line, Yangzonghai lakeside belt and slope are used as four constraints Condition, the distance from the district center, the distance from the town center, the distance from the highway, and the distance from the existing construction land are used as the influencing factors to make the suitability atlas of the model. According to the above conditions, the land use in 2020 was simulated and compared with the actual land use. The Kappa coefficient calculation result was 0.7524, indicating that the consistency was high and the simulation effect was good. According to the multi-scenario setting conditions, the suitability atlas was modified accordingly, and the "two-line" elements and group distribution elements were added, and nine simulation results were obtained, as shown in Figure 2.



Scenario 1（a） Scenario 2（b） Scenario 3（c）

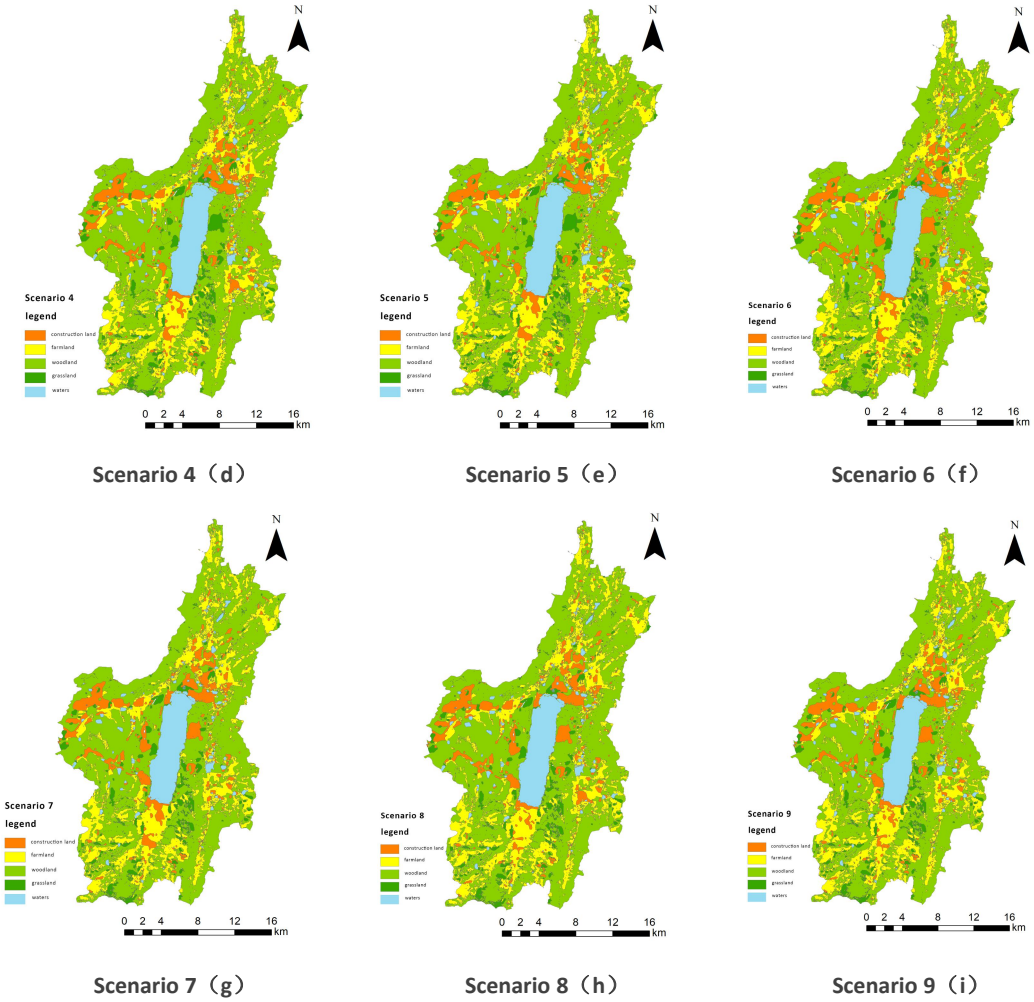


Figure 2 Multi-scenario land use simulation results. Source: the authors.

3.3.2 Evaluation of multi-scenario simulation results of urban development boundary

Calculate the per capita urban construction land and ecological service value in each scenario. According to the scores of each scenario, a multi-scenario comprehensive benefit comparison chart is drawn, as shown in Figure 3. It can be seen from the figure that Scenario 5 has the highest comprehensive benefit, so the delineation idea that is most in line with the Yangzonghai regional development concept is Scenario 5.

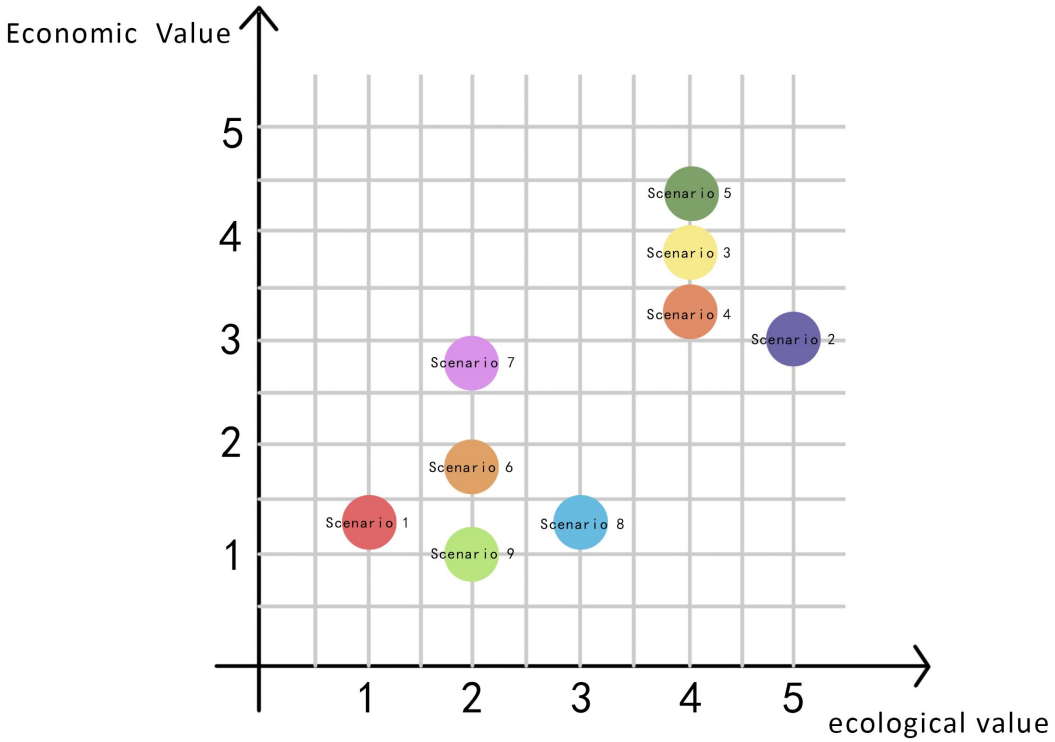


Figure 3. Comparison of comprehensive benefits of multiple scenarios.Source: the authors.

3.3.3 Coordinate the delineation of urban development boundaries

According to the above research results, the urban concentrated construction area is demarcated according to the model of Scenario 5, and the group development model with high ecological security is adopted. On the basis of moderately adjusting the scale of basic farmland in Yangzong Town, the scale of adjustment and reduction is limited according to the upper plan. Then, according to the land use development direction and land suitability evaluation of the simulation results, 15% of the conditional construction areas are demarcated, and special-use areas are demarcated according to the actual situation of the surrounding ecological environment, and finally the complete urban development boundary is obtained, as shown in Figure 4.

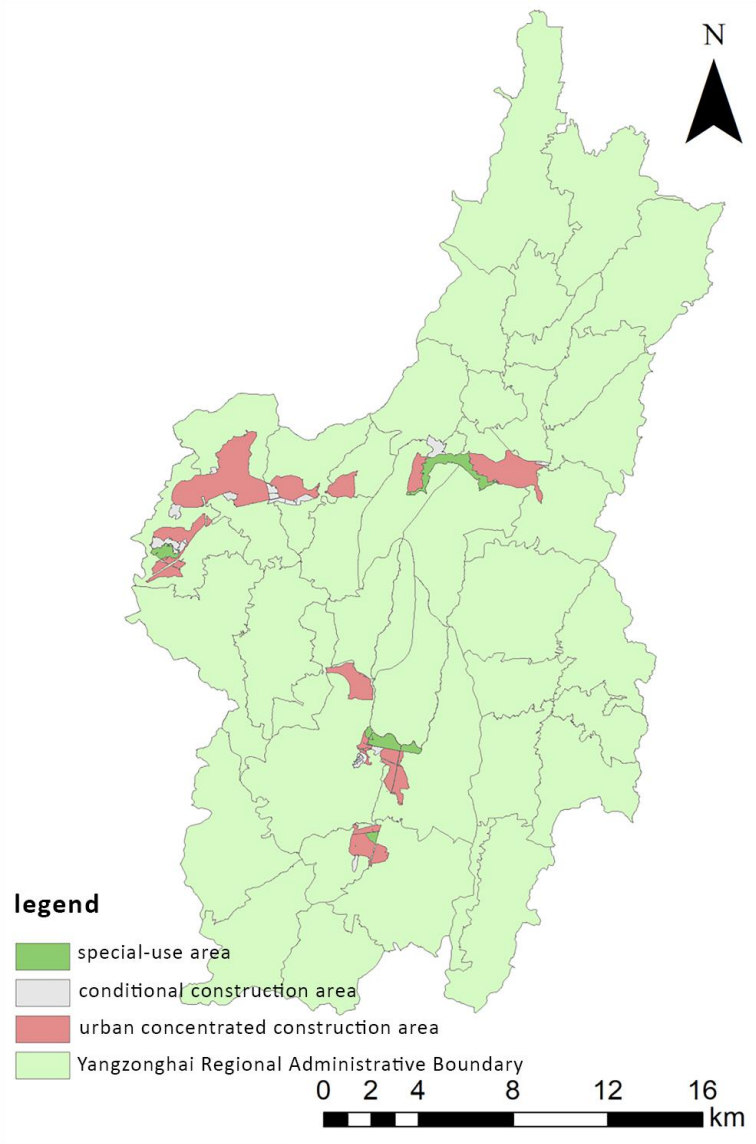


Figure 4.The result of the delineation of the urban development boundary. Source: the authors.

3.4. Urban Development Boundary Control Strategies

(1) As a spatial management and control tool, the urban development boundary needs to be clearly defined in its legal status and supported by corresponding policies in order to maximize its control effect.

(2) There are great differences inside and outside the urban development boundary, and detailed management and control measures should be formulated to ensure the orderly progress of urban construction within the boundary, strictly control the construction behavior outside the boundary, and achieve green development.

(3) There should be differences in the management and control policies of urban development boundaries. While ensuring the normal construction behaviors are carried out in an orderly manner, each town (street) should be encouraged to give full play to its own advantages, and corresponding support should be given in management and control measures.

(4) A dynamic evaluation system should be established in the process of boundary implementation to cope with various changes and challenges, and to ensure that urban development boundary is always scientific and effective.

4. Discussion and conclusion

At present, geodesign has been widely used in the field of planning, but the case of combining it with national spatial planning is rare in China. Geodesign theory can effectively improve the scientificity and practicability of planning, and it is consistent with national land space planning, especially the delimitation of urban development boundary, in terms of research purposes, research scales and research methods. Based on the technical route of urban development boundary delimitation in the "Guidelines for Urban Development Boundary Delimitation" (trial, draft for comments), this study integrates the core concepts of geodesign and geodesign framework, and establishes a geodesign framework for urban development boundary delimitation, and took Yangzonghai Scenic Spot as an example to carry out practical research. The research results show that urban development boundary delineation under the framework of geodesign has the advantages of clear goals, full consideration of the diversity of development scenarios and immediate feedback of boundary delineation benefits. The corresponding models and evaluation methods used in the geodesign framework for the delimitation of urban development boundary constructed in this paper are commonly used methods in various disciplines, and have certain universality. We hope to provide references for other cities to scientifically delineate urban development boundary.

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