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Contents

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REVIEW ARTICLE

Ecology and nature conservation in Russia

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ABSTRACT

The article is devoted to nature conservation in the context of the eco-tourism development. The leading problems in the work of modern *specially protected natural areas* theorists and practitioners are the following: 1) the organization of tourist destinations and management systems for ecological tourism: it is necessary not only to meet the needs of environmental, as well as related pilgrimage and educational tourism, but also the needs of the destination itself, restoration of unique biological objects, flora, fauna, territories and water areas; 2) the issues of increasing the ecological culture of the population and meeting the needs of the population in a way that does not hinder and helps the development of reserves and other previously closed or inaccessible areas or water areas. Special attention was pay to the phenomenon of diversification and its role in the development of environmental and other types of tourism. The article considers the integrative model of geo-branding in ecotourism.

Keywords: Nature Conservation; Agrotourism; Eco-tourism; Diversification; Geo-branding

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1. Introduction

The ecological situation in the modern world as a whole is characterized by the ever-increasing intensity of anthropogenic impact on the natural environment, the diversity of environmental problems, the range of which is expanding both qualitatively and quantitatively. First, these are problems associated with (re)creating favorable conditions for life and development of a person, his health, as well as the problems of protecting the environment and using natural resources. The development of scientific and technological progress and the creation of means of human influence on the environment, irrational use of natural resources, pollution of ecosystem elements caused the deterioration of the ecological situation. These are the problems of ensuring environmental safety. They include the implementation of processes and programs that ensure the ecological balance of the natural environment. They also presuppose the creation and implementation of programs for the development of production and other aspects of the life of the society that will not lead to damage (or threats to such damage), the natural environment and man in nature. The impact of human activity on nature is ambiguous: in the process of interaction between man and nature, various effects arise, from direct destruction to mediated hormesis, the stimulating effect of moderate doses of stressors, from direct development and expansion to mediated degeneration, degradation of the natural flora and fauna, water areas, territories, air basins. However, in addition to discussions and studies on the impact of man and man on nature, measures and programs for preserving nature in its “pristine” form are necessary.

The aim of the research is to analyze modern problems of protected areas, including in the context of the development of ecological tourism.

Materials and methods of the research: the article summarizes the views of leading Russian and world PA researchers. The article is devoted to the theoretical analysis of the problems of protected areas and ecological tourism in Russia and in the world.

2. Discussion

The reserve business and creation of a system of specially protected areas (abbreviated as SPNA) is the process and result of systemic and constant efforts of a variety of practitioners and theoreticians of various sciences and fields of activity that protect nature[1-15]. A reserve can be defined as a complex, or, ideally, as a system of organizational, legal, scientific, economic and educational activities/actions and programs. These programs and measures are aimed at preserving, restoring and developing unique and typical landscapes or natural objects. The list of tasks of these programs and measures includes research, environmental and other tasks.

A reserve is a territory or water area (a set of territories and water areas) allocated to preserve or restore the natural state of typical or unique natural complexes. Usually, the natural mean the harmonious state of the system, that is, the entire aggregate of its components. In addition, the reserve is a place of non-destructive and non-interfering research into the natural course of the processes and phenomena occurring in them, and the development of scientific bases for nature protection. Ideas for the creation of reserves, the isolation of special territories, including those "closed" for visiting and human activity, for the protection of animals and plants (fauna and flora of the Earth and its various regions) arose at the beginning of the twentieth century (Konnodz, Sarazen, Warming). Before all these things formulated A. Humboldt already in the XIX century. However, at first these ideas did not arouse much interest. The term conservation, which was proposed by Humboldt, was returned to the use of Convent, who put a lot of effort into preserving nature. Already at the end of the XIX—the beginning of the XX century in Europe, developed a movement for the protection of natural monuments ("Naturdemkmaller"). Monuments of nature are small areas that have preserved a "pristine" appearance among the actively populated or long-settled, transformed or already transformed landscapes of Europe and the rest of the world. Thus, both the protective and the restoration context of the creation of SPNA has emerged. In Russia, the theory of the reserve business and its practice—as one of the best and unique practices of protected areas in the world. It was formed thanks to the works of Borodin, Dokuchaev, Semenov-Tian-Shanskiy, Kozhevnikov, Tanfiliev, Taliev, Anuchin, Vysotsky, Morozov, Stanchinsky *et al*.[16,17] Traditionally, several tendencies and sources of environmental protection, including protected activities, creation and development of the theory and practice of protected and other specially protected territories are singled out in the creation and development of protected areas[18-25]. At the end of the XIX century interest in nature and its protection, in the human community, especially in the field of science and education, was already great. The reason and at the same time the consequence of this interest are a number of large geographic expeditions. Within the framework of these expeditions, scientists carried out numerous botanical and zoological studies in the framework of these expeditions and the study of the flora and fauna of the Earth as a whole. An important role played in this process by the military, who along with scientists carried out numerous studies in Asia, the Caucasus, and the polar regions. At the head of the movement for the protection of nature and its "monuments" stood prominent Russian and world researchers of the time, such as Borodin, Anuchin, Morozov, Soloviev, Kozhevnikov, Taliev, Semenov-Tian-Shanskiy, and Semenov-Tian-Shanskiy[12,13,26-31]. The geographic and ecological foundations for the creation of a network of reserves are laid by such scientists as Dokuchaev, Stanchinsky, Morozov, Sukachev, Taliev, Formozov, Isakov, Shtilmark[13]. The enumerated scientists belong to the ideal of the "ethical-aesthetic" approach

to nature protection, and, in particular, to SPNA. The superiority of the Russian system of SPNA is associated with the reserves as a unique form of conservation of natural areas and water areas. Their ascent took place in a series of stages. At the end of the XIX century, Dokuchaev noted the need for special conservation stations, which will be different from the national recreational parks of America, etc.: they will serve primarily nature, and then—man. Dokuchaev justified the importance of the "commandment" of land and water. He stressed the need to "provide it for exclusive use" to indigenous species of flora and fauna. This idea was developed by other scientists and practitioners-naturalists[29,32]. The national approach to the concept of conservation of natural monuments (SPNA) was also formed by Borodin: "we have already understood the need to protect the monuments of our antiquity, it's time for us to feel the consciousness that the most important of them are the remnants of that nature, among which our state power developed, our distant ancestors lived and acted. To lose these remnants would be a crime."[26,33] Morozov proposed to identify and take under special protection the most important and valuable "standards" of natural territories and water areas, their flora and fauna, in different regions of Russia: "the allocation of protected areas should be as planned as possible with the position of a botanico-geographical subdivisions: protected areas should be located in each botanical-geographical area, representing in their totality a number of the most characteristic and most valuable in the scientific respect types of vegetation"[34]. Semenov-Tian-Shanskiy also supported them: "it is our duty to preserve for the posterity, wherever possible, in complete integrity, entirely the features of the face of the mother Earth, so that it always has the opportunity to peer in and learn from it, about what it only heard from books"[35]. He also believed that "preservation of an intact natural geographical landscape from distant ancestors will help the descendants to more easily critically understand all the complex artificial environment in which they will have to live and act."[35] Russian researchers, that is, who initially adhered to these views, formed a specific protective and restoration approach to the territories and water areas of the earth as nature monuments, that is, as part of the cultural heritage.

The ideology of this approach to environmental protection is reflected in the terms, "conservation", "restoration", etc. This approach is much more promising and ethical than the earlier, European, natural-historical approach. It leads ethical and aesthetic arguments ("awe" before the living, etc.). These arguments are often externally quite far from the arguments of the biological and ecological type.

The third—a pragmatic (resource) approach—is aimed at protecting recreational resources. This approach is common in America, in the United States, where, unlike Europe, there are vast spaces that have been slightly damaged by humans, and, like human life, natural life is not a great value ("in itself"). To date, there are more than 400 national parks and other reserves in the US that are actively used by people who visit them to restore their health and to touch the purity and greatness of nature. This approach developed in Russia in the early twentieth century. Through the efforts of numerous environmental commissions operating in each region, unique botanical or geological objects, rare species of flora and fauna that are rare and useful from human eyes, and the most picturesque corners of nature were taken under protection. However, such reserves had practically no relation to the reserves. In addition, some species of flora and fauna were actively destroyed: in whole, increasing the indices of "national economic activity": no "harmony" or "inviolability", and, even more so, "primordiality", was not forthcoming. Another variant of the pragmatic approach is the reasonable use of the biological resources of the territories or "rational nature management": PA practitioners and theorists proceed from the tasks of ensuring economic benefits through the effective use of natural objects. It is a question of natural territories and water areas, separated for hunting, gathering, and also actions on restoration and reintroduction, etc.

Kozhevnikov sets the natural-historical approach forth. It is now the theoretical basis of the Russian reserve business: reserves are considered as "reference untouchable" plots (the leading mode of human-nature relations is "control", and not "experience"—as in relations with the transformed territories). "In order to be able to study nature, we must try to preserve it in its primitive integrity in the form of its most typical formations. Of course, we must strive most of all to preserve the virgin steppe and the primitive forest of the taiga type". Answering a question about the purpose of preserving untouched areas, Kozhevnikov noted: "first of all, purely scientific, and then, of course, practical as well. only a scientific study of nature provides us with solid bases for practical activity. Having before us first a devastated and then reclaimed nature and not having to compare either the corner of nature more or less primitive, we cannot unravel the whole range of interesting riddles that the animal poses to us and plant life[36]. He also postulated the main characteristics of the reserves as a special type of protected areas: "sites designed to preserve specimens of primitive nature must be of a rather large size so that the influence of the cultural properties of neighboring localities does not affect them, at least at parts far from the edge. These areas must be reserved in the strictest sense of the word. All measures that violate the natural conditions of the struggle for existence are unacceptable here[37]. He also believed that "With respect to the flora, it is necessary to prohibit cutting through the clearings, clearing the forest, even haymaking, and, of course, all crops and planting." There is nothing to eliminate, nothing to add, nothing to improve. It is necessary to provide the nature to itself and observe the results. If possible, it is necessary to prohibit the passage and passage on these sites, which will not be particularly difficult to do if they are located in remote, uninhabited areas[37]. According to Kozhevnikov, "Compliance with these requirements, coupled with the strict prohibition of hunting and serious restrictions for the collection, will allow us to have protected areas in the strict sense of the word, where there would be no interference of human activity, and where it would be possible to study the natural conditions of life." Thus, several ideas emerged as the basis for the creation and development of the reserved business in Russia:

- The idea of preserving natural complexes, and not just individual species of flora and fauna, not just individual "natural monuments";
- The idea of creating protected areas on an area sufficient to establish the processes characteristic of territories where there is no human impact for the study of natural historical processes without human influence;
- The idea of creating different types of protection zones around reserves to prevent human influence on their nature and preventing the destruction of reserves, and also for the unconventional territories to be enriched by more or less asymmetric and regulated exchange with protected areas.

This makes it possible to resettle different species of flora and fauna from reserves to adjacent areas, ensures the existence of "green corridors" for the passage of animals and plants from neighboring SPNA, etc.

The complexity of working in the reserve is connected with the fact that the study of natural processes requires a great deal of time: "where can the very process of struggle for survival and survival of the fittest be studied? Only when working in absolute reserves, at their biological stations, over a period far exceeding the life of one person"[30,38]. Therefore, there are difficulties in the work of specialists in the territory of SPNA. These difficulties for their resolution require diachronic and synchronic coordination and specialization of the activities of professionals: "in the reserve, one researcher is replaced by another and works on the same objects as the previous one if the work is properly planned, and does not represent a series of separate topics, little related or quite not connected with each other"[30,38]. Therefore, only research is allowed in the reserves, which, on the one hand, cannot be carried out on another, including uninhabited territory, and on the other— are not dan-

gerous in the context of the task of preserving "intactness" and developing natural complexes of protected areas. This is especially true of tourism: it was supposed to be made to minimize the impact on protected natural complexes and maximally useful for raising the image of the reserve and patching budget holes[27,39]. Such a requirement is still preserved. However, it remains far from everywhere: the value of human life in Russia at the end of the twentieth century has declined catastrophically. Therefore, one cannot even talk about not talking about the value of life of animals and plants. The state went and continues to go on the reforms of various spheres of the life of society that are destroying millions of lives without any attempts to take into account and comprehend the consequences of the "democratic" bourgeois genocide, culturicide and ecocide. The commodification of relations, their crude pragmatization as a reduction to the maximization of economic and political benefits, is absolutely the opposite of the aesthetic-ethical and other models of the Soviet-era SPNA.

At the same time, formally, the Law on Reserves exists: the Law of the Russian Federation (1995) "On Specially Protected Natural Territories" is working. It defines the reserve: "The reserve is an environmental, research and environmental education institution that has the purpose of preserving and studying the natural course of natural processes and phenomena, the genetic fund of plant and animal life, certain species and communities of plants and animals, typical and unique ecological systems. "In general, the reserve is a form of specially protected natural areas, specific for the USSR and later for Russia (See **Table 1**).

Table 1. Specially protected natural territories

Category of protected areas	Categories of international protected areas	Categories of protected areas in Russia
I	strict nature reserve	reserves, zapovednik
II	national park	national and nature parks
III	natural monument	monuments of nature, federal sanctuaries
IV	habitat/species management area	federal and regional reserves e
V	protected landscape (netscape)	zakazniks regional, botanical gardens, dendroparks resort areas, green areas, sections of sea coasts
VI	managed resource protected area	tundra forest, walnut fields, soil and water protection belts, belt burs, and the like

In April 1981, the USSR approved a "standard clause on state reserves, natural monuments, sanctuaries and natural national parks"[40]. According to this provision, state reserves initiate and coordinate research on the development of scientific principles for nature protection, monitor and monitor the changes in the background state of the biosphere, and develop scientific bases for the conservation and restoration of rare and endangered species. Their territories are almost completely and "permanently" withdrawn from economic use, tourism and mass excursions in them are also not permitted. Their territories are almost completely and "permanently" withdrawn from economic use, tourism and mass excursions in them are also not permitted. In the territory of the reserve, any activity, contrary or not corresponding to the tasks of the state nature reserve, is prohibited, thus. For example, in the territory of the reserve, the introduction of other organisms that are not characteristic of the region for the purposes of their acclimatization is forbidden. The exchange of protected areas with other territories and water areas is initially asymmetric, migration of flora and fauna beyond the SPNA is possible and supported, provided that there is oversaturation, but not vice versa. At the same time, measures and activities aimed at:

a) Conservation of natural complexes in a natural state, restoration and prevention of changes in natural complexes and their components as a result of anthropogenic impact are partially (very meticulous and justified);

b) Maintenance of conditions ensuring sanitary and fire safety;
c) Prevention of conditions capable of causing natural disasters, threatening the lives of people and human settlements;
d) Implementation of environmental monitoring and related studies of flora and fauna;
e) Fulfillment of scientific research tasks, including reconstruction and restoration of species and number of endangered animals and plants;
f) Conducting ecological and educational work;
g) Exercise of control and supervisory functions.

As a result, the reserves became the base for the conservation and reproduction of many rare species, for example, beaver, kulan, bison, Caucasian tiger, sable and others.

However, at the end of the 20th century, in connection with the collapse of the USSR, not only the infrastructure of the reserves was transformed, etc., but the rules (simplified) of access to reserves and other SPNA previously closed to tourists and other "stakeholders" changed.

The reserve today is a two-unit system, which includes:
1) The water area or the territory with ecosystems inhabiting it and communities of organisms;
2) A research institution organized to carry out scientific research work. Sometimes a third component is connected here;
3) A fragment of a tourist destination, including "protected paths"—routes of tourist trips/excursions.

Table 2. Territories of protected areas (econet)

The system of protected natural territories and water area ("econet")	Is a set of different categories of territories and water area, functionally and territorially related to each other and providing a natural balance and sustainable nature management: more than 45 thousand territories of different status with a total area of about 15.0 million km^2	
Main	1. Ecological framework nodes—territories that perform "environment-forming functions" ensure preservation of the ecological balance, maintenance of biodiversity and influence significant areas of adjacent territories. (interfluvial plains with areas of zonal vegetation, large forest tracts, marsh systems, upper reaches of large rivers, areas of intensive underground runoff).	3. Territories of ecological restoration lands on which natural systems are restored: the ecological infrastructure of the landscape is broken due to agricultural development, residential areas, etc.
Buffer	2. Transport corridors—territories that perform most of the transport functions, i.e., represent the leading routes for real-energy exchange between nodes SPNA: "the circulatory system of the landscape" the valleys of rivers and streams, the ravine-girder net, the "corridors" of the movement of the surface layer of air, groundwaters, etc. often reduced to linear strips—"environmental bridge".	4. Buffer zones—preserving bridges and nodes of specially protected natural areas.

The opening of the reserves for visits with special clarity marked the set of problems and issues of the activities of reserves and zakazniks. The opening of centers of new tourist destinations for ecological tourism, the development of different types and forms of which is also closely related to the transformations in the social, political, cultural life of the country at the turn of the past and this century.

There are also "Indigenous and Community Conserved Areas (ICCA) or areas and areas protected by indigenous peoples and communities. Indigenous peoples or local communities manage them. These indigenous peoples or local communities preserve the biological and cultural diversity of the regions. The existence of the JIOT is related to the tasks of continuing, reviving or changing the traditional practice of protecting and restoring natural resources and cultural values in the face of new and old threats and in the situation of new and old opportunities and limitations. ICCA are exposed to both external and internal threats.

As external threats to the existence of ICCA and other protected areas can be called the processes of development of territories and water areas and the use of their resources, in particular,

mining and fossil fuels. This threat is particularly important, since even if indigenous peoples and local communities have rights to land, the government usually reserves for itself the use of subsoil resources. The processes of logging, tree planting, industrial fishing, seabed-deepening work, conversion of land to large-scale pastures or agriculture (including plantations of agro-esters), drainage and drainage, urbanization and large infrastructure (roads, ports, airports, tourism). Also, the expropriation of the community's land resources through nationalization, privatization and environmental initiatives, in particular the creation of protected areas in public power, is dangerous for SPNA. No less dangerous are wars, violent conflicts or movements of refugees, other territorial seizures and invasions, conflicts with other communities and municipalities. Dangerous, inadequate, and incorrect levels and forms of recognition, for example, the imposition of institutional mechanisms by the Institute, which are alien to the community, devalue and demotivate the work in the ICCA and SPNA. The same can be attributed to the imposition of unacceptable taxes and other financial burdens on the ICCA and SPNA and the population of the ICCA. Interfere with, not only help, programs for active re-cultivation of communities, for example, programs showing disrespect for local cultures, ignoring damage to livelihoods and values. Even one-sided and primitive educational programs, or propaganda programs of religions that lead to deprivation of freedom of faith and disrespect for the lives of various faiths, can have a negative impact. In general, the modern business has very negative impact on community gaps and conflicts, fueled by political reasons or sharp asymmetries in the community as a result of a sudden and asymmetric inflow of funds that strengthens or creates local inequality. Very strongly hamper poaching and unauthorized removal of animals and plant resources. Worldwide, air and water pollution are caused by the discharge of residual waste (for example, through acid rains, chemical pollution from mining, or chemical dumping from agriculture). It disrupts the life of protected areas and the spread of invasive or exotic species. Here we can include extreme natural and technical situations and catastrophes, including droughts, floods, forest fires, hurricanes, earthquakes and tsunamis. They are especially harmful when they are often associated with human activity (transformation of the landscape, waterways and the climate). To the internal causes of disharmonies and blockades of the development of the company can also be attributed a number of points. The most important are connected with the change of values, acculturation and integration of local communities into the dominant, consumer society. Such integration leads to a commodification of relations to nature and culture (commoditization). Eventually, there is a loss of traditional knowledge and skills adapted to local conditions of management practices and governance institutions. A particularly negative point is the alienation of young people from the traditions, nature and culture that these SPNA protect. Negative is the increased pressure on resources—the region, in particular, those that lead to the replacement of local, cooperating economies with globalization, market-based methods of economic and production activities. This reinforces the existing or creates a new inequality between economic and social classes and gender groups in the community, which leads to conflicts in the management of natural resources and elites, gaining benefits for themselves[41,42].

Teoretiko-methodological bases of the organization of excursion and tourist activity in the territory of SPNA are indicated in the modern works of many foreign and domestic researchers, such as Strassdas, Jungk, Ziffer, Tseballos-Lascureine. Lindberg, Hawking, White, Johnson, Western, Ledovskikh, Drozdov, Panov, Spiankov, Stukalov, Kuznetsov. Voskoboinikov, Zorin. Pozdeev, Prelovsky, Preobrazhensky, Birzhakov, Putrik, Yakovenko, Leonov, Avrah, Chuvatkin[12,31].

The leading problems in their work are:

(1) The organization of tourist destinations and management systems for ecological tourism: it is necessary not only to meet the needs of environmental, as well as related pilgrimage and educa-

tional tourism, but also the needs of the destination itself, created for the preservation and restoration of unique biological objects, flora, fauna, territories and water areas (see **Table 3**);

(2) The issues of increasing the ecological culture of the population and meeting the needs of the population in a way that does not hinder and helps the development of reserves and other previously closed or inaccessible areas or water areas.

Table 3. Structural principles of the organization of reserves

When designing and using SPNA, it is undesirable	When designing and using SPNTs, it is desirable
People are not allowed, there is no buffer zone	People are allowed into the buffer zone
Same small patches Sites of different sizes	Individual management of reserves
An elongated or other irregular shape of the territory	A round (compact) form of the territory
Reserves with monotonous habitats	Reserves with diverse habitats
Isolated reserves, far apart from each other	Reserves with intermediate protected areas
Isolated areas	United sites
Fragmented nature reserve	One-piece nature reserve
A small nature reserve	A large nature reserve
Maintain the river basin partially	Maintain the river basin completely

Note: It's given by Fomichev AN[8].

The famous ecologist Dažo stressed the importance of creating and developing buffer zones around the reserves. He believes that the existence of a small territory, devoid of free communication with the surrounding world, is only the appearance of nature conservation[43]. In zapovedniks it is important to take into account both geographical zoning and the ability of ecosystems of various natural areas to restore, in general, SPNA are systemic activities and, as a system, it includes different levels of accessibility of territories and water areas with different operating conditions, etc. Dazho, following Prenan, believed that the basis of ecology and conservation of ecosystems is the principle of adaptation, i.e., a certain correlation between the organism and its environment. Therefore, system-forming links in the ecosystem are adaptation or correlation links. Therefore, system-forming links in the ecosystem are adaptation or correlation links. In ecological tourism, therefore, it is necessary to strictly split into zones (segments) the interests of tourists and their level of ecological culture. It is necessary to allow or not allow for participation in programs of different types of people. People can be divided into groups with different interests, with different levels of preparedness and perceptions of nature, SPNA, etc. (ecological culture). We need to manage their participation in the context of the temporary and spatial organization of the reserve's life. Management is achieved by taking decisions on admission or non-admission of a particular group or individual tourist to one or another zone of protected areas, as well as by taking decisions on the route and the form of the tourist trip. It is necessary that between the usual areas of human activity and the boundary of the protected area there is a wide band of neutral territory of land or water, preferably several kilometers long, a buffer zone. The task of the buffer area is the protection and conservation of rare species of plants and animals.

In the buffer zone, as it should, and its intended use, a softer environmental protection regime is maintained than in another area of protected land. Even some forms of agricultural work are allowed here, and, for example, "village tourism" is possible. Areas that act as a protected core, integrate territories and water areas, where the rarest and valuable plant specimens grow, where the rarest animals live, including those listed in the Red Book. It is here that live, breed and preserve populations of rare, legally protected animals and plants. Here, there is the most pure, oxygenated and other important and useful or even necessary for the development and reproduction of some species, elements of air, water, land, etc. Here, in the core, access is practically closed to all but the employees of the SPNA: specialists in the field of conservation

and visitors for consultations and other events of scientists and practitioners working in the reserve.

In addition to the protection, study and development of flora and fauna in a given territory, buffer zones are places of more mass ecological tourism routes.

Ecotourism (green tourism) is a form of tourism, focused on visits of relatively natural areas untouched by anthropogenic influence: more or less unique, exotic, different from others[44-46]. Ecotourism naturally develops in specially created protected natural areas: nature reserves, national and nature parks and sanctuaries, nature monuments, etc.: there, where the free stay of tourists and other visitors is usually prohibited. But there are destinations with a long and even centuries-old history, open to everyone, but for one reason or another, for example, inaccessibility of natural or benignity of local residents and tourists - retained their potential. Usually, these are places of worship or "places of power", which are connected with religious purposes (pilgrimage or esoteric tourism).

A narrow understanding of the essence of ecotourism presupposes conducting ecological tours within the boundaries of different categories of specially protected natural areas (water areas)[46]. Abroad, a narrow understanding of ecotourism is often correlated with its "Australian" model. In Russia, a narrow understanding presupposes that ecological tourism scientists and practitioners define as travels made for acquaintance with reference areas of pristine nature, places of growth and habitat of valuable, relict, small, rare and endangered species of plants and animals, forests and areas of the forest, especially valuable in their characteristics (breed composition, productivity, genetic quality), natural objects that play a special role in maintaining the hydrological regime, a unique landscape geological outcrops, the location of rare and especially valuable communities of plants and animals. To the broad meaning of the term ecotourism or the Western European model, considers all types of ecologically oriented tourism not only within the boundaries of specially protected natural areas (water areas), but also outside their borders. In this case, the ecological aspect will be agro-ecotours, ecological-ethnographic, speleological, mountain tours, etc.

In general, ecological tourism is a kind of natural tourism, the main purpose of which is to promote the ecological foundations of nature management in the real economy, production and public consciousness. "ecotourism" is given a "pioneering role" in the development of new territories; great importance is also attached to science research opportunities. The development of ecotourism is closely connected with the system of SPNA, including a protected area. It is important to note that from the very beginning of the history of SPNA in Russia, eco-tourism as a practice of eco-awareness has been included in one way or another in the system of tasks for the creation and development of a SPNA system. The need to protect nature should be presented to the masses in an interesting form for them, using widely available concepts. The existing system of Russian specially protected areas (SPNA) is not only inferior in its potential to international nature reserves, but it also has significant advantages: Russian reserves cover virtually all unique and diverse landscapes and ecosystems that have not been disturbed by human activities. At the same time, Ecological tourism is currently one of the most promising ways of sparing nature use. This type of tourism involves not only visiting undisturbed natural areas, but also studying their properties and characteristics and actively participating in the conservation of flora and fauna.

At the same time, the central issues in considering the correlation of these concepts are the following:

(1) The organization of tourist destinations and systems for the management of ecological tourism, in such a way as to meet both the needs of environmental, as well as related pilgrimage and educational tourism, and meet the needs of the destination itself, designed to preserve or restore unique biological objects, flora, fauna, territories;

(2) The issues of increasing the ecological culture of the population and meeting the needs of

the population in a way that does not hinder but helps the development of reserves and other previously closed or inaccessible territories or water areas;

(3) Issues of zoning protected natural areas and clustering of tourism in each of the types of territories, including in terms of the possibility of creating and the type of tourist destinations.

Each such territory or water area defines indicators of the "tourist potential", including "untouched" territories, their entertainment, educational and recreational opportunities and restrictions. The tourist and recreational potential of the territory integrates a system of indicators (criteria) that provide a systematic assessment of the recreational potential of a tourist object, as well as its individual elements—natural and cultural landscapes: their origin and history, uniqueness, safety, attractiveness and various characteristics of diversity, including species richness of flora and fauna.

There are many natural sightseeing objects on the Earth; they are intended to preserve the idea of the characteristic features of flora and fauna, land and water, peculiarities of a certain epoch of development of the natural world, and so on[43,47,48]. Traditionally in the role of sightseeing objects are used:

- Natural objects—geological outcrops, forests and certain types of trees, shrubs, grasses and fungi, animals—inhabitants of forests, meadows and steppes, river valleys and their constituent parts, lakes, water and terrestrial vegetation, fauna, mountains and glaciers, karst caves and their flora and fauna much more;
- works of architecture and town planning—civil buildings, palaces, castles, kremlins, fortresses, mausoleums, triumphal arches, cathedrals, churches, chapels, monasteries, fountains, tombstones, garden and park ensembles, works of monumental painting and sculpture;
- archaeological sites—various fortifications and earthen ramparts—mounds, dolmens and stone women, pyramids and ancient sculptures, caves with ancient drawings carved on rocks, etc.;
- Territories—expositions of local lore and other museums and galleries, museums of arts and crafts and art;
- Streets and squares of cities and towns, buildings and structures associated with major historical events in the life of the peoples of Russia, affecting the development of nature, flora and fauna, sculptural monuments erected in honor of significant events or significant people, including those engaged in reserve business and nature conservation in general.

Often, as the researchers note, the ecological or "Green tourism is an activity that is associated with agricultural work (ideally, but not necessarily), acquaintance with the life of small towns, walking tours of natural sites, studying flora and fauna, sports, organization of courses national cuisine and tasting of local dishes" [49]. For the successful development of tourism, it is necessary to develop specialized infrastructure and use of technologies, including services that provide various services to provide information and services to domestic services, "Govorova"[28]. Ecological tourism, therefore, requires a high ecological culture from employees of tourist destinations and their cooperation with SPNA staff. Ecological tourism requires a highly professional approach. However, in reality there is a huge deficit of qualified specialists. Such specialists understand the specific nature of ecological tourism. It is difficult for tourist agencies and management of SPNA to find professionals who understand the essence of tour operator activity, pricing policy in the field of agro-tourism, the importance of advertising, geomarketing, information and educational support for the flow of visitors. Such an understanding is all the more important because, in addition to rural tourism as such, specially protected natural areas are the leading components in the development of modern ecological tourism in the world[40,47,48]. They are in the most picturesque, attractive, interesting places; have an established system of service for tourist groups. They also have a well-developed system of tourist routes, experience in organizing educational and recreational work. Such destinations

have the infrastructure and trained personnel necessary for the hotel and tourism business. They have a formed attitude of the local population to a specific natural reserve and the existing ecological restrictions on economic activities on its territory[40]. In addition, despite all the person's desire for "unknown" and "untouched", they must remain intact and "unknowable". In a world undergoing a powerful unification, preserving and developing the identity of regions and their independence, cooperation based on partnership and goodwill largely resists the "globalization" strategy of "survival", forced exchange of resources and forced redistribution as a whole[50,51]. This is particularly noticeable in the practice of SPNA, for which unification and commodification are deadly. In a world undergoing a powerful unification, preserving and developing the identity of regions and their independence, cooperation based on partnership and goodwill largely resists the "globalization" strategy of "survival", forced exchange of resources and forced redistribution as a whole[50,51]. Survival dictates the expansion of contacts and the optimization of ecological tourism as a business: its diversification. Diversification of SPNA' activities include their strategic reorientation to the development of green tourism. Green tourism is perceived as a business. There is also a reorientation of the community and state structures to the diversity and diversification of various aspects of tourism and related tourist sites and destinations, including protected destinations (territories). Diversification is the simultaneous development of unrelated productions, the expansion of the range and range of products within a single enterprise. During periods of intense change, diversification of activities becomes the basic basis for achieving a new level of internal and external flexibility, survival and development. In a world undergoing a powerful unification, preserving and developing the identity of regions and their independence, cooperation based on partnership and goodwill largely resists the "globalization" strategy of "survival", forced exchange of resources and forced redistribution as a whole[1,2]. Survival dictates the expansion of contacts and the optimization of ecological tourism as a business: its diversification. Diversification of SPNA's activities include their strategic reorientation to the development of green tourism. Green tourism is perceived as a business. There is also a reorientation of the community and state structures to the diversity and diversification of various aspects of tourism and related tourist sites and destinations, including protected destinations (territories). Diversification is the simultaneous development of unrelated productions, the expansion of the range and range of products within a single enterprise. During periods of intense change, diversification of activities becomes the basic basis for achieving a new level of internal and external flexibility, survival and development.

On the one hand, so, survival dictates the reserves and other SPNA, the strategy of opening at least part of their territories and water areas for mass visits, on the other—optimizing environmental tourism as a business and part of the reserve and security activities: its diversification. As a result, we are talking about developing and maintaining a strategic orientation of green tourism as a business, reorienting the community and state structures to the diversity and diversified development of various components and aspects of tourism activities and associated tourist sites—destinations, including protected areas.

Diversification—the simultaneous development of unrelated productions, the expansion of the range and range of products within a single enterprise—as a principle of operation of protected and other protected areas speaks about the possibility and importance of segmenting the types of tourism services and routes according to the goals and levels of ecological culture (preparedness) tourists, etc.

Diversification is the simultaneous development of unrelated productions, the expansion of the range and range of products within a single enterprise. The following marketing strategies for diversification stand out:

(1) The strategy of centered diversification, which does not affect the key points of the business and does not involve the development of its new

spaces. Its essence is to find new opportunities for the production of new products and services on existing areas and resources using the technologies used on them;

(2) The strategy of horizontal diversification involves looking for opportunities for growth in the existing "market" through new products and services that will be produced using a new technology that differs from the one already in use. In this case, it is advisable to turn to the release of technologically unrelated products and services that would use the already available capabilities of the company, and could be associated with already produced products and services;

(3) The strategy of conglomerate diversification is one of the most expensive and difficult to implement. Its success depends not only on the availability of the funds necessary to finance the implementation of the strategy, but also on the competence of the staff, seasonality in the life of the market, etc. The essence of the strategy is that business should expand due to the production of new technologically unrelated products and services that are already being produced, which are realized in new markets. During periods of intense change, diversification of activities becomes the basic basis for achieving a new level of internal and external flexibility, survival and development.

During periods of intensive changes and for intensive changes, the diversification of companies, tourist sites and territories, and other structures becomes the basic basis for achieving a new level of internal and external flexibility and survival. Especially important is diversification in the presence of "super resources", that is, untapped resources for the development of SPNA as "enterprises". Geo-branding can work with these resources.

Geo-branding is territorial branding. It acts as a component of the marketing system for protected areas as conservation areas and its diversity, its scientific research, as well as recreation and education of the population. Geo-branding helps to realize vertical and horizontal, external and internal diversification as activating existing or attracting new resources from outside and from within the territory and its cultural, historical and socio-economic potential. So, the reserve can initially attract and "earn" not on mass, but on exclusive visits to the territories: the more SPNA are initially inaccessible, the higher the value of the tourist tour and the requirements for the level of preparation of tourists, for their escort and route.

A special power of geo-branding in the work with protected areas of reserves, zakazniks, etc., gives the systemic character: taking into account as many layers and aspects as possible to the life of the protected and pristine regions, its internal and external relations, opportunities and constraints in the synchronic and diachronic perspectives. The system methodology of geo-branding should reflect the needs of all interested groups (stakeholders), the first among which, however, are "stakeholders" such as fauna and flora of protected areas. It allows and involves the consideration of the past (history and archetypes) and the future (goals and foresight projects) of the formation and development of the region. In addition, in relation to reserves, the central "stakeholders" are scientists and practitioners representing the interests of representatives of protected flora and fauna. These interests are central, and therefore, define as a strategy for building conservation relations with environmental tourism, and geo-branding strategy for the reserve, buffer and adjoining zones. The system methodology of diversification and geo-branding is based on the region's identity and the main problems of its development, including from the point of view of the region's inclusion in larger structures (countries). Another point is—in the case of protecting large and huge territories and water areas, constructive interaction several states in the field of conservation of protected areas not as parts of one country, but as an asset and resource base for the development of the Earth and humanity as a whole. Thus, in the process of development of ecological tourism it is important to take into account the entire arsenal—all the resources of the territory, including recreational ones: conducting ecological tourism requires not only high professionalism, but also systematic interaction of all the specialists involved

in it, cooperation with stakeholders and the leadership of the region. Prospects for the development of ecological tourism are related to the use of geo-branding technologies, tourist destinations and ecotourism in general, aimed at developing the ecological culture of tourists and the whole population, as well as helping destinations and protected and other natural areas in the protection and development of the environment.

Ecological and related types of tourism in protected areas were originally intended to make a minimum impact on protected natural complexes and maximally useful for raising the image of the reserve and maintaining its economic well-being. However, the tourism business is a huge system that presupposes the creation of tourist destinations and a radical transformation of the relations of reserves with the world around them. Tourism implies and gives an opportunity to enhance the image of reserves and ecological culture, education of the ecological culture of the population. For its rational—non-destructive SPNA and developing people—the use should be limited to the system of destinations in the buffer zones and a system of programs that ensure not only the development of tourism business but that promote the spread of moral ideals of human and nature relations. This implies, along with the transformation and intensification of marketing and the bending of protected areas, the systematic diversification of the tourism business, the growth of those spheres and programs that really contribute to the development of both nature and society. However, as noted by the creators of the idea of the reserve business, the nuclear structures of the reserves should remain intact and, if possible, expand: no matter how and what a man fears, he must understand in order to be happy that he is not alone on the planet.

In the modern world, there is a need to develop buffer zones and "transport corridors" around and between nature reserves and other specially protected natural areas, increasing restoration areas and expanding the "skeleton" areas of SPNA. The existence of some strictly reserved, enclosed zones as "framework nodes" creates only the appearance of nature protection. Without buffer and other territories that allow maintaining the harmonious life of the reserve, the latter degrades or is destroyed. Successful and real protection assumes zoning and systemic character in the construction of protected areas and adjacent zones of more or less anthropic activity. Similarly zoning in ecological tourism is necessary: it is necessary to clearly distribute and correlate the interests of tourists and the level of ecological culture that they and society have in common, and the zones in which they can be safe for themselves and reserves are allowed. It is also necessary to develop different visiting regimes in the context of their time and spatial organization. Ecological tourism requires a highly professional approach, but in reality, there is a huge shortage of qualified specialists who would understand the specifics of eco-tourism, the essence of tour operator activity, pricing policy in the field of agro-tourism, the importance of advertising, geo-marketing and geo-branding, information and educational support for the flow of visitors.

3. Conclusion

"Zapovednoe delo" (nature conservation) is a sphere of activity that includes the planning and development of the system of reserves, the conservation of species and ecosystems in them, the organization of research work and the development of multi-level and flexibly changing regimes for environmental and economic activities. The reserve business is a system of organizational, legal, scientific, economic and educational activities aimed at preserving, researching and developing unique and typical landscapes or individual natural objects from scientific, environmental and other purposes, as well as the formation and development of the ecological culture and competences of the population. The reserve, as a territory or water area, is allocated from the general fund of territories and water areas in order to preserve in a natural state typical or unique natural complexes with the totality of their components, to study the natural course of the processes and phenomena occurring in them, and to develop the scientific basis for nature protec-

tion. The reserve is an institution that operates as a system of environmental, research and environmental education structures whose purpose is to preserve and study the natural course of natural processes and phenomena, the genetic fund of plant and animal life, certain species and communities of flora and fauna, typical and unique ecological systems and their interactions, including with human systems. In Russia and some countries of the former USSR, the reserve is part of the territories and objects of the natural reserve fund (SPNA). Plots of land, its subsoil and water spaces with all natural objects within the reserve are withdrawn from economic exploitation. They transferred to the reserve for unlimited and uncompensated use. To optimize the work of the reserve, buffer territories and green corridors are created, in which excursion and other types of activities serving the interests of the reserve are possible.

"Zapovednoe delo" (nature conservation) is a special sphere of human life, integrating the planning and development of a network of reserves, protection and preservation of various ecosystems in SPNA, organization and implementation of research work on optimization of environmental and economic (including tourism) regimes. In the reserves themselves, only studies and other types of human activity are permissible, which, on the one hand, cannot be carried out in an uninhabited territory, and on the other, do not pose a (significant) danger to the conservation of natural complexes of protected areas. However, the notion of "materiality" of the danger is very ambiguous: in a world where even, human life is not of particular value, where whole communities and territories where environmental problems are not being resolved but are aggravated destroy wars, the fate of reserves and other SPNA cannot yet be optimistic.

The most important problems in this area are the lack of a common national concept for the development of rural tourism; clearly formulated state policy; standards and regulations applicable in the field of rural tourism; qualified staff; knowledge and work experience in the service sector of foreign and domestic tourists; normative and legal acts regulating activities in the field of rural and ecological tourism; unwillingness and inability to rationally use their own recreational resources. Despite the numerous problems in the last few years, research and practical developments in the field of ecological tourism have intensified. Research and works of the geo-branding sphere play an important role in them. Geo-branding as a modern technology of territory marketing can be directly used to work with different population groups (stakeholders) in the direction of understanding and maintaining the dignity (resources) of the region, its cultural and historical heritage and innovations. Territory branding is a strategy of forming and strengthening the competitiveness of cities and other settlements with the aim of conquering new and strengthening old external and internal markets, attracting investors and tourists, as well as harmonizing relations of residents in the region and attracting new residents, including migrants. The main conditions for the productivity of geo-branding are its consistency. The system methodology of geo-branding takes into account the needs of all interested groups (stakeholders). It also includes the consideration of the past (history and archetypes) and the future (goals and foresight projects) of the formation and development of the region. It relies on the identity of the region and the main problems of its development, including, from the point of view of the region's inclusion in larger structures (countries). It presupposes a comprehension of the development of social and human, as well as cultural and historical capitals, no less than the capitals of financial and material. It relies on the crowd-technology and technology of social partnership and social service, intersubjective, and not only monosubjective management. In addition, geo-branding in many ways meets the challenges of diversifying the strategic orientation of business, the community and state structures to the diversity and diversified development of activities. Possessing a brand, sanctuaries and reserves it is more often easier to keep oneself as an organization protecting territories and water areas. However, the most important thing is the preservation of the

territories and water areas themselves, and not just the organizations and destinations. Diversification of the activities of protected areas should serve not just business, but is an environmental technology.

Conflict of interest

The author declared no conflict of interest.

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ORIGINAL RESEARCH ARTICLE

Formation clusters of nature using in Agrarian regions of Dagestan: Theory and practice

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ABSTRACT

The principles and methods of strategic analysis of processes of using natural resources of Dagestan are justified. The purpose of the study is determined by the tasks of forming territorial clusters capable of ensuring the growth of the competitiveness of the regional economy and the intensification of the mechanisms of public-private partnership. The term "cluster of natural resource management", underlying the basis of the work, on content corresponds to the notion of a territorial cluster that is at the initial stages of its development. The formation of territorial clusters in rural areas of Dagestan is aimed, in particular, to overcome the dominant trend of monopolized for many decades, it means the indifferent in solving the problems of low level and quality of life of the rural population, resource use.

Keywords: Dagestan; Natural Resources; Cluster of Nature Using; Nature-use Management; Agro-tourist Cluster

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1. Introduction

(1) The relevance of the study is determined by the alarming economic reality of Dagestan. There is the high resource and row orientation of the economic system in the most southern republic of the Russian Federation. Highly effective processing productions are poorly developed there, and that is the reason for a low level of incomes and quality of life. As a result, the migratory balance of Dagestanis has been negative for many decades. Therefore, one of the strategic objectives of the economic development of Dagestan is to create conditions for doing business that would maximally contribute to the growth of efficient and competitive industries based on using of local natural resources and, ultimately, the improvement of the living standard and quality of life of the local population.

On closer inspection, Dagestan, with its exceptionally diverse natural and economic and ethnocultural structure, has resemblance to the "geographical portrait" of the whole of Russia, which still maintains the "resource curse" (a negative impact of the economic structure on the country's economic growth) as a legacy from the USSR. This circumstance gives the additional importance to the scientific development of environmental management issues in Dagestan from the position of strategic management objectives.

(2) The methodological basis of the study is determined by modern theories of cluster analysis of spatial production processes and the formation of territorial clusters in the region. The methodological apparatus includes general scientific methods of modeling, comparison, and expert opinions of the studied processes. In order to solve the problems

put forward in the work, methods of system and statistical analysis, logical-graphical and cartographic methods of investigation were applied.

(3) The scientific novelty of the study is the development of a methodological apparatus for studying clusters of nature management in rural areas in order to enhance the competitiveness of enterprises and expand the practice of public-private partnership in the region's economy.

(4) The practical importance of the work is determined by constructive proposals for the formation of effective clusters of nature management in rural areas of Dagestan, strengthening of competitive advantages, expanding the practice of import substitution in the agrarian sector and reducing the level of threats to the socio-economic systems of the territories in question.

2. Resource system clustering

The cluster approach to the study of problems related to the environmental management in the region includes two main aspects of the systemic research: analytical and synthetic.

(1) The analytical aspect involves the identification and classification of ecosystem elements, and also the structuring of their channels to the office. Such an analysis is usually accompanied by the indexation of disparate elements of the natural environment, capable of acting as generating or realizing, promoting or restraining, negative or positive factors in the development of the studied territory[1,2]. The methodology of such an analysis is improved primarily in the field of statistics, so in this case it is rather a statistical-analytical approach to clustering ecosystems.

(2) The synthetic aspect of clustering is a traditional approach to geographic and economic science. It is aimed at rationalizing the whole cycle of the movement of substance, energy and information within the studied spatial system: from the development of the natural resource (deposit) to the transport-geographic (logistic) optimization of links between the nodes of supply and demand[3]. At the same time, the information is mainly drawn from the documentation of enterprises and industries to identify clusters as integral spatial systems.

2.1 Analytical aspect of clustering

On the basis of statistical analysis, the various relationships between resource users and environmental components in the region were indexed, which subsequently served as the formation of a computer database for environmental management. The algorithm for such an analysis consists of the following main steps: the definition of the set of variables by which objects in the sample will be evaluated; normalization of values of variables; calculating the values of the measure of similarity between objects[4].

An important point in cluster-statistical analysis is the definition of "similarity" of objects[5]. In this case, one vector of the object's characteristics can be oriented to its numerical values (for example, the amount of reserves in tons, the possible lifetime of the resource), and the other on qualitative parameters (geoecological hazards, medical and environmental consequences, tourist attraction of a natural monument, etc.).

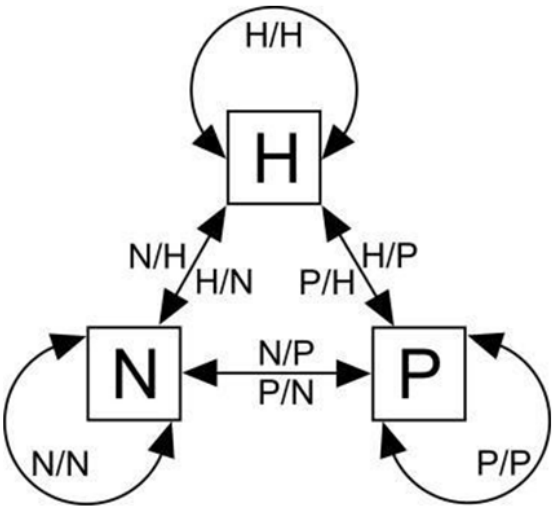

Figure 1. Morphology of the resource system.

Clustering of the spatial resource system begins with the designation of its main morphological elements—Natural, Human, Production—specific symbols (N, H, P). In this scheme, the Human subsystem is located at the top of the triangle, and the controller functions of the remaining elements of the system are assigned to it (**Figure 1**)[2]. An important theoretical premise is the notion that the entire variety of the studied functional connections and relations in the system Natu-

ral-Human-Production is reduced to the flows of substance (including people), energy and information within a particular territory[6,7].

It should be noted that the scope of this study was limited to analyzing the central morphological relationships between the two regulated resource blocks of the system—Nature (N) and Production (P). At the same time, in the analysis of cluster processes in the agrarian and tourist spheres of the region, serious attention was also paid to the links and conflicts along the lines of interaction between Nature (N) and Human (H).

The main communication channels between the resource system blocks can be designated as N/N, P/N, H/H, H/P, H/N, P/P, and the direction of the links—PH, NP, etc., where the first character indicates the source, and the second—on the final communication agent. The difference in pairs H/P and P/H, P/N and N/P, N/H and H/N is determined by the dominant influence of one or another morphological element of the resource system.

When introducing additional symbols (i—information, e—energy, s—substance, p—people), the symbolism can be concretized by indices (a combination of symbols) characterizing some state of this element. For example, the HPp index will refer to the movement of people to and from production facilities, etc.

Further, we list the indices of resource links along the main channels and directions of interaction: N/N—a set of links between individual components of the natural environment; H/H is a set of social connections, among which are demographic links (HHp—all kinds of natural, migration and social movement of the population), social information links (HHi—Internet information flows, telephone conversations, mail correspondence, money transfers, etc., not related to the maintenance of production) P/P—a set of production links, including technological links that combine individual elements of production along the line of changes in the state, properties, shape or size of raw materials, mothers ala or semi-finished product in the process of obtaining the finished product, as well as almost all types of movement of raw materials and material from the supplier to the consumer.

The first stage of clustering the regional system of nature management in our study was the mapping of 100 major deposits for 22 types of natural resources of Dagestan. At the same time, the administrative boundaries of the territorial districts of the republic—the Northern, Central, Mountainous and Southern (**Figure 2**) acted as spatial limits of statistical compilation. On the basis of such a map, it was determined that these districts were provided with resource deposits (in%) and, accordingly, a promising specialization of the districts on specific types of subsoil use.

The second stage of clustering relied on a computer-software basis. In this, the information on natural resources in accordance with the principles of development of geoinformation databases was grouped into 14 classes and 54 species. The catalogue of natural resources of Dagestan is denoted by the root index [nature]:

(1) Space resources [index: space]: 1. territory resources [ter_are]; 2. resources of the sea water areas [sea_are]; 3. resources of lake water areas [lake_are]. (II) Climatic resources [climat]: 1. republic-wide climate resources [rep_clim]; 2. regional climate resources [reg_clim]. 3. atmospheric air in settlement [atm_settl]. (III) Water resources [water]: 1. seawater [sea_water]; 2. lake water [lake_water]; 3. river water [riv_water]. (IV) Land resources [land]: 1. republic-wide land fund [rep_land]; 2. surface geomorphological structures [surf_geo]; 3. deep geomorphological structures [deep_geo]; 4. geomorphological structures of the sea coast [coast_geo]. (V) Soil resources [soils]; 1. republic-wide soil cover [rep_soil]; 2. regional soil cover [reg_soil]. (VI) Vegetation [flora]: 1. republican vegetation cover [rep_vege]; 2. grass cover [grass]; 3. forests and shrubs [forest]. (VII) Animals [fauna]: 1. wild animals [wild_faun]; 2. hunting resources [hunt_faun]; 3. fish resources [fish_res]. (VIII) Natural recreational resources [rekrea]: 1. resources of ecological tourism [eco_rekr]; 2. balneological resources [baln_rekr]. 3. resources of seaside holidays [sea_rekr]. (IX) Hydromineral resources [hydrom]: 1. underground industrial waters [under_wat]; 2. artesian water [artesi_wat]; 3. healing mineral water [heal_wat]. (X) Energy resources [energy]: 1. geothermal energy [geo_therm]; 2. hydropower of rivers [rive_ener]; 3. solar energy [solar_ener]; 4. wind energy [wind_ener]. (XI) Fuel resources [fuel]: 1. oil [oil_res]; 2. natural gas [gas_res]; 3. coal [coal_res]; 4. peat [peat_res]; 5.

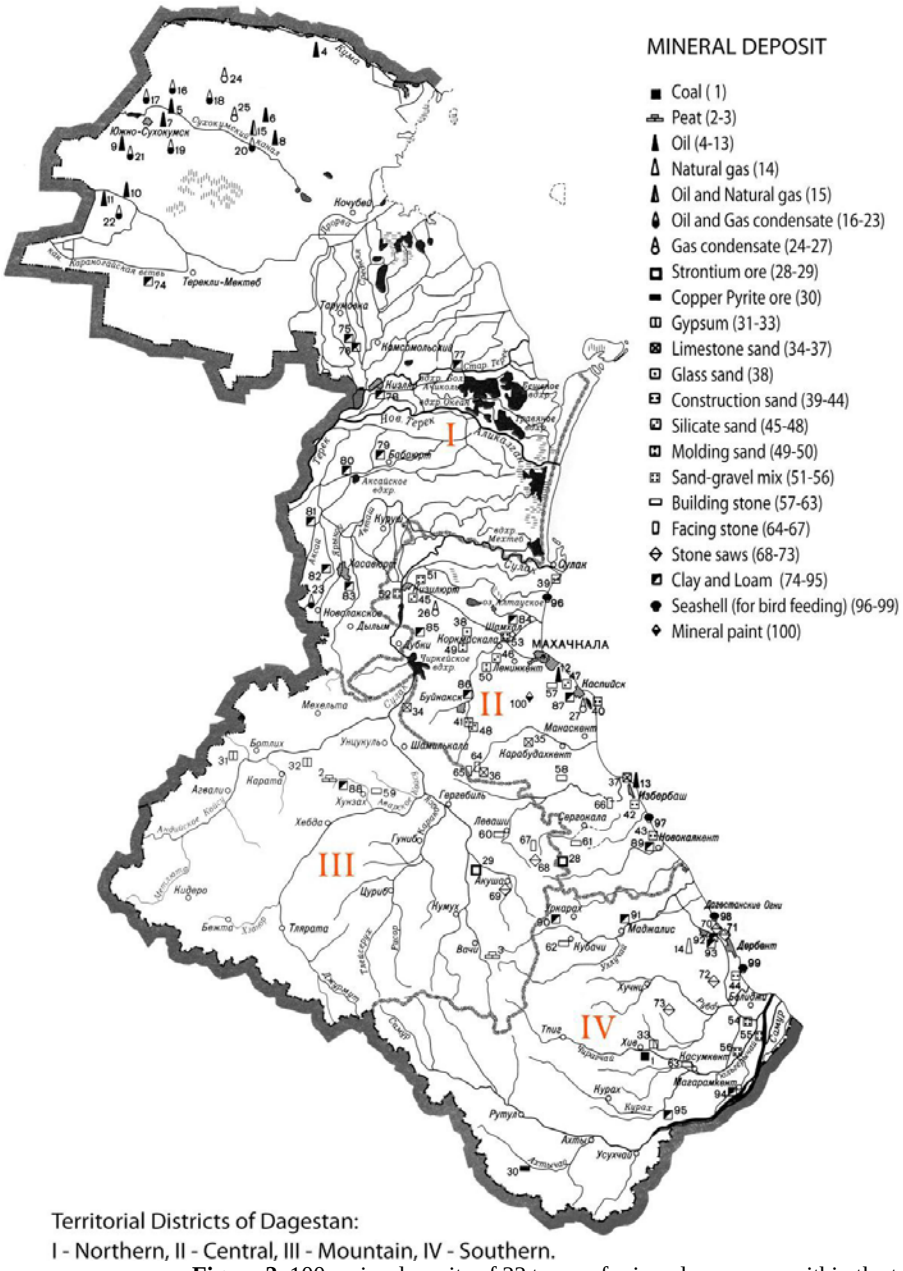

Figure 2. 100 major deposits of 22 types of mineral resources within the territory of Dagestan.

combustible shales [shal_res]; 6. wood [wood_res]; 7. biogas [biog_res]; 8. agricultural waste (straw, dung) [dung_res]. (XII) Building materials [build]: 1. construction sand [const_sand]; 2. sand-gravel mixtures [sand-grav]; 3. building stones [stone_res]; 4. construction and refractory clays [clays_res]; 5. limestone for lime production [lime_res]; 6. gypsum [gyps_res]. (XIII) Mineral-chemical raw materials [minchem]: 1. glass sands [glass_res]; 2. sands molding [moldi_res]; 3. carbide limestones [karb_res]; 4. sulfur [sulf_res]; 5. phosphorites [phosp_res]; 6. rock crystal [cryst_res]; 8. sea shell for bird feeding [shell_feed]. (XIV) Nonferrous metal [nonfmet]: 1. copper [copp_res]; 2. strontium [stront_res].

A special object of ecological clustering of the territorial districts of Dagestan is the occurrence of natural and industrial conflicts[8]. Each such a conflict indicates a tendency of degradation of natural resources and conditions of the region: ambient air, ground and surface water, soil and forest cover, fauna, marine shores, nature monuments, resort areas, protected areas, etc. In total, 26 types of natural and industrial conflicts (k) are considered in the work, each of which has its own serial number (index): k1—mechanical pollution of

the atmosphere; k2—chemical pollution of the atmosphere; k3—destruction, flooding and waterlogging of sea shores; k4—destruction and flooding of river banks; k5—siltation of water bodies; k6—depletion and pollution of waters of small rivers; k7—depletion of lakes and lagoons; k8—pollution of groundwater; k9—pollution of surface waters by domestic sewage; k10—degradation of the environment of populated areas as a result of anthropogenic impacts; k11—destruction of the environment of populated areas under the influence of natural forces; k12—degradation of delta complexes as a result of anthropogenic impacts; k13—destruction of delta complexes under the influence of natural forces; k14—degradation of natural forage lands; k15—extermination of valuable and rare animals; k16—violation of land by mining; k17—decrease in the quality of resort areas; k18—degradation of forests under the influence of non-forest activities; k19—forest cutting; k20—pollution of sea waters; k21—intensive gully formation; k22—blowing (deflation) of soils; k23—secondary salinization of soils; k24—chemical contamination of soils; k25—accelerated erosion of soils; k26—depletion of fish stocks. This made it possible to determine the diversity of environmental problems and the level of environmental tension in each of the territorial districts of Dagestan.

2.2 Synthetic aspect of clustering

The spatial-synthetic approach to clustering concentrates on the territorial integrity of the processes of using natural resources. These are the problems and prospects for the formation of clusters as groups of interconnected enterprises (firms, companies) in the production and use of local resources with common territorial interests and in many cases with strict self-restraints (in order to achieve social and environmental consensus) in the nature of their development[9]. The identifying element of a territorial cluster is its innovative core in the form of a separate enterprise, their cooperation or economic sectors that ensure the spread of technological innovations and, at the same time, increase the competitiveness of industries that extract and process resources.

In the functional model of the resource cluster, its objective function is designated as a “competitive advantage”. The main stimulating factor of such a system is the “economic initiative” of people. The main regulating factor in the cluster is associated with the notion of “effective management” (**Figure 3)**.

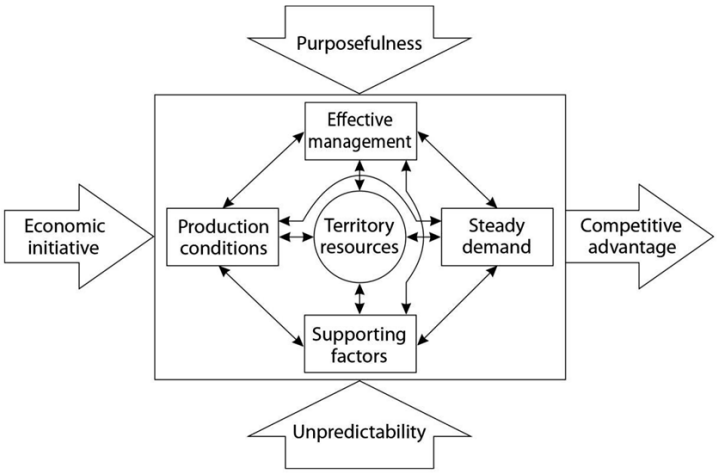

Figure 3. Basic functional model of the resource cluster**.** (the scheme was compiled according to the literature[12] with the author’s additions).

The solution of problems of cluster formation in the sphere of nature management is impossible without effective interaction of government and business, formation of public-private partnership (PPP) between them. For this, it is necessary to strengthen mutual interest between specific au-

thorities (environmental, industrial, agrarian, tourist, trade and marketing, etc.) and representatives of small businesses representing the countryside[10]. Such a partnership can significantly improve access to natural resources, facilitate the procedures for registering a lease, the right to use, ownership of resources. Unfortunately, in Dagestan there is no experience in implementing investment environmental projects based on PPP. Meanwhile, such a partnership is able to ensure mutual respect and a balance of interests in determining the ways and stages of the solution of the tasks, the implementation of mutual agreements, and regular and proper monitoring of their implementation in the use of the region's natural resources[11].

The main attention was paid to the study of the genetic and functional structure of clusters. The genetic structure of clusters assumes the identification of resource cycles, taking into account the three main stages of their evolution: (1) initial (prevalence of production and initial processing), (2) intermediate (deep processing) in the region, (3) final (implementation outside the region). The functional structure of clusters reflects real and potential real-energy-information cycles of production activity within the space under study.

In the course of the study, it was revealed that the natural resource potential of Dagestan's agrarian landscapes at the current level of technology and technology development can ensure the formation of at least 11 functional types of nature use clusters of different scale: 1) ore-industrial, 2) construction-industrial, 3) oil-chemical, 4) geothermal-industrial, 5) hydropower-chemical, 6) waterintake-irrigation, 7) agrarian-industrial, 8) agrarian-tourist, 9) fish-production, 10) protected-tourist, 11) spatio-logical.

When solving problems of forming clusters of environmental management of a regional scale, the General Scheme of social and economic development of the territorial districts of Dagestan: Northern, Central, Mountainous and Southern, adopted in 2013, is adopted as a basis[13]. At present, these districts are the largest objects of strategic planning in the republic (**Table 1**).

Table 1. Prospective of nature-use clusters for territorial districts of Dagestan

Districts	Nature-use clusters
Northern	1) fish-production 2) agro-industrial 3) reserved-tourist 4) watertake-irrigation 5) agro-tourist 6) oil/gas-chemical 7) geothermal-production
Central	1) space-logistic 2) buildmaterial-industrial 3) watertake-irrigation 4) agro-industrial 5) agro-tourist 6) geothermal-production 7) oil/gas-chemical
Mountain	1) agro-industrial 2) agro-tourist 3) reserved-tourist 4) watertake-irrigation 5) hydroelectric-chemical 6) buildmaterial-industrial 7) ore-industrial
Southern	1) agro-industrial 2) agro-tourist 3) reserved-tourist 4) space-logistic 5) hydroelectric-chemical 6) buildmaterial-industrial 7) oil/gas-chemical

To determine the production specialization of districts for each of them, a ranked scale of 7 clusters of resource use on a district scale was established. Ranking of district clusters was carried out on the basis of a detailed analysis of the resource potential of the territorial districts of the Republic of Dagestan, as well as strategic goals and objectives substantiated by an expert way.

The methodology of strategic planning of regional resource systems presupposes the allocation of two forecast-extreme trends of their development. The first trend is the result of the influence of internal and external factors. The second trend is a consequence of possible positive and negative trends in the development of the system under study. This kind of "parametric" approach to the strategy of development of spatial systems of nature management is usually based on the application of PEST- analysis and SWOT-analysis techniques. PEST-analysis focuses on the study of external competitive environment, SWOT-analysis—with the identification of features of functioning and development of internal competitive environment

(**Table 2**).

Table 2. Matrix of strategic analysis of spatial systems of nature management

External competitive environment (in the first approximation)				**Internal competitive environment (in the first approximation)**			
The main positive processes		The main negative processes		The main positive processes		The main negative processes	
External competitive environment (in-depth study)				Internal competitive environment (in-depth study)			
Political	**E**conomic	**S**ocial	**T**echnological	**S**trengths	**W**eaknesses	**O**pportunities	**T**hreats

The results of PEST- and SWOT-analysis were taken as a basis for the development of forecast scenarios of nature use within the traditional objects of statistical analysis in the region under consideration—its territorial districts and municipal districts.

3. Formation of clusters of agrarian specialization in the region

By now, there is a wealth of experience in studying the processes of agrarian cluster formation abroad[14-21]. Such experience is quite applicable in the practice of creating clusters of nature management in rural areas of Dagestan.

The main measures and, at the same time, the stages of implementing cluster economic policy within rural areas include the following:

(1) Disclosure of opportunities and motives, as well as all-round support of initiatives of association of agricultural producers and related structures in clusters.

(2) Substantiation of the goals, prospects and effective forms of integration of participants in a cluster association in rural areas.

(3) Development of an environmental management cluster project, including: the identification of the participants, the formation of a central cluster company, the development of a cluster management structure, the division of responsibilities between cluster members, and the establishment of close collaboration between the cluster leadership and the local administration. Substantiation of legal documents of a cluster of nature management in a particular territory.

(4) Development of a system of financial and credit relations in a cluster.

(5) Feasibility study of the environmental management cluster project.

(6) Determination of the efficiency of cluster operation (its main indicators).

(7) Organizational activities, including: the development and signing of the Treaty on the creation of a cluster.

(8) Preparation of normative documents jointly with the administration of the municipality.

(9) Development of the Charter of the central company of the cluster.

(10) Dagestan is characterized by a natural interaction of mountain nodes, trails and ranges of the location of valuable natural resources (glaciers, waterways and reservoirs, soils of river valleys, basins and mountain plateaus, mineral deposits, etc.) with nodes, paths and areas located on the plain formation of productions for the processing of natural raw materials, transportation and sale of finished products[22]. Ultimately, through this interaction, production links between depressive mountain areas and the main poles of the socio-economic growth of the lowland zone are activated.

The seaside and mountainous rural landscapes of Dagestan with their extremely diverse and sometimes unique natural and cultural and historical sights create a fertile environment for the development of various tourist and recreational technologies for serving the population[8,23] Tourist and resort institutions in the agrarian zone are able not only to successfully fit into the natural landscapes, but also harmoniously combined with local ethnographic and economic colors, which serves as a guarantee of the formation on the territory of Dagestan of unique agro-tourist “conveyors” along the chain: the seacoast–the plain–foothills–low mountains–middle mountains–high mountains. The spatial configuration of such “conveyors” is determined by the nature of the location of river basins, which should be the basis for the development of strategic plans for agrarian and tourist cluster formation in the republic.

3. Research results

(1) A theoretical model of the spatial resource system of the region was developed.

(2) The author's approach to the systematization of factors and the scientific explanation of the mechanisms for the functioning and development of environmental management clusters in the region are outlined.

(3) The main production functions and the structure of environmental management clusters in the projection of the territorial districts of Dagestan are described.

(4) The mineral resource potential was investigated and the main directions for the formation of territorial clusters of nature management in Dagestan was established.

(5) The concept of "conveyor" tourism development in the region based on the chain is substantiated: the seaside–plains–foothills–lowlands–highlands.

(6) The horizons for the formation of agrarian and tourist clusters of various specializations in the scale of Dagestan are highlighted.

4. Conclusions

The strategy of socio-economic and ecological development of the region should be based on a sufficiently deep knowledge of the functional, spatial and temporal structure of the process of using the resource potential of the studied territory. At the initial stage of such structurization, two methodological approaches to research of the resource use scheme (statistical-analytical and spatio-synthetic) are implemented, which create the necessary deductive base for clustering regional ecosystems.

One of the tasks of clustering as a statistical-analytical procedure is not only the analysis of various factors and processes, but also the structuring of control channels. Clustering as a spatio-synthetic procedure is aimed at optimizing the entire cycle of spatial movement in the region of substance, energy and information from the development of natural resources (deposits) to specific centers for their processing and implementation with the formation of integral systems of nature management.

The most rational is the general scheme of nature management in Dagestan, in which, at the level of planning decisions, cluster interaction of the depressive mountain zone with economically active plains territories is provided.

Conflict of interest

The authors declare that they have no conflict of interest.

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ORIGINAL RESEARCH ARTICLE

Study on the current situation of grassland resources and ecological environment protection countermeasures in Sichuan Province

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ABSTRACT

Sichuan Province is rich in grassland resources which is one of the five pastoral areas in China. It is an important part of the national Qinghai–Tibet plateau ecological barrier area and has a very important strategic position in the country. Starting from the current situation of grassland resources in Sichuan Province, based on the achievements and existing problems of grassland ecological protection, this paper puts forward countermeasures for grassland ecological protection in Sichuan, aiming to better promote the high-quality development of grassland in Sichuan and the construction of ecological barriers in the upper reaches of the Yangtze River and the Yellow River.

Keywords: Grassland Resources; Grassland Degradation; Ecological Protection; Compensation Mechanism; Qinghai-Tibet Plateau

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1. Introduction

Located in the southeast edge of the Qinghai–Tibet Plateau, the grassland in Sichuan Province is an important part of the ecological barrier area of the Qinghai–Tibet Plateau. It is the second largest Tibetan area, the first largest Yi area and the only Qiang inhabited area in China. It plays a very important role in the protection and construction of the ecological environment, the maintenance of national ecological security, the structural adjustment of animal husbandry, the economic development and social stability of ethnic areas. Since the 18th CPC National Congress, the quality of grassland ecological environment in Sichuan Province has shown a steady and positive trend, and the service function of grassland ecosystem has been steadily improved, laying a solid foundation for the decisive victory in building a moderately prosperous society in all respects. At the same time, affected by the continuous increase of population and material demand, the current grassland natural ecosystem in Sichuan Province is still relatively fragile, with insufficient ecological carrying capacity and environmental capacity, and the pressure of ecological protection brought by economic development is still large. Strengthening the research on ecological protection of grassland in Sichuan is the basic requirement to further strengthen the national ecological security barrier, and it is also a concrete manifestation of the further practice of Xi Jinping's ecological

civilization construction in the new era.

2. Overview of grassland resources in Sichuan Province

2.1 Distribution of grassland resources in Sichuan Province

The grassland area of Sichuan Province is 21 million hectares, accounting for 43% of the total area of the province. The available natural grassland area is 18 million hectares, accounting for 84.7% of the total grassland area in the province. There are 16 million hectares of natural grassland in the province, which are concentrated and distributed in Ganzi, Aba and Liangshan Autonomous Prefectures, mainly in the area with an altitude of 2,800–4,500 m. It borders Tibet, Qinghai, Gansu, Yunnan, Guizhou, Chongqing and Shaanxi provinces (cities and districts), and is one of the five major pastoral areas in China[1].

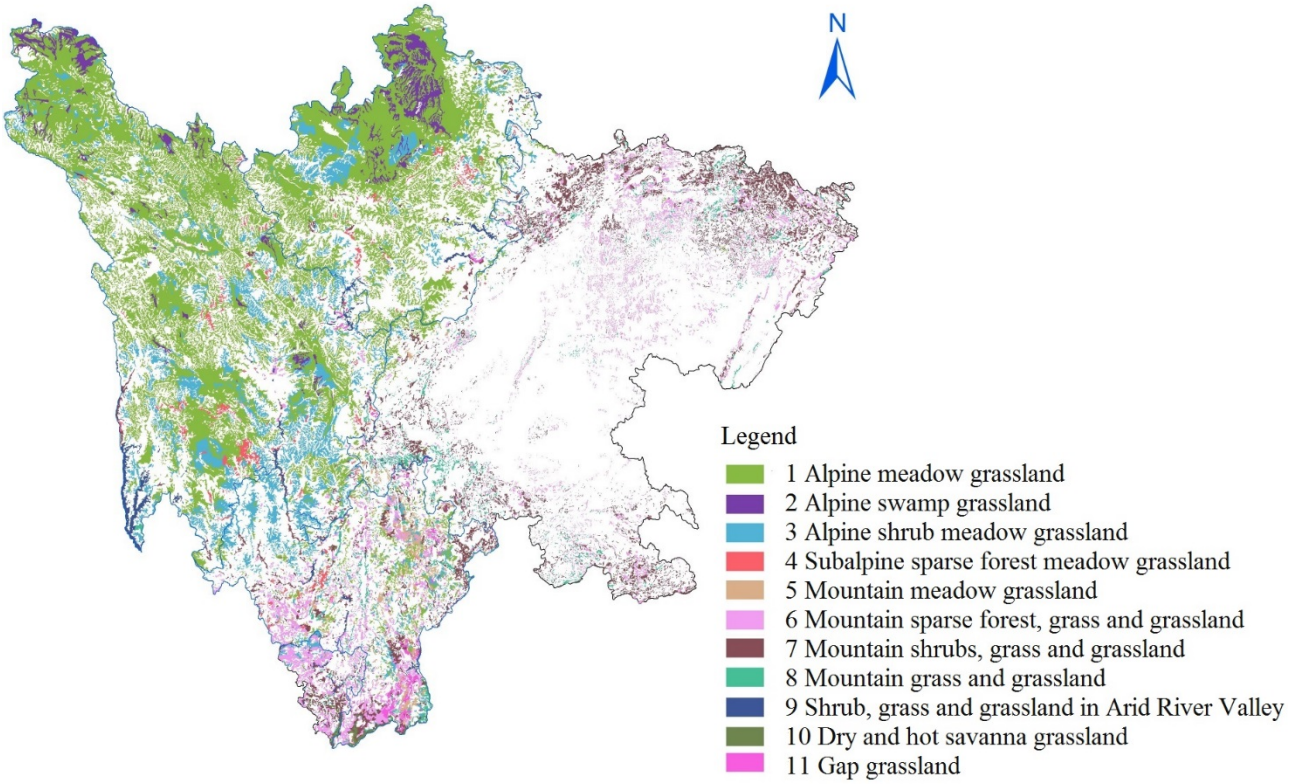

Figure 1. Distribution of grassland types in Sichuan Province.

The grassland distribution areas in the province have complex landform, uneven distribution of hydrothermal conditions, diverse vegetation types, and frequent natural disasters such as grassland snow disaster, fire, debris flow and so on. The west is the eastern extension of the Qinghai–Tibet Plateau, with an average altitude of about 4,000 m. The relative altitude difference in the northwest of the plateau is 50–100 m. The terrain is open and flat, the climate is cold, and the sunshine is strong. 80% of the precipitation is concentrated in May–August. The grassland is mainly alpine meadow and alpine shrub grassland. The southeast of the plateau is Hengduan Mountain area, with vertical and horizontal high mountains and valleys, wide height differences, significant microclimate effects, obvious vertical changes, large temperature differences, and distinct dry and wet seasons. The grassland is dominated by mountain meadow grassland and mountain shrub grassland. Southwest Sichuan is a mountainous area, with an altitude of 1,000–3,500 m. The landform is similar to that of Yunnan–Guizhou Plateau. Some areas have a subtropical climate, with long warm seasons and high heat. The vertical distribution of grassland resources in the area is obvious. From high to low, there are subalpine

meadows, mountain meadows, mountain shrub grass, and dry valley shrub grass. The interior of the basin is dominated by plains and hills. The climate is mild, the soil is fertile, and the land reclamation and utilization is high. There are mainly agricultural gap grassland and sporadic shrub grassland.

2.2 Characteristics of grassland resources in Sichuan Province

There are various grassland types in Sichuan, including 11 categories, 35 groups and 126 types, with an altitude of 270–5,500 m. The top three types of grassland with the largest area are alpine meadow grassland, alpine shrub grassland and mountain shrub grassland, accounting for 49%, 15% and 9% of the total grassland area of the province, respectively. The natural grassland is mainly composed of Gramineae, Cyperaceae, Leguminosae and miscellaneous grasses, of which 355 species belong to 107 genera of Gramineae vegetation and 213 species belong to 64 genera of Leguminosae plants.

In 2017, the province's natural grassland fresh grass output was 86.97 billion kg, and the average yield of available natural grassland fresh grass per acre was 327.5 kg/667 m^2. Among the 11 types of grassland in the province, the usable grassland area of four types of grassland, including alpine meadow grassland, alpine shrub grassland, mountain shrub grassland and mountain sparse forest grassland, account for 80% of the grassland in the province, of which the output of fresh grass is 67.01 billion kg, accounting for 77.0% of the total output of the province; and the output of fresh grass is 227.5–458.0 kg per 667 m^2. According to statistics, the grassland area in Sichuan ranks fifth in the country, but the grassland productivity per unit area ranks first in the five pastoral areas in the country, and the total output of fresh grass in natural grassland ranks second in the country.

3 Current situation of grassland resources in Sichuan Province

3.1 Protection and effectiveness of grassland resources in Sichuan Province

Since the 13th Five–Year Plan, the Sichuan provincial Party committee and government have put grassland ecological protection in a more prominent position, always strengthened the upstream awareness, strengthened green development, continued to strengthen projects such as returning grazing to grassland, returning farmland to grassland, grassland ecological protection and restoration, and steadily implemented policies such as subsidies and incentives for grassland ecological protection. The quality of grassland ecosystem has been improved, and grassland ecological functions have been gradually restored. According to statistics, Sichuan Province has implemented the project of returning grazing to grassland since 2003. The project has covered 48 counties, 1,110 towns and townships in Ganzi, Aba and Liangshan prefectures, more than 1.07 million herding households and more than 4.13 million herdsmen. By 2019, a total of 9.421 million hectares of fences for returning grazing to grassland will be assigned (including 2.35 million hectares of grazing prohibition, 5.963 million hectares of rest grazing, and 1.017 million hectares of regional rotational grazing), 2.446 million hectares of grassland supplementary sowing improvement, 72,700 hectares of artificial feeding grassland construction, 47,000 households will be assisted in the construction of sheds, 17,300 hectares of black soil beach treatment, 13,300 hectares of toxic grass treatment. The total investment is 4,709.44 million yuan, including 3,672.37 million yuan from the central government and 1,037.07 million yuan from local supporting facilities.

3.2 Degradation status of grassland resources in Sichuan Province

At present, the grassland natural ecosystem in Sichuan Province is still fragile on the whole, with insufficient ecological carrying capacity and environmental capacity. The pressure of ecological protection brought by economic development is still large, and the contradictions accumulated by emphasizing development and neglecting protection in some areas are becoming increasingly prominent. According to statistics in 2018, the degraded area of natural grassland in the province was 9.814 million

hectares, accounting for 69.59% of the total area of natural grassland in the province. Among them, the area of rats and pests is 3.3707 million hectares, accounting for 34.35% of the degraded area of the province; the area of poisonous weeds is 2.7342 million hectares, accounting for 27.86% of the degraded area in the province; the area of grass hardening is 3.3402 million hectares, accounting for 34.04% of the degraded area in the province; the desertification area of grassland is 215,800 hectares, accounting for 2.20% of the degraded area of the province; the pasture disease area is 153,000 hectares, accounting for 1.56% of the degraded area in the province (see **Table 1**).

Table 1. Distribution area of degraded grassland in Sichuan Province (10,000 Hectares)

Name of prefecture and city	Total area of degraded grassland	Rodent infestation area			Distribution area of poisonous weeds			Grassland hardening area	Grassland desertification area	Pasture disease area
		Subtotal	A plague of rats	Insect pest	Subtotal	Poisonous grass	Of which: crofton weed			
Total of the whole province	981.40	337.1	265.9	71.18	273.42	273.42	15.94	334.02	21.58	**15.3**
Ganzi Prefecture	700.10	214.99	178.13	36.86	128.53	128.53	0.37	334.02	10.81	**11.73**
Aba Prefecture	245.10	106.82	76.98	29.85	125.33	125.33	-	-	10.3	**2.64**
Liangshan Prefecture	36.19	15.25	10.78	4.78	19.55	19.55	15.78	-	0.46	**0.92**
Other cities	0.004	-	-	-	0.004	0.004	-	-	-	-

The lightly degraded grassland area in the province is 4.5708 million hectares, the moderately degraded grassland area is 3.1007 million hectares, and the severely degraded grassland area is 2.1425 million hectares, with a total area of 9.814 million hectares. The three prefectures are the main areas of grassland degradation in Sichuan Province, including 2.6536 million hectares of mild degradation, 2.6371 million hectares of moderate degradation and 1.7103 million hectares of severe degradation in Ganzi Prefecture, with a total degradation area of 7.001 million hectares, accounting for 71.34% of the grassland degradation area in the province; Aba Prefecture has slightly degraded 1.8198 million hectares, moderately degraded 294,300 hectares, and severely degraded 336,900 hectares, with a total degraded area of 2.451 million hectares, accounting for 24.97% of the grassland degraded area in the province; Liangshan Prefecture has slightly degraded 97,400 hectares, moderately degraded 169,300 hectares, and severely degraded 95,200 hectares, with a total degraded area of 361,900 hectares, accounting for 3.68% of the grassland degraded area in the province; other cities have slightly degraded 0.04 thousand hectares, without moderate and severe degradation (see **Table 2**).

4. Existing problems of grassland resource protection in Sichuan Province

4.1 Insufficient understanding of grassland resources

On the one hand, the base number of grassland resources is unclear. Grassland data has not been separated from the extensive stage of “statistics + estimation”, which is highly subjective. The grassland monitoring network in the whole province has not been effectively established, and the grassland monitoring and evaluation lacks integrity and systematicness. The current monitoring system mainly relies on quadrat data, which is highly arbitrary, and focuses on resource monitoring and construction protection project monitoring. It lacks systematic monitoring of grassland resources and ecosystem processes. The value of grassland ecosystem services, the benefits of grassland ecological engineering, the balance between grassland and livestock, and the assessment of glass-

Table 2. Summary of grassland degradation degree and area in Sichuan Province (10,000 Hectares)

Serial number	Name of prefecture and city	Total	Mild degradation	Moderate degradation	Severe degeneration	Proportion of grassland degradation area in the whole province (%)
	Total	981.40	457.08	310.07	214.25	100
1	Ganzi Prefecture	700.10	265.36	263.71	171.03	71.34
2	Aba Prefecture	245.10	181.98	29.43	33.69	24.97
3	Liangshan Prefecture	36.19	9.74	16.93	9.52	3.68
4	Other cities	0.004	0.004	-	-	0.0004

land disasters are still in the primary stage, grassland resource data can no longer effectively support the needs of grassland ecological protection and high-quality development at this stage[2,3].

On the other hand, there is insufficient understanding of the versatility of grassland. grassland has the functions of ecological environment maintenance, the development of agriculture, animal husbandry and people's livelihood, the bearing function of traditional culture, the supply function of industrial raw materials, and the support function of social stability. In the past, based on the needs of social development stage, the grassland function was mainly reflected in animal husbandry production, and other functions were not fully played, which was difficult to meet the needs of high-quality grassland development in Sichuan Province at this stage and in the future[4,5].

4.2 The carrying capacity of grassland resources is overburdened

In recent years, due to the rapid growth of the population in pastoral areas, the per capita grassland area has continued to decrease. According to statistics, the per capita grassland area in Ganzi, Aba and Liangshan prefectures has decreased from 12.37 hectares, 6.23 hectares and 0.75 hectares in the 1980s to 7.49 hectares, 4.18 hectares and 0.44 hectares now, with a decrease of 39.5%, 32.9% and 41.1%, respectively. The contradiction between population growth and the shortage of grassland resources has become increasingly prominent, resulting in serious phenomena such as over grazing, indiscriminate cultivation and excavation, illegal requisition and occupation of grassland, grazing by looting, grazing by theft, grazing by disorder, and so on, which makes the grassland unbearable. In 2017, the overload rate of grassland livestock in pastoral areas of the province was 9.23%, and the overload rate of some pastoral counties and some towns was as high as 20%–30%.

4.3 Systematic deficiencies in grassland ecological protection and restoration

It does not fully follow the succession law of grassland natural ecosystem and give full play to the self-healing ability of grassland ecosystem, which is still far from the concepts and requirements of overall protection, system restoration and comprehensive management put forward in the *Master Plan of Major National Ecosystem Protection and Restoration Project*s (2021–2035)[6]. The construction objectives, construction contents and treatment measures of some ecological projects are relatively simple, and some construction projects still have problems of patchwork, as well as the neglect of natural endowments such as water resources, soil, light and heat, and protozoa. The overall improvement of regional ecosystem service functions is not obvious.

4.4 Unreasonable investment in grassland ecological protection funds

First, the standard of grassland subsidy policy is low. After the implementation of grazing prohibition and grass livestock balance system, there is a

large gap with the original income level of herdsmen, resulting in the low enthusiasm of farmers and herdsmen for ecological construction, and the achievements of grassland ecological protection cannot be effectively consolidated. Second, the project of returning grazing to grassland and the subsidy standard are low. The current national investment standards for returning grazing to grassland projects are difficult to match the high-quality construction of grassland protection on the Qinghai–Tibet Plateau, and the lack of post construction management and protection funds makes it difficult to ensure the effectiveness of grassland ecological engineering construction. Third, there is a lack of funds for the construction of grassland animal husbandry infrastructure. The construction of productive facilities such as feeding grassland, livestock sheds, emergency channels for disaster prevention materials, drinking water for human and livestock, and processing of livestock products lags behind, and the transformation and upgrading of grassland animal husbandry is slow, which is difficult to support the sustainable ecological environment protection of grassland[7].

4.5 Imperfect grassland ecological protection mechanism

First, there is a lack of participatory management and operation mechanism and mode of herdsmen. Herdsmen are isolated from the protection project and have low participation. The construction of ecological protection projects failed to achieve “from the pastoralists, for the pastoralists and to the pastoralists”, and the actual results of the project implementation are far from expected. Second, the diversified investment mechanism has not been established. Ecological protection and restoration work have obvious public welfare and externality, and there is a lack of effective policies and measures to encourage social capital investment in ecological protection and restoration. Third, the lack of grassland ecological industry guidance mechanism. Insufficient support for socialized services, imperfect institutional guarantee mechanism for herdsmen to participate and share benefits, backward infrastructure conditions in pastoral areas and other subjective and objective difficulties have seriously limited the development of grassland ecological animal husbandry[8].

4.6 Scientific and technological support capacity needs to be strengthened

The construction of ecological protection and restoration standard system, the promotion of new technologies, the transformation of scientific research achievements and other aspects are still lacking. There is a certain degree of disconnection between theoretical research and engineering practice, and the systematicness and long-term effectiveness of key technologies and measures are insufficient. The scientific and technological service platform and service system of grassland resource protection are not perfect, and the grassland ecological protection and restoration industry is still in the cultivation stage. In addition, the ability of investigation, monitoring, evaluation and early warning to support grassland ecological protection and restoration is insufficient, and the inter departmental information sharing mechanism has not been established.

5. Countermeasures and suggestions

5.1 Establish regular grassland investigation and routine monitoring system

Organize and carry out grassland monitoring throughout the province, implement decadal, monthly and annual regular grassland monitoring, issue monitoring reports, timely provide information on grassland productivity, grassland comprehensive vegetation coverage, grassland degradation, grassland overload, and the implementation effect of ecological restoration projects, and provide technical support for agriculture, animal husbandry, people’s livelihood, production and life, and grassland management departments to formulate grassland ecological protection policies. Regularly carry out grassland resources investigation, implement the system of grassland resources inventory every 5 years and general survey every 10 years, and timely find out the current situation of grassland area, grassland type, grassland grade, grassland produc-

tivity, grassland degradation and other resources in the province.

5.2 Strengthen the spatial management of grassland resources

Strengthen the preparation of grassland ecological space planning and the delimitation of grassland ecological protection red line, study and clarify the control boundary of grassland resource use, grasp the changes of grassland resources involved in the development of land space in each county, strengthen the conversion management of grassland ecological space to other natural ecological space, explore and study the grassland ecological environment damage assessment and compensation system, establish a dynamic monitoring account, and strengthen real-time control. Vigorously build a digital grassland, plan and establish a provincial grassland big data center, strengthen the construction of grassland data collection, resource management, monitoring and early warning, data release and other information platforms, and comprehensively improve the level of grassland information management.

5.3 Strengthen the systematic repair of zoning and classification

With the goal of improving the self-healing ability of grassland ecosystems in Sichuan Province and effectively enhancing the stability of ecosystems, we will scientifically layout and organize the implementation of major projects for the protection and restoration of important ecosystems. According to the types and levels of different degraded grasslands, on the basis of adjusting measures to local conditions and seeking truth from facts, fully combine the wishes of local farmers and herdsmen, pay attention to the improvement of ecological quality and ecological risk response, scientifically allocate protection and restoration, natural and artificial, biological and engineering measures, improve the follow-up management measures and standards of ecological engineering, and promote the integrated ecological protection and restoration of grasslands in Sichuan Province.

5.4 Strengthen scientific and technological support ability

Increase support for scientific research on grassland resources, ecological environment monitoring, biodiversity protection, etc., and focus on scientific and technological problems in the protection and utilization of grassland resources and research on technological bottlenecks restricting development; establish and improve the system of scientific and technological support services, strengthen extensive docking and cooperation with domestic and foreign scientific research institutions, share scientific research achievements, and promote the application and practice of scientific and technological achievements; in order to cultivate practical talents who can be used and retained, local governments, provincial forestry and grass administration, relevant colleges and universities and scientific research institutions should strengthen the joint training of “targeted students” of grassland talents, strengthen the study and training of professional knowledge, and strengthen the talent reserve.

5.5 Establish and improve the economic compensation mechanism

Under the protection of the system of laws and regulations, give full play to the incentive role of interests, guide and encourage the participation of enterprises, people and other social investment subjects. Form a new pattern of ecological protection dominated by the government and jointly participated by multiple subjects, establish a mechanism for interest expression, regulation and compensation, and stimulate the enthusiasm of local farmers and herdsmen to participate in protection and management; reasonably formulate the economic reward and subsidy mechanism for planning grassland and residents, and appropriately improve the standard of grassland reward and subsidy.

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Conflict of interest

The authors declared no conflict of interest.

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ORIGINAL RESEARCH ARTICLE

Analysis of decoupling between land use degree and ecosystem service intensity in China

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ABSTRACT

Scientifically exploring the decoupling relationship between land use degree and ecosystem service intensity can effectively reveal the interference degree of land use change in the ecosystem, and provide a scientific basis for land use policy-making and ecosystem protection. However, previous studies lack specific research on the decoupling relationship between land use and ecosystem service intensity at the county level in China. In order to make up for this deficiency, combined with the remote sensing monitoring data of China's land use status from 2000 to 2015 and the vegetation coverage index, the spatial and temporal pattern characteristics of China's county scale ecosystem service intensity and land use degree from 2000 to 2015 were measured respectively by using the measurement methods of ecosystem service intensity and land use degree, and the decoupling relationship between the two was detected by using the decoupling analysis theoretical framework. The results showed the followings. (1) During the study period, the intensity of ecosystem services in China showed significant spatial heterogeneity, and the intensity of ecosystem services in Southeast China was significantly higher than that in Northwest China; the ecosystem service intensity in plain areas, urban agglomerations and the surrounding areas of big cities is significantly lower than that in mountainous and hilly areas. (2) China's land use degree continued to increase during the study period. The land use degree in the southeast was significantly higher than that in the northwest. The distribution of land use degree in the southeast was "high and low", and the distribution of land use degree in the northwest was "low, medium, and high". (3) The results of the decoupling analysis show that strong decoupling and expanding negative decoupling are the main relationship types between land use and ecosystem service intensity in China. The former is a dilemma, and the latter is a win-win model. The study found that the interference of land use at different stages on the intensity of ecosystem services showed significant differences. The results can provide scientific guidance for the formulation of land use and ecosystem management policies.

Keywords: Ecosystem Service Intensity; Land Use Degree; Space-time Relationship; Decoupling Analysis; China

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Land use/land cover change has been recognized as an important component and one of the main causes of global change, and will continue to play an important role in global change[1,2]. Since the 1990s, China's rapid urbanization has accelerated the process of China's land use transformation. At the same time, it has seriously disturbed the sustainable supply of ecosystem services, triggered a series of problems such as land degradation and biodiversity loss, and then brought great challenges to China's ecological civilization construction and sustainable development. At present, the increasingly serious contradiction between man and land forces human beings to effectively coordinate the relationship between land use and the ecosystem. How to scientifically

assess the disturbance degree of land use change to the ecosystem, effectively alleviate the deterioration of the ecosystem, and formulate effective ecosystem protection strategies is a hot topic discussed by Chinese government decision-makers and urban planners. In this context, scientific exploration of the decoupling relationship between land use change and ecosystem services is of great significance for formulating effective ecosystem protection and land use policies.

Ecosystem services research mainly focuses on ecosystem services evaluation, trade-offs, and analysis of influencing factors, supply and demand analysis, scenario prediction, and optimal regulation[3-6]. Previous studies have done a lot of empirical research on ecosystem services at different time and space scales based on the value method, material method, and energy method[7-9], but it is difficult to compare the results of ecosystem services evaluation based on different research scales and different research objectives, It is more difficult to incorporate into the national scale ecosystem protection and land use decision-making[10]. Among them, the value quantity assessment method mainly measures the use value and non-use value of ecosystem services by assigning value quantity coefficients to different ecosystem types[11]. The determination of ecosystem value equivalent coefficient based on expert knowledge lacks consideration of spatial heterogeneity of ecosystem services, resulting in subjectivity and uncertainty in ecosystem service assessment[12]. However, ecosystem service assessment based on material quality and energy is often difficult to conduct large-scale and long-time series comparative analysis due to the difficulty in obtaining assessment data[8]. In view of this, this paper introduces the ecosystem service intensity to measure the national county scale ecosystem service supply capacity, so as to enrich China's ecosystem service measurement methods[10,12]. Ecosystem service intensity can be used to characterize the intensity that nature and the ecosystem provide ecological products, support functions, regulation functions, and other ecological benefits to humans[12,13]. The introduction of the concept of ecosystem service intensity effectively integrates various ecosystem functions and provides a new perspective and method for ecosystem service measurement.

Previous studies have comprehensively explored the impact of land use change on ecosystem services from the aspects of quantitative change of land use[13,14], change of land use mode[15], change of land use pattern[16], comprehensive dynamic degree of land use[17,18] and degree of land use[19,20]. Specifically, previous studies on the relationship between land use and ecosystem services were mostly limited to local areas. Due to different research methods and scales, the relationship between land use and ecosystem services showed great differences. Some studies believe that the increase in land use will lead to the deterioration of ecosystem services. However, some studies have reached the opposite conclusion[21,22]. How use affects ecosystem services has not been determined. The impact of land use degree on ecological services is not a simple linear relationship. The existing studies usually use the elastic analysis method to detect the relationship between the two, and rarely use the decoupling analysis method to conduct a comprehensive study on the relationship between the land use degree of county units and ecosystem services[19,23]. The decoupling analysis method can be used to analyze the response relationship between two or more elements, and can effectively reveal the impact of land use change on ecosystem services. Based on this, this paper uses decoupling analysis to explore the decoupling relationship between the land use degree of county units and the intensity of ecosystem services in China, and effectively explain the interference of land use change on ecosystem services, in order to provide scientific reference for the formulation of land use policies and the protection of ecosystems in China.

Based on the remote sensing monitoring data of China's land use status from 2000 to 2015 and the vegetation coverage index, this paper uses the measurement methods of ecosystem service intensity and land use intensity to measure the spatial-temporal distribution pattern characteristics of China's county scale land use intensity and ecosystem service intensity from 2000 to 2015 and ex-

plores the decoupling relationship between them with the help of the theoretical framework of decoupling analysis. Specifically, the previous studies were supplemented and improved from the following three aspects: (1) based on the measurement method of ecosystem service intensity and land use degree, the spatial-temporal distribution characteristics of ecosystem service intensity and land use degree of county units in China from 2000 to 2015 were measured; (2) based on the spatial matching relationship between ecosystem service intensity and the change of ecosystem service intensity, this paper explores the spatial evolution characteristics of ecosystem service intensity in China; (3) based on the decoupling analysis method, the impact of land use change on ecosystem services change was analyzed. This paper intends to solve the following three problems. (1) what are the spatiotemporal distribution characteristics of ecosystem service intensity and land use degree? (2) What is the decoupling relationship between ecosystem service intensity and land use degree? (3) How to support the application of relevant policies?

1. Research methods and data sources

1.1 Data source

The remote sensing monitoring data of land use in China in 2000, 2005, 2010, and 2015 came from the resource and environmental science data center of the Chinese Academy of Sciences (http://www.resdc.cn), resolution of 1,000 m × 1,000 m is currently the most accurate remote sensing monitoring data product for land use in China and has played an important role in national land resource survey, hydrology and ecological research[24,25]. The data production and production in 2000, 2005, and 2010 were mainly based on Landsat TM/ETM remote sensing images of various periods. The data in 2015 were updated on the basis of 2010 data. Based on Landsat 8 remote sensing images, they were generated through manual visual interpretation, and the data accuracy was higher than 90%[24,25]. Land use types include 7 primary types, cultivated land, forest land, grassland, water area, construction land, unused land, and wetland. The administrative boundary data is from China National Geographic Information Center (NGCC) (http://ngcc.sbsm.gov.cn/). The spatial distribution data sets of normalized difference vegetation index (NDVI) of China in 2000, 2005, 2010, and 2015 are also from the resource and environmental science data center of the Chinese Academy of Sciences (http://www.resdc.cn)[26]. Due to the lack of data, Hong Kong, Macao, and Taiwan are excluded.

1.2 Research methods

1.2.1 Ecosystem service intensity

Based on the theoretical framework of ecosystem service value measurement proposed by Costanza *et al*.[13], Xie *et al*.[14] revised the classification and equivalent table of China's ecosystem on the basis of the knowledge of more than 700 ecologists and experts and in combination with the characteristics of China's ecosystem. However, the equivalent factor proposed by Xie *et al*.[14] is a national equivalent means of ecosystem service value, which lacks the expression of spatial heterogeneity of ecosystem service value in China. Previous studies have corrected ecosystem service value based on biomass, but biomass and ecosystem function are not completely positively correlated, especially in areas with vast water areas[27,28]. For example, aquatic ecosystems contain very little biomass, but aquatic ecosystems play an important role in water purification, waste treatment, and climate regulation. Chen *et al*.[29] proposed a correction method based on the biomass of cultivated land to compensate for the deviation caused by the correction based on the regional biomass. Based on this, this paper improves the previous studies and believes that it is more reasonable to correct the equivalent table of ecological service values proposed by Xie *et al*.[14] based on the biomass on cultivated land. Based on equations (1) and (2), the correction coefficient of the ecosystem service value of each county unit is estimated, and the calculation formula is as follows:

$$f = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \quad (1)$$

$$F_k = \frac{f_k}{\bar{f}} \quad (2)$$

Where: F_k is the correction coefficient of ecosystem service value of the kth county unit; f_k is the average biomass of cultivated land in the k county unit; $\bar{f}$ is the average biomass of cultivated land in China. Because there is no cultivated land in some counties in Northwest China, this paper obtains the correction coefficient by taking the mean value of the surrounding counties.

Based on the equivalent table proposed by Xie *et al.*[14] (equation 3), the standardized mean value of ecosystem function of each land type (equation 4) is taken as the ecosystem service intensity value per unit area of the land type (**Table 1**). Since there is no one-to-one matching between land use types and ecosystem types, according to previous studies, the closest ecosystem service intensity value of each land use type is selected for the assignment[18,30], and the county ecosystem service intensity in China is measured according to equation 5. The calculation formula is as follows:

$$w_{ij} = \left(\frac{I_{ij} - I_{ij-\min}}{I_{ij-\max} - I_{ij-\min}} \right) \times 100 \quad (3)$$

$$w_i = \sum_{j=1}^{m} w_{ij} / m \quad (4)$$

$$ESI_k = \sum_{i=1}^{n} w_i S_{ik} F_k / \sum_{i=1}^{n} S_{ik} \quad (5)$$

Where: w_{ij} is the equivalent factor of j ecosystem service value after i land type standardization, and its score is between 0 and 100; $I_{ij-\max}$ and $I_{ij-\min}$ are the maximum and minimum values of j ecosystem function types provided by land types respectively; w_i is the ecosystem service intensity of the i land use type; m (m = 1, 2, 3, …, 9) is the number of ecosystem function types; ESI is ecosystem service intensity; S_i is the area of soil type i (hm^2); n is the type of regional land use.

Table 1. The standardized equivalent weighting factor of ecosystem services value per hectare for each land type.

Primary type	Secondary type	Woodland	Grassland	Cultivated land	Wetland	Waters	Unused land	Land used for building
Supply services	Food production	33. 00	43. 00	100. 00	36. 00	53. 00	2. 00	0. 00
	Raw material production	100. 00	12. 00	13. 00	8. 00	12. 00	1. 34	0. 00
Regulation service	Gas conditioning	100. 00	35. 00	17. 00	56. 00	12. 00	1. 39	0. 00
	Climate regulation	30. 00	12. 00	7. 00	100. 00	15. 00	0. 96	0. 00
	Hydrological regulation	22. 00	8. 00	4. 00	72. 00	100. 00	0. 37	0. 00
	Waste disposal	12. 00	9. 00	9. 00	97. 00	100. 00	1. 75	0. 00
Support services	Soil conservation	100. 00	56. 00	37. 00	50. 00	10. 00	4. 23	0. 00
	Maintain biodiversity	100. 00	41. 00	23. 00	82. 00	76. 00	8. 87	0. 00
Cultural Services	Provide aesthetic landscape	44. 00	19. 00	4. 00	100. 00	95. 00	5. 12	0. 00
	w	60. 08	26. 00	23. 69	66. 64	52. 52	2. 89	0. 00

1.2.2 Land use degree

Land use degree Lui can be used to reflect the depth and breadth of land use, and then reveal the natural balance maintenance state of land resources natural complex under the interference of human social system[31]. In order to quantitatively evaluate the land use degree, Liu[31] proposed that the land use degree is divided into four levels according to the natural balance of the land natural complex under the influence of social factors, and the land use degree of each land use type is assigned (D_i). For example, construction land such as towns, residential areas, and other construction land is defined as the highest level of land use, and the value is 4; the land use mode that is in the original state, naturally developed and not interfered by human factors is defined as the lowest level, with a value of 0, so as to give a quantitative expression of the utilization degree of the excavated land. Li *et al.*[20] refined the

assignment of utilization degree of different land types proposed by Liu[31]. For example, the unused land with less human interference and input-output is assigned as 0, the urban construction land with strong human interference and input-output is assigned as 10, the rural residential area is assigned as 8, and the cultivated land is assigned as 7, realizing a more accurate assessment of land use. For the specific assignment, please refer to the research of Li *et al*.[20] The calculation formula is as follows:

$$LUI = \sum_{i=1}^{n} \frac{S_i}{\sum_{i=1}^{n} S_i} \times D_i \quad (6)$$

Where: D_i is the land use degree assignment of land type i.

1.2.3 Decoupling analysis

The decoupling analysis method has been widely used in the fields of agriculture, transportation, energy, construction land expansion and carbon emissions, but few studies have measured the relationship between land use and ecosystem services based on the decoupling method. This paper uses the decoupling analysis method to study the relationship between the two. According to the development and enrichment of decoupling theory by Tapio[32] and OECD[33], the theoretical framework of decoupling is divided into eight logical possibilities, including strong decoupling, strong negative decoupling, weak decoupling, expansion connection, expansion negative decoupling, recession decoupling, recession connection, and weak negative decoupling. Referring to previous studies, taking 1.2 and 0.8 as the critical values of decoupling elasticity, the change rate of ecosystem service intensity (%Δ*ESI*) is divided by the rate of land use change (%Δ*LUI*) to construct the decoupling index[34]. Where $DI > 1.2$, $\%\Delta ESI > 0$, $\%\Delta LUI > 0$, expansion negative decoupling; $0.8 < DI < 1.2$, $\%\Delta ESI > 0$, $\%\Delta LUI > 0$, expansion connection; $0 < DI < 0.8$, $\%\Delta ESI > 0$, $\%\Delta LUI > 0$, weak decoupling; $DI < 0$, $\%\Delta ESI < 0$, $\%\Delta LUI > 0$, strong decoupling; $DI > 1.2$, $\%\Delta ESI < 0$, $\%\Delta LUI < 0$, recession decoupling; $0.8 < DI < 1.2$, $\%\Delta ESI < 0$, $\%\Delta LUI < 0$, fading connection; $0 < DI < 0.8$, $\%\Delta ESI < 0$, $\%\Delta LUI < 0$, weak negative decoupling; $DI < 0$, $\%\Delta ESI > 0$, $\%\Delta LUI < 0$, strong negative decoupling. Refer to[32] for the meaning of each type, and the calculation formula is as follows:

$$DI_{t2-t1} = \frac{\%\Delta ESI}{\%\Delta LUI} = \frac{(ESI_{t2} - ESI_{t1})/ESI_{t1}}{(LUI_{t2} - LUI_{t1})/LUI_{t1}} \quad (7)$$

Where: DI_{t2-t1} represents the decoupling index from $t1$ to $t2$; ESI_{t1} and ESI_{t2} represent ecosystem service intensity index in $t1$ and $t2$ respectively; LUI_{t1} and LUI_{t2} represent land use index in $t1$ and $t2$ respectively.

2. Result analysis

2.1 Spatial and temporal distribution of ecosystem service intensity in China from 2000 to 2015

From 2000 to 2015, the spatial distribution pattern of China's ecosystem service intensity remained basically stable. On the whole, the ecosystem service intensity in the south of Qinling Mountains Huaihe River was significantly better than that in the north. The ecosystem service intensity in the eastern monsoon region was higher than that in the Qinghai Tibet high cold region and the northwest arid region (**Figure 1**). The intensity of ecosystem services in the Northwest Economic Zone (Xinjiang, Tibet, Qinghai, Gansu, and Ningxia) and some provinces in the middle reach of the Yellow River Economic Zone, including Inner Mongolia and Shanxi, is relatively low; the Huang Huai Hai Plain in the eastern monsoon region (including Beijing, Hebei, Tianjin, Shandong, Jiangsu, the eastern part of Henan and the northern part of Anhui), the Sichuan Basin, the economic zone in the middle reaches of the Yangtze River (Hubei, Hunan, and Jiangxi), the Yangtze River Delta (Shanghai, the southern part of Jiangsu, the eastern part of Anhui and the northern County of Zhejiang) and the Pearl River Delta (Guangdong), as well as the Liaoning coastal economic belt, the central and southern city clusters of Liaoning along the Harbin Dalian line in the northeast The ecosystem service intensity of Shenyang Economic Zone and Harbin Changcheng city group is also low. The low intensity of ecosys-

tem services in the Northwest Economic Zone and the middle reaches of the Yellow River Economic Zone is mainly due to poor natural conditions, insufficient rainfall, dry climate, widespread deserts, fragile ecological environment, and low overall resource and environmental carrying capacity; the low-value areas of ecosystem service intensity in the eastern monsoon region are caused by social and economic development. These areas have superior natural conditions, convenient transportation, a strong economic agglomeration effect, and an obvious pulling effect on the population. Social and economic development and population agglomeration are the main reasons for the low ecosystem service intensity in these areas.

In order to further analyze the ecosystem service intensity and its spatial matching, based on the spatial distribution of China's County Ecosystem service intensity index, three-level areas (low level, medium level, and high level) are divided into 0–25, 25–50 and ≥50, and then based on the changes of ecosystem service intensity, they are divided into five horizontal zones of <0.50, 0.50–0, 0–0.25, 0.25–0.75, and ≥0.75 (high-speed deterioration, low-speed deterioration, low-speed improvement, medium speed improvement, and high-speed improvement) can be combined to obtain 15 zoning combination types (**Figure 2**). The low-level and deteriorating regions are mainly distributed in some counties in Northwest China, such as Qinghai, Tibet, Xinjiang, and Inner Mongolia; the regions with low level and continuous improvement are mainly distributed in some areas of the Loess Plateau and some counties of Xinjiang; the regions with deteriorating medium level are mainly distributed in the transitional counties of the second and third ladder in China, the counties around the Sichuan Basin, the North China Plain, and the southeast.

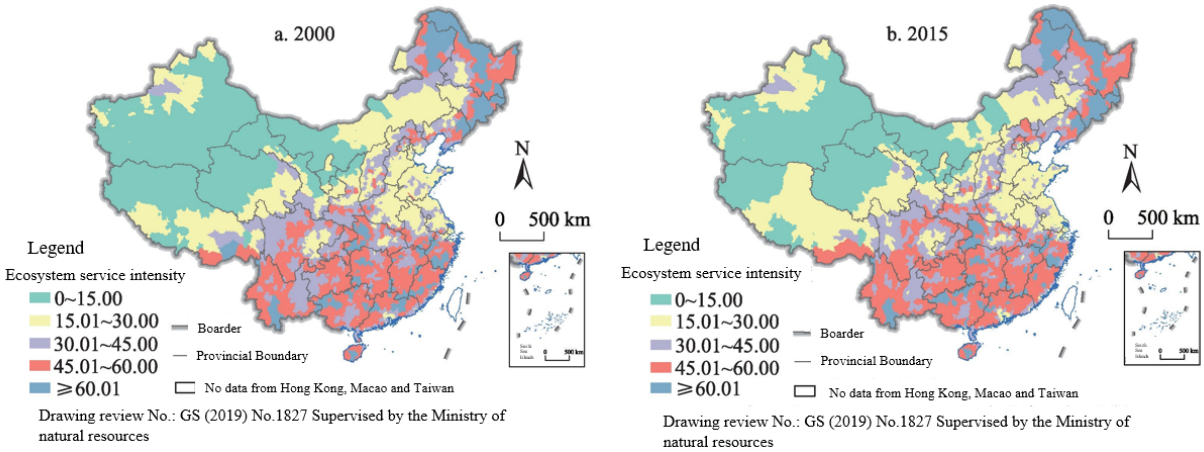

Figure 1. Spatial distribution of ecosystem services intensity at the county level in China in 2000 and 2015.
Note: this drawing is based on the standard map downloaded from the standard map service system of the Ministry of natural resources. The base map is unchanged, the same below.

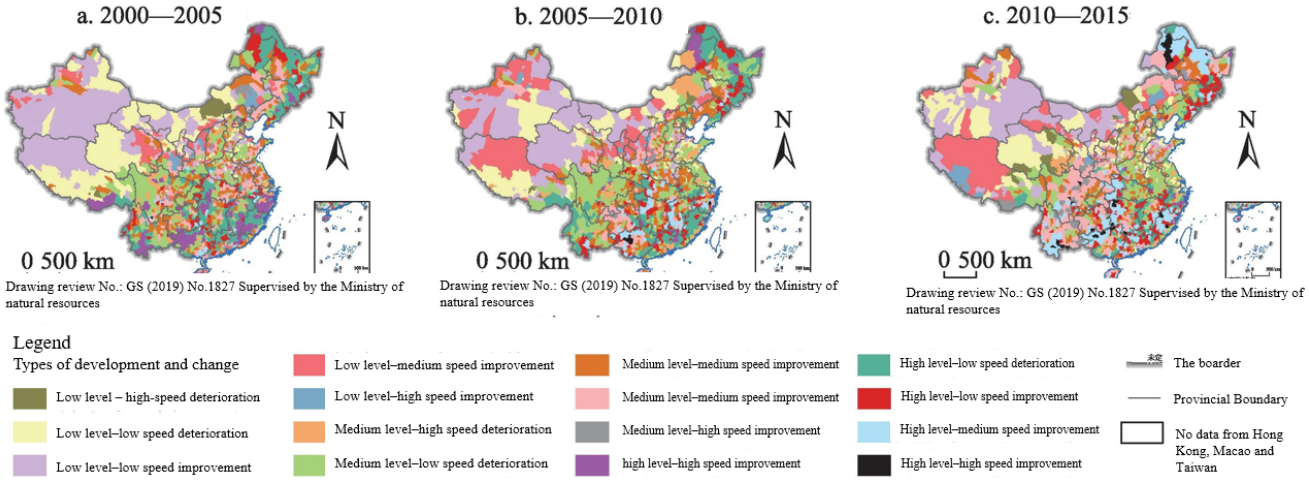

Figure 2. Development types of ecosystem services intensity at the county level in China from 2000 to 2015.

Some large cities and surrounding areas of urban agglomerations (Urban Agglomerations in the middle reaches of the Yangtze River, urban agglomerations in the Yangtze River Delta and urban agglomerations in the Pearl River Delta); the high-level improvement areas are mainly concentrated in the greater Hinggan Mountains, Changbai Mountains, Taihang Mountains, Wushan mountain, Xuefeng mountain and Wuyi Mountain; high level deterioration areas are mainly distributed in the surrounding areas of these mountains.

2.2 Spatial and temporal distribution of land use degree in China from 2000 to 2015

In terms of time scale, China's land use degree showed a continuous increasing trend from 2000 to 2015, from 1.97 in 2000 to 2.01 in 2015. With the rapid growth of China's economy and population, the impact of human activities on the natural complex of land use has become more and more intense. In terms of spatial scale, the land use degree in the eastern monsoon region is significantly higher than that in the northwest arid region and the Qinghai Tibet alpine region, and the overall spatial pattern of "high in the southeast and low in the northwest" has not changed significantly. The land use degree distribution in the southeast region is "high and low", and the land use degree in the northwest region is "low, medium and high". The low value areas of land use degree in the eastern monsoon region are mainly distributed in mountainous and hilly areas, while the high value areas of land use degree are mainly distributed in the Huang Huai Hai Plain, the Yangtze River Delta, the Sichuan Basin, the middle reaches of the Yangtze River, the Pearl River Delta and the central and southern part of the northeast region; the high value areas of land use degree in the northwest arid region and the Qinghai Tibet high cold region are mainly distributed in Xining, Lhasa, Urumqi and other provincial capitals (**Figure 3**).

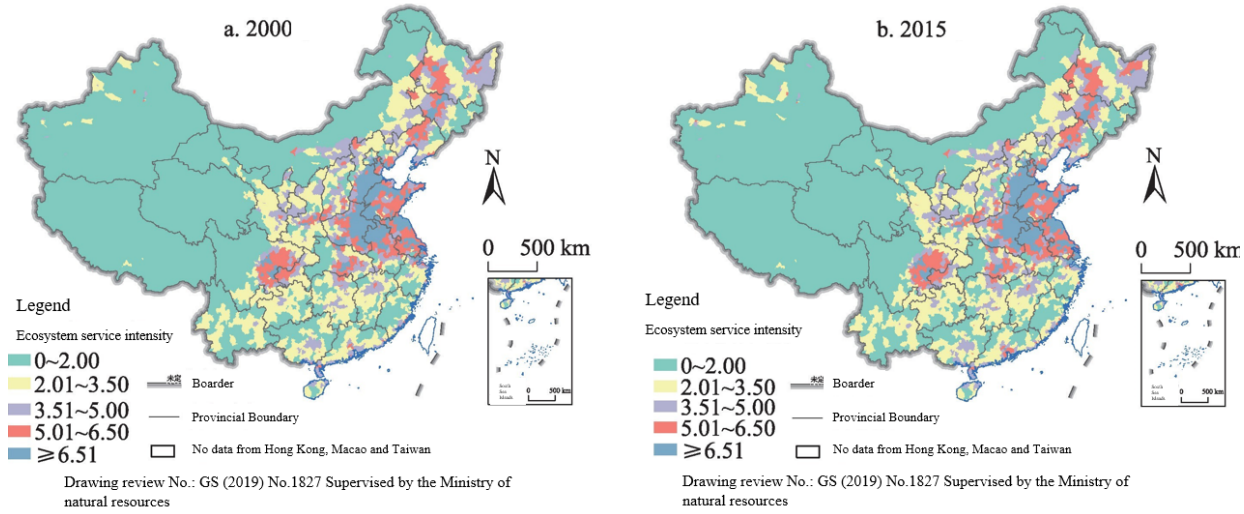

Figure 3. Spatial distribution of land use intensity at the county level in China in 2000 and 2015.

2.3 Analysis of decoupling between land use degree and ecosystem service intensity in China from 2000 to 2015

In order to fully reveal the relationship between ecosystem service intensity and land use degree, the scatter diagram between ecosystem service intensity and land use degree is first analyzed (**Figure 4**). From the scatter diagram of four time points from 2000 to 2015, it can be seen that there is not a simple linear relationship between land use degree and ecosystem service intensity. Ecosystem service intensity increases with the increase of land use degree and decreases with the increase of land use degree after reaching the threshold. In the primary stage of land use, it is mainly from unused land (low ecosystem service supply potential) to forest land, grassland, cultivated land and other land use types (high ecosystem service supply potential), so as to promote the improvement of the overall ecosystem service intensity. With the increase of land use, the transformation of land use types mainly occurs between land use types such as forest land to

cultivated land, grassland to cultivated land, forest land to construction land, grassland to construction land, which will inevitably lead to the reduction of the overall ecosystem service intensity. The results of Pearson correlation analysis between ecosystem service intensity and land use degree showed that the correlation coefficient between them was -0.519 in 2000, p = 0.000; in 2005, the correlation coefficient between them was -0.526, p = 0.000; in 2010, the correlation coefficient between the two was -0.546, p = 0.000; in 2015, the correlation coefficient between the two was -0.571, p = 0.000. On the whole, it can be seen that there is a negative correlation between ecosystem service intensity and land use degree, but the increase in land use degree in local areas will lead to an increase of ecosystem service intensity.

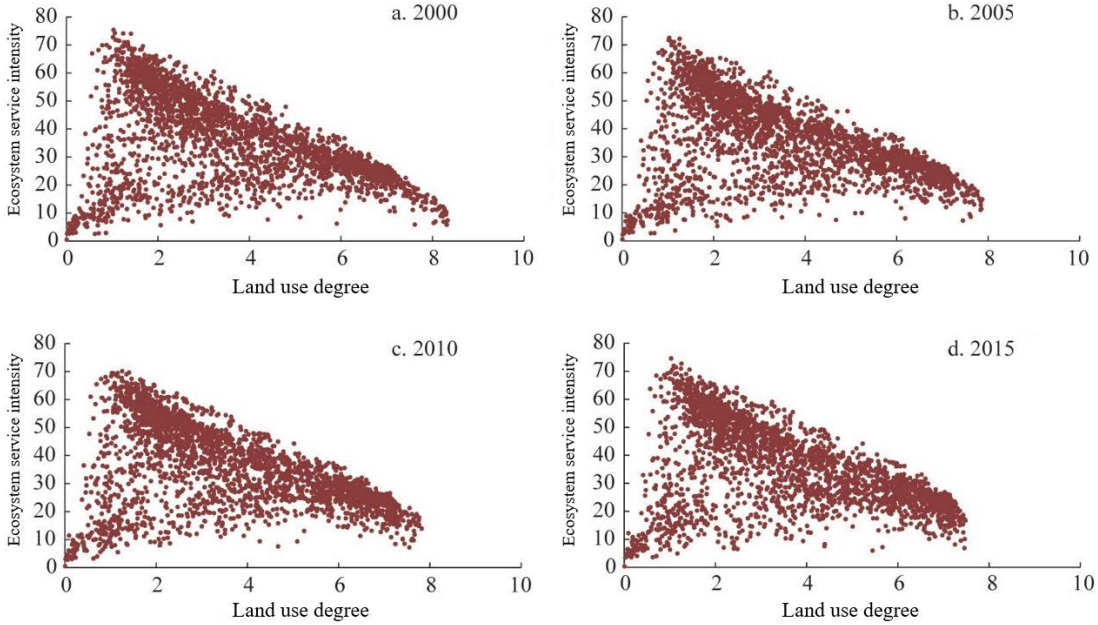

Figure 4. Scatter plot of *ESI* and *LUI* in China from 2000 to 2015.

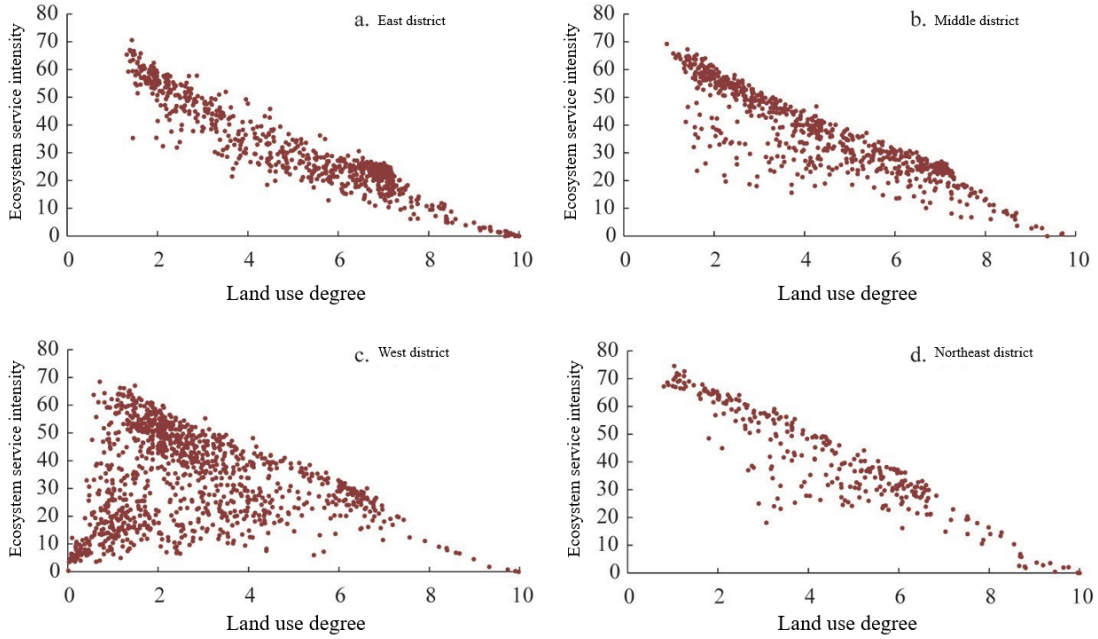

Figure 5. Scatter plot *ESI* and *LUI* in different regions of China in 2015.

In order to further explain the relationship between ecosystem service intensity and land use degree in different regions of China, the scatter map of ecosystem service intensity and land use degree

in eastern, central, Western and Northeast China in 2015 is further analyzed (**Figure 5**). It is obvious that there is a significant negative correlation between ecosystem service intensity and land use degree in eastern, central and Northeast China. Among them, the increase of land use degree in the eastern region will lead to the most significant decrease in ecosystem service intensity. On the contrary, the increase in land use degree in most counties and regions in the northwest region will promote the increase of ecosystem service intensity, and only a few counties and regions will promote the decrease of ecosystem service intensity. The scatter plots of ecosystem service intensity and land use degree in different regions reveal that the impact of land use degree on ecosystem service intensity has significant regional differences.

Based on Equation (7), the spatial distribution characteristics of the decoupling index of land use degree and ecosystem service intensity between 2000–2005, 2005–2010, and 2010–2015 are obtained (**Figure 6**). Statistics on the proportion of counties with different logic types are shown in **Table 2**. Among the eight decoupling types in 2000–2005, 2005–2010 and 2010–2015, the strong decoupling type accounted for the highest proportion, 33.68%, 36.85% and 41.90% respectively, showing a gradually increasing trend. The strong decoupling type represents that the increase of land use will lead to the decrease of ecosystem service intensity. This development model is in a dilemma. From 2000 to 2005, the types of strong decoupling were mainly distributed in Zhejiang, Fujian, Hunan, Guangxi, Yunnan, most of the northeast and some of the central and western regions; from 2005 to 2010, it was mainly distributed in Shandong, Jiangsu, Zhejiang, Guangdong, the eastern part of Inner Mongolia and some parts of the central and western regions; from 2010 to 2015, it was mainly distributed in Henan, the middle and lower reaches of the Yangtze River, the Bohai Rim and some parts of the central and western regions. The second is the expansion negative decoupling type, which accounts for 20.69%, 29.86%, and 35.90% respectively in the three research periods, and also shows a gradually increasing trend. The expansion negative decoupling type represents that the increase of land use degree will lead to the increase of ecosystem service intensity, and the increase of ecosystem service intensity is higher than the increase of land use degree, which is a win-win development model. From 2000 to 2005, the types of expansion negative decoupling were scattered throughout the country; from 2005 to 2010, it was mainly distributed in the central and western regions; from 2010 to 2015, it is mainly distributed in Southwest China and Northeast China. The second is the strong negative decoupling type, accounting for 16. 58%, 15.60%, and 6.95% respectively, showing a gradually decreasing trend. The strong negative decoupling type represents that the reduction of land use in these areas has led to the improvement of ecosystem service intensity. This type is a sustainable development type, which is mainly distributed in the central and western regions and Northeast of China. The recession decoupling type is also an important decoupling logic type, accounting for 12.82%, 13.66%, and 3.34% respectively in 2000–2005, 2005–2010, and 2010–2015. The reduction of land use degree of this type of county unit leads to the reduction of ecosystem service intensity, and the reduction of ecosystem service intensity is higher than the reduction of land use degree. This type is an unsustainable development type.

3. Conclusion and discussion

3.1 Conclusion

Based on the measurement method of ecosystem service intensity and land use degree, this paper analyzes the temporal and spatial distribution characteristics of ecosystem service intensity and land use degree in China from 2000 to 2015, and makes an in-depth study on the decoupling relationship between the change of land use degree and the change of ecosystem service intensity in combination with the decoupling theoretical model, the conclusions are as follows: (1) from 2000 to 2015, the spatial distribution of ecosystem service intensity in China has significant spatial heterogeneity. The ecosystem service intensity in Northwest China is significantly lower than that in eastern China. The ecosystem service intensity in plain areas with eco-

nomic agglomeration and population agglomeration is significantly lower than that in mountainous and hilly areas, it can be seen that the spatial pattern of the supply potential of China's ecosystem service intensity is formed under the combined action of natural geographical factors and socio-economic factors.

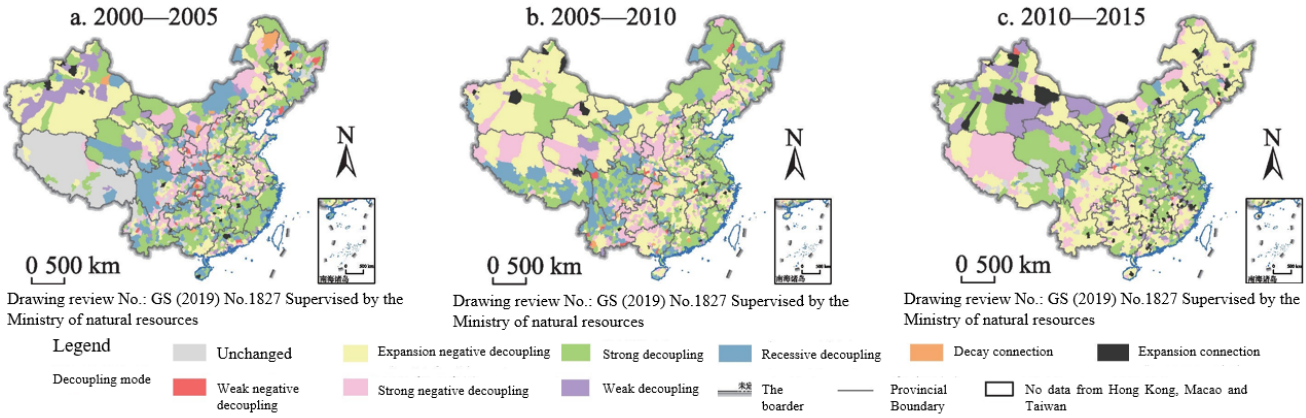

Figure 6. Spatial distribution of decoupling patterns at the county level in China from 2000 To 2015.

Table 2. Logical possibilities statistics (%)

Decoupling category	2000–2005	2005–2010	2010–2015
Unchanged	9.59	0.25	3.86
Expansion negative decoupling	20.69	29.86	35.90
Expansion connection	1.37	0.84	2.39
Weak decoupling	3.76	1.83	5.30
Strong decoupling	33.68	36.85	41.90
Recessive decoupling	12.82	13.66	3.34
Decay connection	0.46	0.42	0.07
Weak negative decoupling	1.05	0.70	0.28
Strong negative decoupling	16.58	15.60	6.95

(2) From 2000 to 2015, China's land use degree gradually increased, and the overall spatial pattern of "high in the southeast and low in the northwest" has not changed significantly. The distribution of land use degrees in the southeast is "high and low", and the land use degree in the northwest is "low, medium, and high". The degree of land use in economic and population concentrated areas is significantly higher than that in mountainous and hilly areas. Natural geographical factors are always important factors that restrict human interference with the natural balance of the land use system.

(3) The disturbance of land use at different stages on ecosystem service intensity is significantly different in time and space. The decoupling analysis results show that the increase in land use will lead to an increase or decrease in ecosystem service intensity. Strong decoupling and expansion negative decoupling is the main relationship types between land use degree and ecosystem service intensity in China. The former is a dilemma, and the latter is a win-win model.

3.2 Discussion

Compared with previous studies, it can be found that the spatial distribution characteristics of land use degree and ecosystem service intensity are both correlated and differentiated, mainly from east to west and north to south. The correlation between the East and the west is caused by the natural attribute of land use, while the differentiation between the north and the south is caused by the social attribute of land use[35]. The relationship between land use degree and ecosystem service intensity in this paper is basically consistent with the previous research results, showing a negative impact in general and a positive impact in local areas[19]. Based on the above research results, it

can be found that there are significant differences in the decoupling degree between land use and ecosystem service intensity in different regions. Based on this, this paper proposes differentiated control policies. For strong decoupling regions, such regions are in a dilemma. The increase of land use activities will lead to the decrease of ecosystem service intensity. The rapid development of urbanization and industrialization leads to the continuous increase in land use. The excessive increase in land use will inevitably lead to the deterioration of the ecosystem. Coordinating the relationship between land use, socio-economic development, and ecosystem protection is an effective way to promote sustainable land use and ecosystem protection. The degree of land use cannot explain whether the land use is reasonable, but the intensity of ecosystem services can be used as a scientific indicator to evaluate whether the land use is reasonable[36]. It is necessary to explore new mechanisms of land management, innovate new models of economical and intensive land use, improve the intensive degree of land use, increase the proportion of ecological land, strictly control the increment of construction land, form a forced mechanism, and alleviate the deterioration of the ecosystem in the process of increasing land use by optimizing the overall land use structure and layout. For the win-win type of expansion and negative decoupling, on the premise of protecting the ecological environment, we should speed up economic development, fully release land dividends and ecological dividends, form a situation of ecological environment protection and economic development, and achieve benign interaction and coordinated development. The strong negative decoupling type is a sustainable development type. It is necessary to promote the reuse of inefficient wasteland, increase input and output, and improve land use efficiency according to the specific regional conditions. The recession decoupling type is also an unsustainable development type. The degree of ecosystem services and land use are reduced at the same time, and the degree of reduction of ecosystem services is higher than that of land use. For this type, it is urgent to optimize the land use structure and layout, alleviate the current low efficiency, disorder, and extensive land use, and alleviate the deterioration of the ecosystem.

Based on the decoupling analysis method, this paper discusses the relationship between land use degree and ecosystem service intensity. The results show that the current land use degree in China has a negative and positive impact on ecosystem service intensity, and the negative impact is greater than the positive impact. The research results can provide scientific guidance for the sustainable use of land resources, land use planning, and ecosystem protection. Limited to the availability of county-level data, this paper introduces ecosystem service intensity to measure the supply capacity of ecosystem services in China and corrects it in combination with vegetation coverage. However, the spatial differences in ecosystem service types and intensity caused by the diversity of the ecosystem itself and environmental conditions are still inadequately considered. In addition, only the relationship between ecosystem service intensity and land use degree is discussed, and the decoupling relationship between ecosystem service intensity and land use change speed (comprehensive dynamic degree of land use), land use structure (land use diversity index), natural factors (altitude, climate, topography, etc.). And socio-economic factors (population density and economic development) are not discussed. Future research can comprehensively consider the decoupling relationship between land use factors, natural factors, and socio-economic factors, and the intensity of ecosystem services. In addition, the impact of the global telecoupling and local coupling systems formed by the implementation of China's land use policies, ecosystem policies, and regional development strategies on the intensity of ecosystem services in China is also the focus of future research[37].

Conflict of interest

The authors declared no conflict of interest.

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ORIGINAL RESEARCH ARTICLE

Status of grassland resources utilization in Ili River Valley and countermeasures for sustainable utilization

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ABSTRACT

From the perspective of grassland resources and their sustainable utilization, this paper expounds the type characteristics and utilization status of grassland resources in the Ili River Valley, and analyzes the main problems of grassland re-sources in the Ili River Valley, such as the annual increase of grassland degradation area, the increasingly serious soil erosion, the imbalance between seasons and years of grassland production, and the imperfect mechanism of grassland ecological protection, restoration and management. This paper discusses the driving mechanism affecting the productivity of grass-land resources, and puts forward the corresponding countermeasures in the sustainable utilization of grassland ecosystem, such as strengthening the management of grassland re-sources, establishing a grass seed gene bank and screening native grass species, implementing the construction of grassland ecological restoration, strengthening grassland ecological monitoring and actively promoting ecological tourism.

Keywords: Ili River Valley; Grassland Resources; Utilization Status; Sustainable Utilization; Countermeasure

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1. Introduction

Grassland is not only the production base of animal husbandry, but also plays an extremely important role in maintaining ecological balance. Grassland is the main body of the ecological environment in Xinjiang, accounting for 34% of the total area of Xinjiang. It not only provides an important material basis for the development of grassland animal husbandry in Xinjiang, but also plays an important ecological function in biodiversity protection, water and soil conservation, etc.[1]. Grassland resources are an important part of natural resources, the material basis for human grassland animal husbandry production, an important condition for national economic development and improving people's living standards, and an important source of social wealth. Grass-land has the ecological functions of wind and sand prevention and water conservation. It is the gene pool of biodiversity, can regulate the climate, and is the basis for the survival and development of all ethnic groups.

2. Natural overview

The Ili River Valley is located in the west of Xinjiang, at 80°09′~84°56′E, 42°14′~44°50′N. It is the largest Intermountain Valley in the Western Tianshan Mountains. It is surrounded by mountains in the North, East and South, with north-west-southeast Keguqin Mountain and Borokonu Mountain in the North, northeast-southwest Haktawu Mountain and Nalati Mountain in the South, and Wusun

Mountain and Awulale mountain in the middle, forming the geomorphic outline of "Three mountains with two valleys". The altitude is 600 ~ 1,500 m, and the altitude of the mountains on the North and South sides is 3,000 m. It is 350 km long from East to West and 180 km wide from South to North.

3. Grassland types and basic characteristics (see Table 1)

The available grassland area in Ili River Valley is 310.43 hm^2, accounting for 6.47% of the available grassland area in Xinjiang. The vertical distribution of grassland in Ili River Valley is relatively obvious. From below the glacier, there are alpine meadows, mountain meadows, mountain meadows grasslands, desert grasslands, lowland meadows, and marshes, with a total of 238 grassland types of 7 major types. The Ili River Valley is overwhelmingly dominated by the ephemeral plant—Artemisia desert[2], and the Ili natural grassland is famous nationwide for its many types, good quality and high productivity. The unique natural environment of the Ili River Valley breeds the world-famous grasslands such as Nalati, Tangbula, Karajun, Baraksu, Kerikante, and makes the Ili River Valley known as "Lush southern type fields north of the Great Wall".

Table 1. Grassland types and grass yield in Ili River Valley

Serial No.	Grassland type	Fresh grass yield (kg/hm^2)	Coverage (%)	Height of grass layer (cm)
1	Alpine meadow	22.81	75 ~ 90	5 ~ 15
2	Mountain meadow	52	85 ~ 100	25 ~ 80
3	Mountain meadow grassland	31.2	75 ~ 95	25 ~ 75
4	Mountain grassland	10.13	25 ~ 50	10 ~ 80
5	Desert grassland	6.67	25 ~ 45	10 ~ 35
6	Lowland meadow	32.67	50 ~ 85	15 ~ 50
7	Plain swamp	27.33	85 ~ 100	20 ~ 100

3.1 Alpine meadow

It is distributed between 2,400 ~ 3,300 m above sea level, with an average annual precipitation of 500~800 mm. The soil texture is coarse sand and gravel. Due to the cold climate in the area, the plant community structure is simple and the plants are low. The constructive species are *Kobresia capillifolia*, *Carex stenocarpa*, *Carex melanantha*, *Carex songorica*, *Polygonum viviparum*, *Alchemilla tianshanica*, *Poa alpina*, etc. Associated species include more than 20 families, more than 150 species, including *Phlomis oreophila*, *Caragana sinica*, *Thalictrum alpinum*, *Alpine Rock Jasmine*, and a total of 23 grassland types.

3.2 Mountain meadow

It is distributed between 1,600 ~ 2,400 m above sea level, with an average annual precipitation of 600 ~ 1,000 mm. It is the area with the most abundant precipitation in Tianshan mountain area, and the soil is chernozem. Mountain meadow is the essence of the natural grassland in Ili River Valley. It has the characteristics of large area, wide distribution, many plant species, good forage quality, rich nutrition, good palatability and high grass yield. The constructive species include *Dactylis glomerata*, *Poa angustifolia*, *Roegneria sinkiangensis*, *Ligularia macrophylla*, *Rumex acetosa*, *Phlomis oreophila*, *Geranium pratense*, etc. Associated species include *Trifolium pratense*, *Bromus inermis*, *Poa pratensis*, *Festuca rubra*, etc., with a total of 58 grassland types.

3.3 Mountain meadow grassland

It is distributed at an altitude of 1,100 ~ 2,600 m. It is distributed in a narrow strip along the front edge of the middle mountain belt in the Ili River Valley. The annual average precipitation is 350~500 mm, and the soil is mainly dark chestnut soil. The constructive species include *Bromus inermis*, *Elymus dahuricus*, *Uraria cristina*, *Festuca ovina*, *Stipa capillata*, *Poa annua*, *Dactylis glomerata*, *Artemisia sacrorum*, *Salvia japonic*a, *Phlomis pratensis*, *Medicago falcata* and *Glycyrrhiza uralensis*. The

sub constructive groups include *Cannabis sativa*, *Onobrychis viciifolia*, *Ziziphora tomentosa*, *Geranium pratense*, etc. Associated species include *Potentilla chinensis*, *Medicago lupulina*, *Achillea millefolium*, *Leymus secalinus*, *Iris loczyi*, etc., with a total of 48 grassland types.

3.4 Mountain grassland

It is distributed between 1,100 and 2,200 m above sea level, with an average annual precipitation of 350 mm. It is mostly distributed on sunny slopes, rich in heat, and the soil is mainly chestnut soil. The constructive species include *Stipa capillata*, *Bothriochloa ischaemum*, *Carex liparocarpos*, *Iris ruthenica*, *Sophora alopecuroides*, *Caragana sinica*, *Ajania fastigiata*, *Spiraea hyperifolia*, *Rosa multiflora*, etc. Associated species include *Agropyron cristatum* and *Leontopodium leontopodioides*, with a total of 39 grassland types.

3.5 Desert grassland

It is distributed at an altitude of 750 ~ 1,500m, with an average annual precipitation of about 200 ~ 250 mm. The soil is calcareous soil. The constructive species include *Seriphidium transiliense*, *Kochia prostrata*, *Ceratoides latens*, *Ceratocarpus arenarius*, *Carex onoei*, etc. Associated species include *Salsola collina*, *Achnatherum splendens*, *Trigonella*, etc., with a total of 10 grassland types.

3.6 Lowland meadow

It is distributed in the fan edge low-lying land of the alluvial proluvial plain in the Ili River Valley. The soil is mainly meadow soil, light chestnut soil, and locally light saline alkali soil. The constructive species include *Agrostis alba*, *Aeluropus pungens*, *Hordeum bogdani*, *Trifolium pratense*, *Iris lacteal*, *Achnatherum splendens*, *Taraxacum mongolicum*, *Glycyrrhiza uralensis*, *Plantago asiatica*, *Phragmites communis*, *Calamagrostis epigeios*, etc., with a total of 35 grassland types.

3.7 Plain swamp

It is distributed in the flood plain and seasonal ponding zone in the lower reaches of Kashi River, Gongnaisi River, Tekes River and the middle and lower reaches of Ili River, and the soil is marshy soil. The constructive species include *Phragmites communis*, *Calamagrostis epigeios*, *Juncus effusus*, *Cyperus rotundus*, etc. There are two grassland types.

4. Current situation of natural grassland utilization (see Table 2)

The natural grassland in Ili River Valley is used in two ways: grazing and grazing-mowing. Grazing is divided into four kinds according to seasons: summer grassland, winter grassland, spring-autumn grassland and winter-spring-autumn grassland. Among them, summer grassland, spring-autumn grassland and some winter grassland are pure grazing grassland, most of which are divided into winter grassland and winter-spring-autumn grassland for grazing and mowing.

Table 2. Grassland area and livestock carrying capacity in Ili River Valley

Serial No.	Seasonal grassland	Area (million hectares)	Theoretical stocking capacity (million sheep units)	Actual stocking capacity (million sheep units)	Stocking capacity (overload –, underload +)
1	Summer grassland	101.14	887.22	758.11	129.11
2	Spring-autumn grassland	84.23	338.99	485.13	–146.14
3	Winter grassland	83.66	559.63	629.48	–69.85
4	Winter-spring-autumn grassland	38.87	228.01	228.01	0

4.1 Summer grassland

The grassland area in summer is 101.14 million hectares, with a theoretical livestock carrying capacity of 887.22 million sheep units and an actual livestock carrying capacity of 758.11 million sheep units. The utilization period is from mid to late June to mid to late September, mainly distributed in mountain meadows and alpine meadows with an altitude of more than 1,700 m; the plant species are mainly miscellaneous grasses, as well as mesophyt-

ic grasses, Kobresia, sedges and other fine grasses.

4.2 Spring-autumn grassland

The spring-autumn grassland covers an area of 84.23 million hectares, with a theoretical livestock carrying capacity of 338.99 million sheep units and an actual livestock carrying capacity of 485.13 million sheep units. It is distributed in low-mountain belts, piedmont hills and some piedmont plains. The grassland types are mainly mountain desert grassland, plain desert and some mountain grassland. The plant species are composed of *Artemisia semi shrubs*, *Tufted grasses* and *Small sedges*. The utilization period is from mid and late April to mid and late June in spring; autumn from mid to late September to mid to late November.

4.3 Winter grassland

The winter grassland covers an area of 83.66 million hectares, with a theoretical livestock carrying capacity of 559.63 million sheep units and an actual livestock carrying capacity of 629.48 million sheep units. It is distributed in the middle mountain forest belt of the river valley and the mountain meadow grassland. This kind of grassland has high forage yield, and the plant species are composed of mesophytic and mesoxerophytic grasses, miscellaneous grasses, leguminosae, artemisia semi shrubs, etc. From the mid to late November to the mid to late April of the next year, the sunny slope in this area has less snow in winter and can be used for grazing, while the shady slope is mostly natural grassland, which is the main grassland for livestock to spend the winter and spring under traditional grazing conditions.

4.4 Winter-spring-autumn grassland

The winter–spring–autumn grassland area is 38.87 million hectares, with theoretical stocking capacity of 132.08 million sheep units and actual stocking capacity of 228.01 million sheep units. It is mainly distributed in the plains and foothills in the middle and upper reaches of Turks River, Gongnaisi River and Kashi River. The utilization time is from the mid to late September to the mid to late April of the next year. The grassland types are mainly meadow grassland, lowland meadow and mountain grassland; the main plants are composed of mesophytic-xerophytic, mesophytic, and xerophytic grasses, leguminous grasses, artemisia subshrubs, miscellaneous grasses, etc.

5. Problems in grassland resource utilization

5.1 The degraded area of grassland increases year by year

The seasonal grasslands in the Ili River Valley with serious degradation are mainly summer grasslands and spring-autumn grasslands. The grassland types with the most serious degradation are mountain meadow, mountain desert grassland, plain desert, mountain grassland, lowland meadow and mountain meadow grassland. In summer, the alpine meadow in the grassland basically did not appear obvious degradation. The most obvious characteristics of grassland degradation are: the species and components of grass groups have changed, the number of tufted grasses has decreased, the coverage of grass groups has decreased, and the exposed area has increased[5]. The degradation process of grassland is the reduction of edible grass, and the composition of grassland grass has changed accordingly[6]. The succession trend of grassland vegetation landscape to desertification vegetation landscape has led to a sharp decline in grass yield and a significant reduction in vegetation coverage[5], and grassland degradation has become a bottleneck restricting the development of local animal husbandry[7].

5.2 Soil erosion in grassland is becoming more and more serious

Grassland degradation succession occurs under the interference of climate change and human factors[8], resulting in grassland vegetation degradation and vegetation coverage reduction. The deterioration of climate further intensifies the degradation and desertification of grassland and water and soil loss. The interaction between them promotes the reverse succession of grassland ecosystem, and the grassland ecological environment falls into a vicious circle[9]. Grassland degradation weakens the ability of grassland to conserve water and soil ero-

sion, and the increase of instantaneous strong convection climate change intensifies the frequency of natural disasters such as landslides and debris flows.

5.3 Seasonal grassland imbalance and annual imbalance of grassland yield

The amount of natural grassland varies from year to year due to the limitation of climatic conditions in that year[10]. The grasslands in the Ili River Valley are complete in four seasons. However, due to different geographical locations and great differences in natural conditions, there are great differences in the vegetation composition, production capacity, forage quality, livestock carrying capacity and utilization conditions of grasslands in different seasons. Spring-autumn grasslands and winter grasslands are seriously insufficient, and there is a serious imbalance between seasonal grasslands. The grass yield of grassland is directly restricted by natural conditions. The imbalance between years is mainly affected by climate, and the level of grass yield is determined by the amount of precipitation.

5.4 The long-term mechanism of grassland ecological protection is not perfect

To curb the deterioration of grassland ecological environment and establish the benign development of grassland ecosystem is the fundamental goal of realizing the sustainable development of grassland ecosystem. The grassland compensation policy has played a good role in promoting the balance between grass and livestock[11]. Subsidies and rewards have been given to herdsmen who implement the prohibition of grazing and the balance between grass and livestock. However, these compensations still have a certain gap compared with the actual needs of ecological protection. The compensation standard is single and the standard is low. It is necessary to strengthen governance and improve governance standards.

5.5 Lack of late management and protection funds to consolidate the effectiveness of grassland ecological restoration

In the grassland ecological restoration and management, the effect of the implementation of supplementary sowing, grassland pest control and other projects reached the standard in the same year and the next year, and the vegetation was restored well. However, in the later project management and protection, the local financial situation is very difficult, and there is no financial guarantee. On the other hand, the technology of grassland management and protection is backward, the technical team is not perfect and unstable, the strength of the regulatory agency is weak, and the consolidation of the results is difficult, which affects the ecological restoration and management.

6. Sustainable utilization of grassland resources

6.1 Strengthen grassland management and make rational use of grassland resources

According to the characteristics of grassland types in Ili River Valley, we should strengthen the management of natural grassland, strengthen the legal management and scientific utilization of grassland resources, determine livestock by grass, and control grazing intensity. In the construction of grassland, based on the enclosure of fences, measures such as the prevention and control of grassland pests, the prevention and control of toxic weeds, supplementary sowing and improvement, and supplementary irrigation are combined to carry out comprehensive management. Further promote the ecological restoration and management of natural grasslands, implement the responsibility of herdsmen to protect and build grasslands, and mobilize their enthusiasm.

6.2 Establish forage seed gene bank and screen local excellent forage varieties

According to the environmental and climatic factors and the actual situation of Ili River Valley, local grass varieties with good ecological and economic benefits are selected, and the local grass seed base is established. Natural grassland ecological restoration project, according to the relationship between forage species and climate environment, reasonably plan the layout of grass species, and promote high-quality native grass species. For example, in mountain meadow, mountain meadow

grassland and mountain grassland, *Onobrychis vicifolia*, *Dactylis glomerata*, *Phleum pratense*, *Bromus inermis*, *Elymus sibiricus*, *Elymus dahuricus* and other varieties are mainly used; in desert grasslands and some mountain grasslands, drought tolerant varieties such as *Agropyron cristatum*, *Seriphidium transiliense*, *Kochia prostata* and *Ceratoides latens* are dominant.

6.3 Increase technical input and implement grassland ecological restoration construction

Increase investment in grassland science and technology, popularize grassland scientific and technological knowledge, and improve grassland management level. By using the techniques of supplementary sowing improvement, supplementary sowing irrigation and fence enclosure, we can increase the species composition and coverage of grassland plants, improve the yield and quality of grassland, rejuvenate the grassland, restore the plant community of dominant species of grassland, and reduce water and soil loss.

6.4 Strengthen grassland ecological monitoring to ensure the sustainable utilization of grassland resources

Based on the dynamic monitoring of grassland, the basic situation of grassland should be scientifically evaluated to grasp the changes of grassland productivity. It provides a systematic and scientific basis for grassland resource evaluation, livestock carrying capacity regulation, natural disaster prediction and so on.

6.5 Actively promote ecotourism

On the premise of protecting the grassland ecological environment, based on the scientific and rational utilization of grassland resources, and from the perspective of the advantages of grassland tourism resources in the Ili River Valley, carry out a reasonable development of grassland tourism. While improving the infrastructure of pastoral areas, optimizing scenic spots, exploring local cultural connotation, and improving comprehensive service functions, creating a green, ecological, environmental protection, and sustainable eco-tourism economic development path is conducive to combining grassland utilization mode with ecological protection, and advocating grassland eco-tourism with grassland natural landscape as the object and grassland folk custom tourism with grassland customs as the main.

Conflict of interest

The authors declare that they have no conflict of interest.

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ORIGINAL RESEARCH ARTICLE

Bottom line and boundary: The logic of rational land resource allocation in the perspective of governance

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ABSTRACT

Land is the most basic production factor of social and economic development, and the allocation of land re-sources is an important means of regulating social and economic development. At present, the contradiction between the needs of economic and social development and the increasingly scarce space resources puts forward new requirements for the allocation of land re-sources in China, and the importance of rational allocation of land resources is increasing day by day. During the reform period of land and space planning system, rational allocation of land resources not only means in-tensive and sustainable development, but also becomes a new expression of the will of land and space governance. It is a governance coordination platform linking macro development policies and micro resource utilization, and an important way to achieve high-quality development. Taking spatial governance as a clue, this paper attempts to sort out the evolution of governance logic behind land resource allocation in the Chinese context, traces back the previous logical transformation of land resource allocation that germinated due to the reform of social and economic system, and divides it into four characteristic stages: planned governance, regulatory governance, policy governance and bottom line governance. Based on the analysis of the governance mode and difficulties faced under the background of "bottom line governance", this paper puts forward the "three bottom lines" of building the governance pattern of land resource allocation, clarifies the function-al boundaries of the three main bodies of government, market and society in the process of land resource allocation, and emphasizes the spatial governance mode of government, market and society, so as to provide useful suggestions for the design of future spatial planning system.

Keywords: Land Resources; Space Governance; Bottom Line Governance; Functional Boundaries; System Design

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1. Introduction

Land is the most basic and fixed factor of production in social and economic development[1]. Land resource allocation is not only a macro means of regulating social and economic development, but also can significantly affect the agglomeration or diffusion of other factors of production. Due to the high coordination cost of land resource pattern change, there is a large "path dependence" in land resource allocation. With the growth of urban population and the development of industrialization and urbanization in China, there has been an imbalance between the scarcity of economic supply of land resources and the growing social demand[2]. According to the data of the National Bureau of Statistics, the supply of state-owned construction land fell by 3.6% year-on-year in 2019, which is the fifth year of continuous contraction of land supply since 2014. Land supply continues to be tight, and China's land resources are scarce and begin to show a trend of forced development model transformation.

In March, 2018, the establishment of the land spatial planning system has greatly affected the pattern of land resource allocation and economic and social development needs. The "intensive and sustainable" development emphasized by the State takes the territorial space planning as the starting point, and realizes the effective implementation of national industrial policies and the orderly flow of production factors through the rational allocation of space resources, so as to achieve the scale of space bearing and orderly agglomeration. Rational allocation of land resources not only means intensive and sustainable development, but also becomes a new expression of the will of land space governance. It is an important way to link macro development policies with micro resource utilization and achieve high-quality development.

In China, the allocation of land resources has always been an important part of the national governance system. As early as the period of agricultural civilization, the early idea of coordinating the development of city states with land advantage areas has sprouted in Guanzi, "Yin tian cai, jiu di li (To rely on natural resources, to take advantage of the terrain.)". Since the reform and opening up, China has vigorously promoted the allocation of land resources to concentrate in advantageous space, and achieved the scale agglomeration of production factors in a market-oriented way of land resource allocation. Since the 21st century, China has established a main functional control area for effective intervention. The logic of land resource allocation has been constantly transformed with the evolution of governance concepts, and the reform of land spatial planning system has placed it under the grand background of national governance modernization, endow the allocation of land resources with more realistic and profound significance.

Therefore, with the change of the overall development environment of the country, the spatial planning governance with land resource allocation as the core should also be actively transformed with the times. This paper attempts to take spatial governance as a clue, sort out the governance logic evolution of land resource allocation in the Chinese context, and on the basis of analyzing the existing governance models and difficulties, put forward the "three bottom lines" of building the governance pattern of land resource allocation, emphasizing the spatial governance model of government, market and society, so as to provide useful suggestions for the design of the future land spatial planning system.

2. Governance logic evolution of land resource allocation in China: From "planned governance" to "bottom line governance"

In China, the logical change of land resource allocation is inseparable from the reform of social and economic system. On the one hand, the reform of social and economic system has promoted the reform of land system, which has become an important institutional support for the allocation of land resources, and provided corresponding governance guidance for the planning and management of various land use, development and construction activities by improving relevant governance concepts; on the other hand, the allocation of land resources also provides a reasonable land development pattern and appropriate spatial security for the change of social and economic system[3] (**Figure 1**).

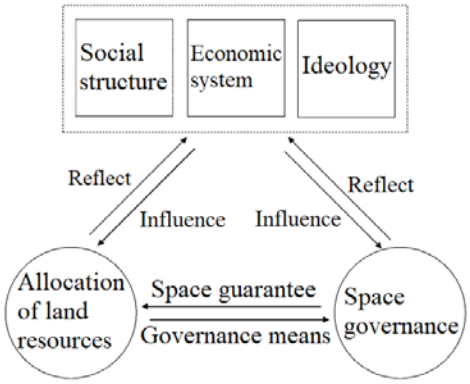

Figure 1. Governance logic of land resource allocation. Source: Self drawn by the author

The allocation of land resources in Chinese cities in different periods reflects the specific socio-economic background and the choice of endogenous governance mode. It always evolves with the alternation of China's socio-economic system and land system. Looking back on the previous logical transformation of land resource allocation sprouted

due to the reform of social and economic system, it can be divided into four governance characteristic stages to deal with different resource allocation periods: planned governance, regulatory governance, policy governance and bottom line governance (**Figure 2**).

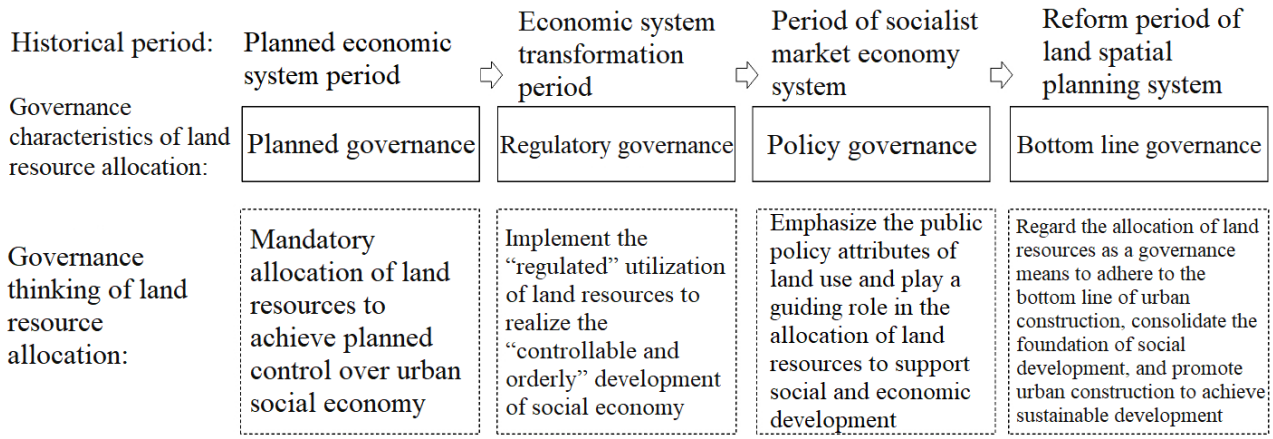

Figure 2. Governance logic evolution of land resource allocation.
Source: Self drawn by the author

2.1 "Planned governance" in the period of planned economic system and land resource allocation

The "planned governance" of land resource allocation refers to the governance thinking that the government limits the threshold of urban and rural spatial production through mandatory means of land resource allocation, so as to realize the planned control of urban social economy. At the beginning of the founding of new China, state-owned and private urban land coexisted. In 1950, the Land Reform Law of the People's Republic of China[1] established and implemented the ownership of farmers' land, so as to liberate rural productive forces and develop agricultural production. In 1956, urban land was fully nationalized. The use method of administrative allocation and free use of urban land by the local government excluded the market regulation mechanism, which has obvious characteristics of planned economy. The management system of urban and rural land division and decentralized land use departments[4] led to serious waste of land resources and low utilization efficiency.

Under the influence of the political situation, the field of urban construction has also entered the "great leap forward" and "people's commune planning period"[5]. The three-tier decentralized construction of "not building a centralized city" made the layout of urban land scattered and the functions disordered during the 10-year turbulence. The heavy industrialization development policy of "supporting industry by agriculture" promotes the single flow of land resources to agricultural production, and the land policy has obvious characteristics of "ideology-oriented governance". The unilinear governance thinking under the overall planning of "planning consciousness" leads to the process from the government will to land management and then to land supply. The allocation of land resources blindly emphasizes the limitation of the single production function of land, ignoring the complexity of land's own production capacity and the flexible demand of urban development. Under the background of planned economic system, the allocation of land resources of the Chinese government has an obvious "planned governance" orientation.

2.2 "Regulation and governance" of economic system transformation period and land resource allocation

The "regulatory governance" of land resource allocation refers to the governance thinking that the government implements the "regulated" utilization of land resources through national macro-control, so as to realize the "controllable and orderly" de-

[1] Land Reform Law of the People's Republic of China, adopted by the Eighth Session of the Central People's Government Committee on June 28, 1950.

velopment of social economy. Since the reform and opening up, the transformation of economic system has stimulated the reform of urban land system. In 1982, the constitution was amended to clarify that urban land belongs to the state, and the land ownership structure of public ownership of land was officially established. In the same year, Shenzhen, as a pilot of reform, began to collect land use fees by location and promoted them nationwide. The circulation of land factors was initially market-oriented, but it was still difficult to avoid inefficient land use. In 1988, the Amendment to the Constitution of the People's Republic of China [2] guaranteed the transfer of land use rights at the legal level. The establishment of the land circulation system further stimulated the activity of the land circulation market, promoted the efficient operation of the flow of land factors, and also laid the institutional foundation for the market to participate in the allocation pattern of land resources under national macro-control. Since then, the land system has completed a profound change in the period of economic system transformation.

The reform of land system has liberated the land circulation market, and the national work focus of 'taking economic construction as the center" is also increasingly dependent on land development and construction activities, and China's urban construction has entered a period of rapid expansion. In 1982, for the sustainable use of land resources, China issued the basic national policy of managing and protecting land resources, emphasizing the "regulated" use of land resources. The emergence of regulatory detailed planning and its focus on land classification and strong regulation of land development intensity mark that China's land resource allocation has entered the period of "regulation and governance". In 1998, the Land Administration Law of the People's Republic of China[3] was revised and passed, and a new land management system with use control as the core was established in legal form for the first time. The allocation of land resources has shifted from "planned governance" that blindly emphasizes the function of land production to "regulatory governance" that is controllable and adjustable and emphasizes the characteristics of land resources. Urban development and construction has moved towards the era of constrained management and control.

During this period, China's land resource allocation focused on centralized and efficient land management, strictly limiting the scale of land development, and comprehensively managing land resources, trying to alleviate the negative external effects caused by paid land use. The multilinear governance thinking of "regulatory governance" runs through the whole process from land management to supply, paying attention to the compound production function of land resources and the development of "regulated", which reflects the governance characteristics of the country "emphasizing regulation and neglecting the market" in the period of economic system transformation.

2.3 "Policy governance" in the period of socialist market economic system and land resource allocation

"Policy governance" of land resource allocation refers to the new thinking of spatial governance that the government regards land resource allocation as a policy means to promote the modernization of national governance, emphasizes the public policy attribute of land use, and plays its guiding role in supporting social and economic development. Since the 21st century, in the face of a series of sustainable development problems caused by blind development, the country has gradually abandoned the traditional concept of development dominated by growth and began to explore a new social and economic development model of win-win economic construction and environmental maintenance. In terms of land control, the Notice on Issues Related to Strengthening Land Regulation in 2006[4] requires

[2] Amendment to the Constitution of the People's Republic of China (1988), adopted at the First Session of the Seventh National People's Congress on April 12, 1988, and promulgated and put into effect by a proclamation of the National People's Congress on April 12, 1988.

[3] Land Administration Law of the People's Republic of China (1998 Revision) was issued by the Standing Committee of the National People's Congress on August 29, 1998.

[4] Notice of the State Council on Issues Related to Strengthening Land Regulation and Control (Guofa [2006] No. 31).

"effectively strengthening land regulation"; the 2011 National Plan for Main Functional Zones[5] defines the concept of spatial control of main functional areas, divides them into four types of main functional areas, and stipulates the corresponding functional positioning and development control principles, aiming to achieve the orderly development and balance of space[6]. In terms of land use, in the transition process of urban land use system from administrative allocation to paid limited term use, urban land use increasingly relies on the role of market mechanism[7], and also puts forward stricter requirements for urban land planning and management, and the role of urban planning public policy is gradually strengthened. The 2006 Measures for the Preparation of Urban Planning[6] defines the policy status and function mode of urban planning as "one of the important public policies for regulating urban space resources".

During this period, planning, as an important government function, embodied the policy guide for the government to guide and manage urban land use[8], and land resource allocation guided urban development by directly affecting land construction and development and clarifying the trend of land use, so as to achieve the governance goal of regulating spatial order with land resource elements.

The allocation of land resources at this stage can be summarized as the logical characteristics of "strong development, strong control, heavy regulation and heavy market": focusing on optimizing the stock, transformation and upgrading[9], the priority development of areas with concentrated production factors and potential areas can be achieved through the rational layout of industrial space; take intensive utilization and ecological maintenance as the development concept, pay attention to the efficiency of land resource utilization, and emphasize the concentration of ecological elements and the restricted development of environmental protection areas; strengthen the macro-control role of land management, and establish a land supply system controlled from top to bottom; clarify the reasonable price threshold for the transformation between different land uses in the plan[10] to establish a fair and just land market environment. The thinking of "policy governance" focuses on the spatial regulation and development guidance function of land resources, which reflects the governance characteristics of the government's macro-control of the trend of social and economic development with the help of the spatial governance function of urban land use.

2.4 "Bottom line governance" during the reform period of land spatial planning system and land resource allocation

The "bottom line governance" of land resource allocation refers to the new thinking of land space governance that, facing the severe situation of land supply and demand, the government regards land resource allocation as a governance means to adhere to the bottom line of urban construction, promote urban construction to achieve from quantity to quality, from economic development to sustainable development, and give play to the bottom line regulatory role of land resource allocation on social and economic development. With the change of economic system and social background, the planning laws and regulations that emphasized urban and rural development and construction in the past are difficult to adapt to the development will of the times. On January 1st, 2008, the Urban and Rural Planning Law[7] was issued, emphasizing that urban planning guides the healthy development of cities, standardizes the construction behavior in rural areas, guides the good development of rural areas[11], coordinates the role of new urban-rural relations, standardizes the bottom line of urban-rural development, and highlights the public policy attribute of planning in the form of law[12]. In terms of land control, the 2008 outline of the National General

[5] On December 21, 2010, the State Council issued the Notice on the National Plan for Main Functional Zones (Guofa [2010] No.46).

[6] Measures for the Preparation of Urban Planning, adopted by the 76th executive meeting of the Ministry of Construction on October 28, 2005, shall come into force since April 1, 2006.

[7] Urban and Rural Planning Law of the People's Republic of China, the People's Republic of the Tenth National People's Congress Standing Committee adopted at its thirtieth meeting on October 28, 2007, is hereby promulgated and shall come into force on January 1, 2008.

Land Use Plan (2006–2020) [8] proposed to strengthen the bottom line control of land use, control the boundary of urban and rural construction land through the "land space control system", and delimit land use areas to further clarify the focus of land use control. In terms of land use, the focus of land resource allocation has shifted from focusing on the layout of production factors to focusing on strictly controlling the bottom line of factor development. The 2017 National Land Planning Outline (2016–2030)[9] emphasizes "adhering to the matching of land development and resource and environmental carrying capacity", "adhering to the coordination of concentrated development and balanced development", "based on resource and environmental carrying capacity", and promoting the optimization of land spatial development pattern and bottom line protection. During the reform period of the land spatial planning system, spatial planning is different from the traditional development and construction oriented urban and rural planning, and from the land use planning with pure control thinking. It is a major adjustment and reconstruction of the logic and methods of spatial planning under the concept of ecological civilization[13], and a "development guide" for social and economic development based on "rigid control". Land spatial governance and spatial structure optimization are regarded as the important basis for the implementation of land spatial use control and ecological protection and restoration[14], and land resource allocation has become a governance tool for regulating land resources, supporting land use and bottom line guarantee, and an important means to promote the modernization of national governance system and governance capacity.

The characteristics of land resource allocation at this stage can be summarized as "overall planning and development, bottom line and height": take land resource regulation as a means to coordinate the demands of the government, market and society, and coordinate the relationship between protection and development, efficiency and quality[12]; give play to the role of macro guidance and planning regulation of land resource allocation[15], "keep the bottom line and determine the height", limit land development indicators to adhere to the bottom line of development, and pay attention to spatial characteristics to improve the height of urban development goals. The logic of land resource allocation under the influence of the "bottom line governance" thinking focuses on the bottom line control function and overall development function of land resources, which reflects the elastic, dynamic and sustainable land space governance characteristics under the guidance of ecological civilization during the reform of land space planning system.

3. Land resource allocation dilemma in the context of "bottom line governance"

The resource allocation of urban and rural land in China, from the free allocation and planned allocation in the early days of the founding of new China, to the centralized and efficient regulation in the period of economic system transformation, to the allocation of "strong development, strong control, heavy regulation and heavy market" since the 21st century, to the bottom line regulation under the guidance of ecological civilization in the context of territorial space planning, has gradually formed the resource allocation mode of "rigid control" and "flexible regulation". At the same time, the governance role of land resource allocation has experienced the evolution path of "planned governance-regulatory governance-policy governance-bottom line governance", and its governance attribute has been continuously strengthened with the phased transformation of social and economic development goals. In the target context of modernization of national governance system and governance capacity, emphasizing the "bottom line governance" function of land resources has become the main feature of land resource allocation in modern China.

At the same time, the public attribute of land resources[16] determines the pattern of government,

[8] Notice of the State Council on the Issuance of the Outline of the National General Land Use Plan (2006-2020) (Guofa [2008] No. 33).

[9] Notice of the State Council on the Issuance of the National Land Planning Outline (2016-2030) (Guofa [2017] No. 3).

public sector, market and public participation in land resource allocation: land resource allocation is a continuous process in which conflicting or different interests of land owners and users can be reconciled and take joint action[17], and attention needs to be paid to the concept of balanced redistribution of land rights and interests between government, market and society and the interaction between public power and society[18]. Therefore, the context of "bottom line governance" not only emphasizes the multidimensional and composite land resource allocation mode and efficient resource allocation efficiency, but also puts forward phased requirements for the governance subjects participating in land resource allocation, which also means that the current governance pattern of land resource allocation in China is facing great challenges.

3.1 Inefficient monopoly of the government

Allocation pattern: Moloch believes that land resource utilization is the source of power for social development, and land resource utilization planning and programming is an important means for local governments to implement economic and social policies[19]. For a long time, the land resource allocation modeled by the Chinese government has provided a strong driving force for the development of industrialization and urbanization[20], forming a hierarchical land resource allocation pattern with central government macro-control, provincial government policy transmission, and local government administrative guidance. As a macro subject, the central government reasonably controls the land supply and the necessary land supply regulation through administrative means, thereby affecting the growth elasticity of population land and the land utilization rate, ensuring the spatial demand of foreign capital, so as to promote the decision-making goal of rational allocation of resources. Based on the competition standard, the provincial government implements a relatively lose control of land resources, focuses on the role of policy transmission and innovation, realizes the targeted regulation of land resources, carries out both protection and security, and carries out innovation and exploration. Local governments are the micro main body of land resource allocation, taking benefits as an important basis for decision-making[21], and changing the pattern of resource allocation by influencing land prices and land use structure, so as to achieve the corresponding assessment indicators and economic performance goals. The government changes the pattern of land resource allocation through hierarchical policy regulation. If it lacks macro-administrative regulation and relies only on the role of market mechanism, it will lead to the disorderly expansion and vicious competition of urban space, and cause structural imbalance and instability in social and economic development[22].

Governance dilemma: However, this land resource allocation model based on the perspective of God often leads to blind spots in the effective operation of land resources. Governments at all levels often ignore the long-term planning of urban land resources in the context of "bottom line governance" because of short-term economic goals. Because the management motivation and information of land managers and users are not equal, and government decisions often serve the performance goals other than economic development, the "high cost and low efficiency" allocation of urban land resources is inevitable. The government has long relied on the income from land sales as a source of funding for infrastructure construction, resulting in unreasonable land use structure within the city; for a long time, the contradictions and conflicts between government departments and enterprises have led to the extensive use of a large number of industrial land sold at low prices, and the poor information dialogue has led to a large number of industrial land resources flowing to the inefficient enterprise market; the division of administrative divisions limits the role of market mechanism and makes it difficult to achieve the optimal allocation of land[23]; there is a lack of standardized management of the land market, and the phenomenon of random reduction and exemption of land prices occurs from time to time. The contradiction between the decision-making goal of the superior government acting on the land quantity and pursuing the maximization of the comprehensive benefits of land

and the development goal of the subordinate government acting on the land price and pursuing the maximization of the economic benefits of land is the main reason for the dilemma of land resource allocation and governance. With the deepening of market-oriented reform, the "economic man" attribute of the government is further intensified, and the "entrepreneurial" government forms a solid interest alliance with developers, placing land resources in a vicious circle of "low price transfer-low efficiency utilization". In the context of "bottom line governance", with the depletion of land resources and the comprehensive socialist economic market-oriented reform, the government led land resource allocation model will face a huge impact.

3.2 Inefficient regulation of the market

Allocation pattern: After the short withdrawal of the market mechanism in the early days of the founding of new China, the government is deeply aware that giving full play to the allocation function of market resources is one of the essential characteristics of the socialist market economy. As the main allocation mode of land resources, the market has a profound impact on the adjustment behavior of the main factors. Since the 1980s, the allocation mode of urban land resources has been constantly adjusted with China's market-oriented transformation, realizing the transformation from the unified allocation of planning to the land transfer system with supply and demand, competition and price as the core mechanism[24]. On the one hand, the market mechanism realizes the behavioral motivation symmetry between land managers and users by building a bridge of information interaction, and the existence of land rent and land price reduces the probability of land users to idle or waste land through financial constraints. The combination of market led land price signals and government led land quantity signals further improves the efficiency of land management and the decision-making level of relevant departments[25]; on the other hand, the market mechanism coordinates the differential income of enterprises caused by regional advantages by coordinating the measurement and distribution of land income, gives land users the power to make efficient use of land resources, and creates an equal competition environment for enterprises. The market mechanism gives full play to its dynamic resource allocation advantages, and promotes the efficient allocation and rational use of land by making up for the defects of government regulation.

Governance dilemma: However, the market mechanism cannot achieve the complete allocation efficiency of urban land resources. First of all, the market's indulgence in land prices has increased the competitiveness of the land transaction market, raised house prices and land prices with "land" as a competitive chip[26], intensified the local government's dependence on "land finance" and "land investment", affected the government's land transfer motivation, and then led to the imbalance between supply and demand of land. Secondly, the "land hoarding behavior" of enterprises holding land for sale leads to a certain degree of monopoly in land supply. Taking land as a "value-added means" means that a large number of land exist in the form of open space or low utilization rate, the effective supply of land is reduced, and the land price is further increased[24]. The excessive market-oriented allocation mechanism places land resources in the vicious circle of "high price transfer-high price supply". The mismatch of resource supply intensifies the endless contradictions between the government, enterprises and the people, which will affect the orderly operation of the whole society, which is obviously contrary to the spirit of the new era that pays attention to the quality of development in the context of "bottom line governance".

3.3 Inefficient social participation

Allocation pattern: As a social wealth with value preservation and appreciation functions, there are problems of who owns land and how to occupy it more fairly[26]. Unlike the government and the market, which focus on the economic benefits of land resources, social forces often participate in the allocation of land resources from the starting point of fairness and justice. Compared with the strength of government policy implementation and the flexibility of market regulation, the main force of socie-

ty in the land resource allocation pattern is slightly weakened, and under the current urban-rural dual structure system, there are differences in the ways in which urban and rural social subjects participate in land resource allocation[27].

Governance dilemma: Similarly, the participation of urban and rural social subjects in the allocation of land resources also faces different problems. The relevant regulations of the Land Administration Law of the People's Republic of China, "the use right of farmers' collectively owned land shall not be transferred, assigned or leased for non-agricultural construction" restrict the circulation of the use right of collective construction land. The aphasia of the market mechanism makes the unreasonable distribution of economic benefits and other contradictions in the process of land acquisition and circulation under the guidance of the government highlighted[28], which has promoted the development of the "invisible market" of rural land in recent years[10]. A large number of circulation methods such as evading the control of land planning and land management taxes and fees by renting instead of levying have become increasingly fierce. The channels for citizens to participate in the allocation of land resources are more limited. The transfer of land development rights and interests will occur only when the land enters the stage of renewal and development. On the one hand, the serious absence of the role of the market in the allocation of rural land resources has led to the continuous breeding of "invisible" land transactions, making the semi solidified rural land market more passive; on the other hand, due to the unequal information channels, the development and use rights of urban land are directly seized by investment enterprises, and follow the principle of "buy low and sell high" of market economy, which is threatening the personal interests of property owners[29]. In the process of land resource allocation, under the strong role of the market and the government, the absence of the public participation system further restricts the development of social equity, and the weak social forces appear to be wavering. The lack of "good governance" attribute of land resource allocation leads to the fierce conflict between personal interests and public interests, the social "bottom line" is difficult to develop well, and spatial governance is in a dilemma.

4. Construct the "three bottom lines" of land resource allocation pattern

In the context of "bottom line governance", facing the requirements of land resource allocation in the new era, China's spatial governance pattern presents imbalances such as the absence of government control, excessive market participation, and the decline of social forces. A series of interest relationship changes and conflicts caused by land resource allocation pose challenges to governance transformation. In the face of the imbalance of the pattern and the reshuffle of land interest subjects and interest relations, spatial governance must change the situation of the inefficient monopoly of the government on resource allocation, the inefficient regulation of the market and the inefficient participation of society. By building the "three bottom lines" of the governance pattern of land resource allocation, we should clarify the core requirements for the governance subjects to participate in resource allocation, improve government efficiency, activate market investment and encourage social participation, to actively respond to the challenges of the bottom line governance period (**Figure 3**).

4.1 Government bottom line—Delimit the efficiency boundary of control intervention

Land resource allocation, as a spatial control means to meet the needs of social activities and sustainable development by adjusting the spatial distribution of resources and the interests of land stakeholders, has the characteristics of control intervention. The "economic man" attribute and decision-making inclination of enterprises and individuals determine the dominant position of the government in the pattern of resource allocation.

[10] The invisible market for land is the sum of the economic relationships that occur during the flow of land property rights of the type not officially recognized by the state that exists in reality.

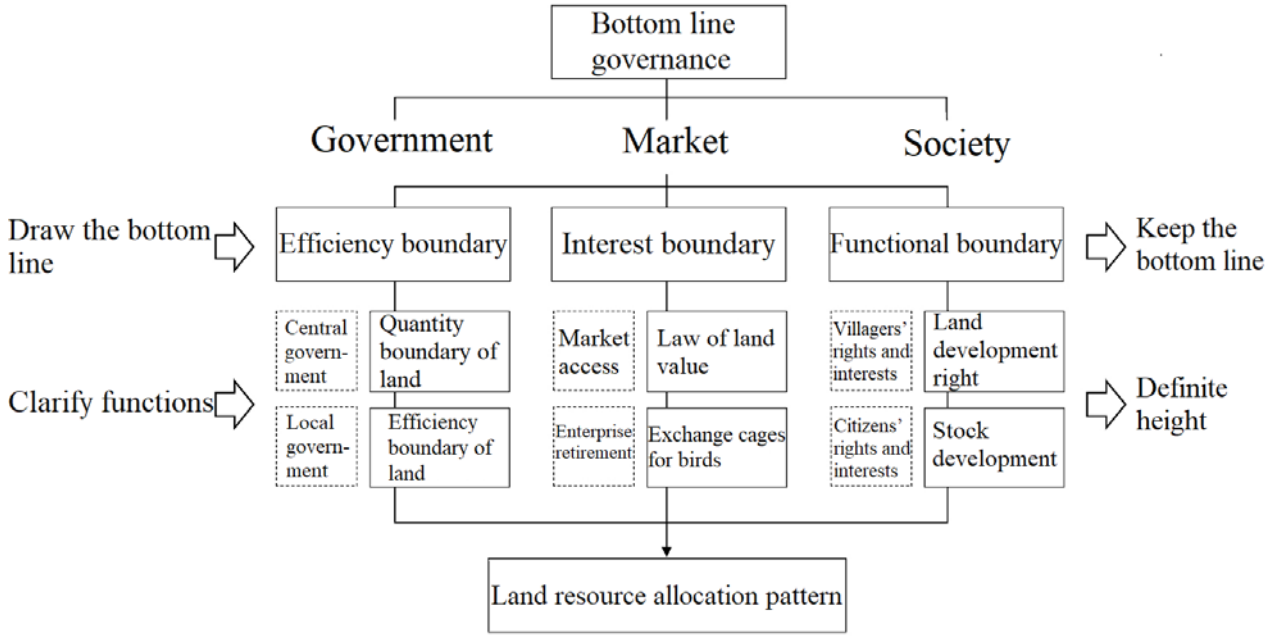

Figure 3. "Three bottom lines" of constructing land resource allocation pattern.
Source: Self drawn by the author

Therefore, as the centralized representative of public interests, the central government first needs to firmly control the "quantitative boundary" of land resource allocation, and gradually set an insurmountable "red line" for the sustainable development of land space on the basis of "1.8 billion mu cultivated land red line" and "urban growth boundary"; secondly, we need to strictly grasp the "quality boundary" of land resource allocation through reasonable control of land supply and necessary land supply regulation, ensure the balance of land use, reduce the proportion of land resource mismatch from the source, and seek to maximize the efficiency of resources.

At the same time, local governments should divest the economic attribute of participating in land management as soon as possible, delegate power appropriately, take allocation efficiency and social benefits as the action criteria for control intervention, and submit the land index formulation process to fair and open social criteria by establishing a series of "transparent" planning and decision-making channels. Repositioning the role of local governments in resource allocation, value neutrality and benefit supremacy are the core guidance for local governments to participate in decision-making. By setting up a planning committee with multiple-participation, we should strengthen the accuracy of decision-making, and the corresponding judicial evaluation institutions should clarify land pricing and property ownership to limit market monopoly behavior, adhere to the efficiency bottom line of control and intervention, and then give full play to the pivotal function of the government's macro planning.

4.2 Market bottom line—Clarify the benefit boundary of value adjustment

Existing studies have shown that when local governments deliberately intervene in land transfer due to financial pressure, the role of marketization in regulating local government behavior is more obvious, and the improvement of land allocation efficiency is greater[21]. At present, a series of preferential policies, such as simplifying examination and approval and lowering the threshold of access, implemented by local governments due to fiscal tightening, have provided favorable conditions for good market development and construction, and the market is facing more open opportunities. At the same time, a wider range of public participation in construction is also a good opportunity to regulate market behavior and clarify the market as a benchmark for the law of land value. The appropriate de-

centralization of government power is conducive to the diversified opening of the market. However, what is more important is that the market itself needs to grasp the interest boundary of participating in the land operation. All market behaviors must be guided by the law of value, clarify the bottom line of market power, and give play to the market value under certain government intervention.

Therefore, while opening up public investment channels as soon as possible, the government should build an open bidding platform, maintain the order of land investment, and limit inefficient enterprise behaviors such as "hoarding land and raising prices" to promote the intensive use of land. Establish a reward and punishment system with clear rewards and punishments, conduct a thorough investigation on land acquisition enterprises on a large scale, find out the allocation efficiency of allocated land, and crack down on monopoly and illegal construction. For example, Shenzhen's "cage for bird" strategy, through the matchmaking of government departments at all levels, the establishment of secondary market platforms and other measures, establishes a "forced + incentive" working mechanism, and vacates zombie enterprises that can no longer operate. At this time, the market will no longer be a vested interest in land development, but a mediator who adheres to the interest boundary of value regulation and plays the role of a flexible coordination platform.

4.3 Social bottom line—Broadening the power and function boundary of public participation

For the vast rural areas, the implementation of collective operating land into the market has strengthened the participation of the market mechanism. The increase in the freedom of land transactions can promote the overall allocation of urban and rural land resources to a certain extent, and the collective interests of villagers can be guaranteed. However, the impact of commercial land on the market is limited, and the scale of collective land transactions is very small. It is difficult to continuously protect the public rights and interests of social subjects only by virtue of policy opportunities rather than mechanism reform. For urban areas, in the development process of stock space, we need to realize that the ultimate goal of maintaining public interests is Pareto optimality[11] rather than Kaldor optimality[12]. We should not only pursue the optimization of the overall interests of the society, but also protect individual interests.

Therefore, the urgent task is to broaden the power boundary of public participation and build corresponding public participation channels according to local conditions. Build a unified land transaction negotiation procedure in rural areas, protect the economic interests and public rights and interests of villagers in the form of agreement, set up a community autonomy mechanism in cities, and let the land use right holder assume part of the governance functions, and expand the channels of public participation through hearings, network platforms, data monitoring, public opinion surveys, etc., so as to strengthen the organizational foundation of public participation. The government must create governance awareness that social equity is higher than economic efficiency, set up an open, flexible and multi-channel public participation and coordination mechanism, alleviate the contradiction between personal interests and public interests, and promote long-term social stability.

5. Conclusion

The allocation of land resources in Chinese cities in different periods reflects the specific socio-economic background and the choice of endogenous governance mode. It always evolves with the alternation of China's socio-economic system and land system. From the planned economic system to the socialist market economic system, from "planned governance" to "bottom line governance", affected by the social structure and ideology of different historical stages, the land resource allocation pattern often shows specific characteristics of the

[11] Pareto optimality, which is a change that does not reduce the welfare of any member of society on the basis of an increase in the welfare of at least one member of society.

[12] Kaldor optimality, by definition, improves overall efficiency if one person's situation is better as a result of the reform, so that it compensates for the loss of another person and there is a surplus.

times, and the governance logic behind it also shows obvious phased differences. In response to the needs of the times for the modernization of the national governance system and governance capacity, China's current land resource allocation model should convey the will of "bottom line governance", take land as the medium to coordinate the development of the "bottom line and height", and emphasize the bottom line management and control role and overall planning function of land resources. Therefore, different resource allocation and governance subjects are facing the transformation of governance thinking. This paper believes that the first thing to clarify the bottom line of urban development is to clarify the bottom line of governance. It proposes to delimit the functional boundaries of the three main bodies of government, market and society in the process of land resource allocation by constructing the three bottom lines of land resource allocation pattern, emphasize the spatial governance mode of government, market and society, and take advantage of the spatial allocation of land resources to strengthen the role and efficiency of governance, try to provide useful suggestions for the future planning system design.

Land resource allocation is a grand topic, which is not only related to the efficiency of resource allocation in economics and the governance logic of politics, but also closely related to the distribution of power in law and the spatial governance of urban and rural planning. This paper only analyzes this grand topic based on the governance dimension, and there is still a lot of research space to be studied. However, no matter from which angle, we should recognize that the core of land resource allocation is a material contract to ensure the orderly development of society, and urban planning should play a role on the basis of public interest and arrange land space with reasonable grounds. At any time, social interests should become the core "bottom line" and original intention maintained by all construction activities.

Conflict of interest

The authors declare that they have no conflict of interest.

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CASE REPORT

Spatial optimal allocation of land resources in Fengweihan, Kaishan, Laos

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ABSTRACT

Abstract: **Objective:** Through the spatial optimal allocation of land resources to improve the efficiency of land use, promote the rational layout of various industries and infrastructure, and provide a theoretical basis for the comprehensive development of regional social economy. **Methods:** Combining GIS spatial analysis technology, logistic regression analysis method and CLUE-S model, taking Kaishan Fengweihan City, Laos, as the research area, the research on the spatial optimal allocation of land resources was carried out. Under the constraints of spatial suitability and quantitative structure, the spatial optimal allocation of land resources in Fengweihan city of Kaishan is carried out based on the land demand, limiting factors, conversion rules and spatial characteristics. **Results:** Urban construction land and paddy fields expanded to suitable areas on the original basis, and the forestry land with sparse distribution was reduced correspondingly due to development and utilization, while other land types did not change significantly in quantity and space. **Conclusion:** Urbanization construction and agricultural development can provide the foundation and support for the economic development of Kaishan Fengweihan city. At the same time, it is necessary to give consideration to ecological protection and promote the overall, coordinated and sustainable use of land resources.

Keywords: Land Use; Space Optimization; CLUE-S Model; Fengweihan City, Kaishan, Laos

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1. Introduction

The optimal allocation of land use space is conducive to the rational and efficient use of limited land resources, thereby promoting the sustainable development of regional economy. How to realize the optimal allocation of land resources in space is still a hot issue in the field of land spatial planning. At present, scholars at home and abroad have carried out a lot of research in this field[1-3], mainly including land use change research based on multi-source data fusion[4,5], spatial analysis based on GIS (Geography Information System)[6], optimal allocation based on suitability evaluation[7], land use simulation[8,9], optimization algorithm research[10], the research content has been deepened[11-13], and the research methods have been improved[14-16].

As the economic center of Laos and the second largest city after the capital Vientiane, Kaishan Fengweihan has an important strategic position in the regional development and future planning of Laos. In recent years, the urbanization of Fengweihan city in Kaishan has developed rapidly. The construction of grain production base and the development of special economic zones urgently need reasonable land

planning to provide guarantee. However, at present, its land planning lags behind and the planning system is imperfect. At the same time, there are few studies and practical explorations on land allocation carried out around Kaishan Fengweihan city at home and abroad[6,17,18]. Although these studies provide methods and data support for the land use of Kaishan Fengweihan city and Laos to a certain extent, the results are still relatively scarce, which is not enough to provide sufficient support for its planning practice. As the premise and foundation of economic development, the rational allocation of land resources is still a key scientific problem to be solved urgently in the land and economic fields of Kaishan Fengweihan city.

Based on the relevant experience at home and abroad, this study combines GIS spatial analysis method with CLUE-S model to carry out the research on the spatial optimal allocation of land resources. At the same time, considering the actual situation of Laos, the control indicators of different types of land use scale are based on the suitability of natural conditions, and constrained by the restrictions of local land use policies and land use development goals, to promote the development and rational use of land resources, and provide a reliable guarantee for local economic development.

2. Overview of the study area and data sources

2.1 Overview of the study area

Located on the southern border of Laos and on the left bank of the Mekong River, Kaishan Fengweihan is the second largest city in Laos, the capital of Savannakhet Province, and the economic center of Laos. Kaishan Fengweihan city is also known as “Savannakhet city”, which means “city in heaven”. In 2005, it was renamed Kaishan Fengweihan city in memory of the second president of Laos Kaishan Fengweihan, with a population of 1.20×10^5, and a land area of 650.51 km^2.

2.2 Data source

The basic data of the study includes three types: land use data, socio-economic data and questionnaire survey data. Among them, the land use data comes from the land use status data (2006), relevant planning data (2006–2015) provided by the Lao government department, the remote sensing image data of the study area (2015–2020) provided by the geospatial data cloud of the Chinese Academy of Sciences, and the field survey and test data of the study area (2015); the socio-economic data are from the statistical yearbook of the study area (2005–2013); the questionnaire data comes from expert consultation and scoring in the field of land planning and social economy (2019–2020).

3. Research methods

3.1 Model construction

Based on GIS spatial analysis technology and CLUE-S model, the data of land use status, suitability, optimal quantitative structure, driving factors, limiting factors and so on are converted into corresponding model input parameters according to the format requirements of the model, and the model operation is carried out to obtain the spatial optimal allocation scheme of land resources in Fengweihan City, Kaishan. The model consists of four input modules: transfer rules, limiting factors, land demand, spatial characteristics, and a spatial layout allocation module[16].

(1) Transfer rules. The transformation rules between different land classes are defined and realized through the transition matrix. See **Table 1** for the transition matrix. Where the value of 1 means that it can be transferred, and the value of 0 means that it cannot be transferred. The specific assignment is obtained by collecting the opinions of relevant experts, local governments and residents in multiple rounds according to the methods of policy research, field survey in the study area in 2015 and expert consultation in 2020 (**Table 1**).

(2) Limiting factors. Restrictive factors include regulatory constraints such as nature reserves. In the CLUE-S model, the allocation of land use pattern is affected by the setting of restrictive factors. There are two types of restrictions: regional restrictions and land type restrictions. For example, the land

Table 1. Transfer matrix between secondary land types in Fengweihan City, Kaishan, Laos

Project	Paddy field	Garden plot	Grassland	Crop planting	Other agricultural land	Forestry land	Urban construction land	Land use for rural construction	Land of water resources	Other land
Paddy field	1	0	0	0	0	0	0	0	0	0
Garden plot	1	1	0	1	1	0	0	0	0	0
Grassland	1	1	1	1	1	1	1	1	1	0
Crop planting	1	1	0	1	1		0	0	0	0
ther agricultural land	1	1	0	1	1	0	0	0	0	0
Forestry land	1	1	0	1	1	1	1	1	1	0
Urban construction land	1	0	0	0	0	0	1	0	0	0
Land use for rural construction	1	0	0	0	0	0	1	1	0	0
Land of water resources	0	0	0	0	0	0	0	0	1	0
Other land	1	1	1	1	1	1	1	1	1	1

within the protected area is not allowed to be transferred to other types of land, which belongs to the restriction of specific areas; whether the transfer between different classes is allowed belongs to the land class restriction.

(3) Land demand. The land demand is obtained by fuzzy prediction calculation and used to limit the change of each land type in the simulation process. A positive value of land demand indicates an increase in the number of land, a negative value indicates a decrease in the number of land, and the total change of all land types is zero, that is, the total area of each land type is constant. Kaishan Fengweihan city has an important strategic position in the regional development and future planning of Laos. Its demand for construction land and agricultural land should not only consider the factors such as population growth, economic development and food supply in the study area, but also consider the role and contribution to the development of the whole region. Therefore, regional factors should be considered in the prediction of land demand.

(4) Spatial features. Based on the principle that all land use types are allocated at their most likely positions, the quantitative relationship between the changes of land use types and the driving factors leading to the changes is analyzed through logistic regression operation, and the spatial distribution probability of each land use type is obtained[19]. The specific calculation expression is as follows:

$$\ln\left(\frac{P_i}{1-P_i}\right)=B_0+B_1\ X_{1i}+B_2\ X_{2i}+\cdots+B_nX_{ni} \quad (1)$$

Where: P_i represents the probability that a grid unit may become a land type i; B_0 is the constant of regression equation; B is the regression coefficient of each driving factor; X is the driving factor.

(5) Space allocation. Spatial allocation is based on the analysis of land use conversion rules, limiting factors, spatial characteristics and other elements. According to the order of the total probability of land allocation from large to small, through multiple iterative operations, the land demand is allocated in space in turn.

3.2 spatial feature analysis

(1) Binary processing of raster data. In order to improve the efficiency of data processing, this study uses the sampling method for regression analysis[3]. First, the grid data of each land use type is binarized, and the grid unit whose attribute is a certain land

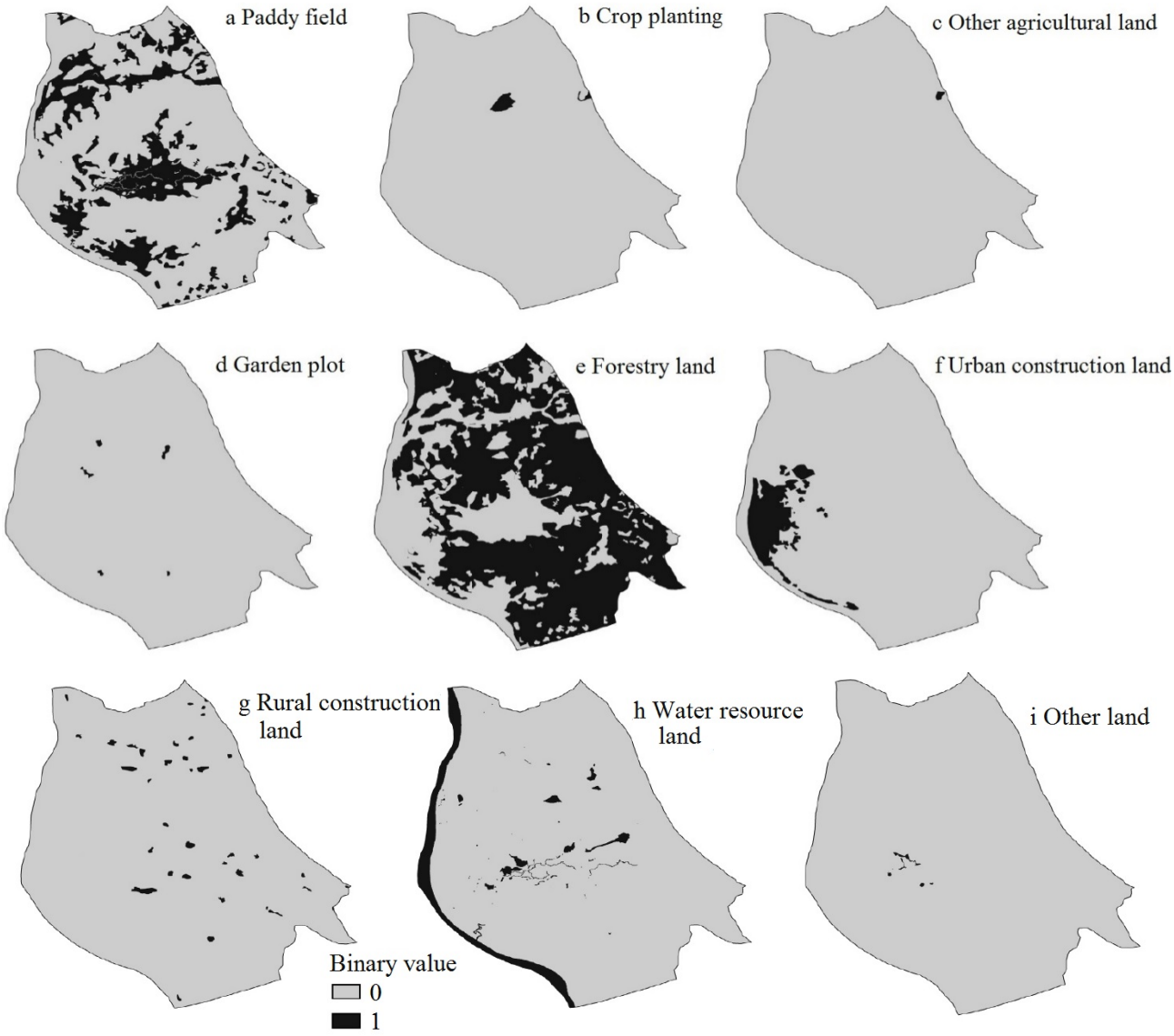

Figure 1. Binary grid map of various land uses in Fengweihan City, Kaishan, Laos.

use type is assigned as 1, and the grid unit whose attribute is not this land use type is assigned as 0, generating grid data with a value of 0, 1 (**Figure 1**).

(2) Random sampling and reclassification. After binarization of each land use type, use the Create Random Raster function of ArcGIS to generate a random grid of the coverage area for random sampling of each land use type and each driving factor. During the sampling process, the closer the percentage correction between cases with cell value of 0 and cases with value of 1 is to 50%, the better the sampling result is. Therefore, it is necessary to reclassify the random grid according to a certain proportion, so that the sampling proportion of each land type is kept at 1, 0, and the number of samples is basically the same. For example, the number of paddy field grids in Kaishan Fengweihan city is 169,022, and the number of non paddy field grids is 553,735. The ratio of the two is about 1: 3. Then the random grids covering Kaishan Fengweihan city are reclassified according to the proportion of 30%, and the reclassified random grids are multiplied by the non paddy field grid layer by using the grid calculator. The number of non paddy field samples randomly sampled at the proportion of 30% is 166,615, which is close to the number of paddy field samples. According to the sampling results, the percentage correction results of random sampling of each land type are maintained between 50.0% and 62.0%, and the sampling data is relatively reliable.

After reclassifying the random grids with cell

values of 0, 1 for each land use type, according to the reclassification results, use the sample tool of ArcGIS to sample each driving factor in turn, and the sampling data obtained are the independent variable (each land use type) and dependent variable (driving factor) of regression analysis. Among them, the driving factors are selected from 12 suitability evaluation indicators. Among the 12 indicators, the land use type factor and the protected area factor are repeatedly constrained in other modules in the model, so these two indicators are removed from them, and a total of 10 driving factors are set, including elevation (X_1), slope (X_2), aspect (X_3), soil type (X_4), soil organic matter content (X_5), soil pH value (X_6), distance from water source (X_7), distance from road (X_8), distance from residential area (X_9), and vegetation coverage (X_{10}). By regression analysis between land use types and driving factors, the regression coefficients of each land use type in the model can be obtained.

(3) Binary logistic regression analysis. Through binary logistic regression analysis of their variables and dependent variables, the correlation between land use type changes and driving factors, regression coefficients, regression equation constants and land type conversion probability and other parameters are obtained. See **Table 2** for regression equation coefficients and constants of various land use in Kaishan Fengweihan city.

(4) Regression equation fitting test. The fitting degree of regression equation is generally tested by ROC curve. ROC value is the area under the curve, which is generally between 0.5 and 1. The larger the value, the better the fitting degree and the more accurate the land use allocation when the model is running. After testing, the ROC values of all land types are greater than 0.85, the fitting degree of the regression equation is good, and the spatial simulation results are more accurate.

4. Results and analysis

4.1 Land use changes before and after optimal allocation of land resources

Through the prediction of land demand, the analysis of limiting factors, the study of transformation rules and the analysis of spatial suitability characteristics, the solution is based on the CLUE-S model, and the results of the spatial optimal allocation of land use in the study area are obtained. The results show that the main land types in Kaishan Fengweihan city are agricultural land, forestry land, construction land and water resources land. All kinds of land develop outward with the current distribution area as the center, and are centralized and contiguous. The results of the optimal allocation of land resources are shown in **Figure 4a**.

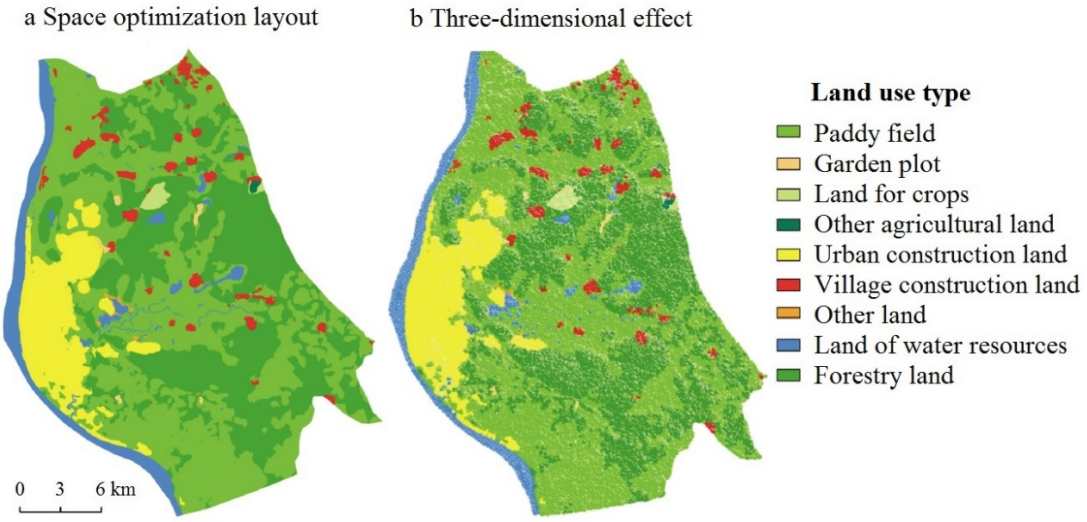

Figure 4. Spatial optimization layout and three-dimensional effect of land resources in Fengweihan City, Kaishan, Laos.

Table 2. Regression equation coefficients and constants of various land types in Fengweihan City, Kaishan, Laos

Evaluating indicator	Regression coefficient and constant								
	Paddy field	Garden plot	Grassland	Crop planting	Other agricultural land	Forestry land	Urban construction land	Land use for rural construction	Land of water resources
Elevation X_1	-0.0946	-0.0729	0.1030	0.0411	0.0706	0.0938	-0.0393	-0.0128	-0.5212
Slope X_2	-0.0473	-0.0308	0.0401	0.2485	0.0324	0.0220	0.0820	-0.0835	0.1530
Slope aspect X_3	-0.0012	-0.0013	-0.0015	-0.0027	0.0010	0.0004	-0.0022	-0.0078	-0.0029
Soil type X_4	0.3148	1.1999	-2.4874	-25.1250	0.8649	1.3648	-3.6264	-13.2591	3.7399
Soil organic matter content X_5	-0.2366	-6.4933	-3.2705	4.1104	1.1748	1.2019	-5.0435	-15.8272	16.7407
Soil ph X_6	1.9907	2.5433	-1.6280	-11.9041	-0.1215	-0.0474	-0.0611	-15.3831	0.5957
Distance from water source X_7	0.0001	0.0002	-0.0002	0.0130	-0.0001	-0.0013	0.0005	-0.0018	0.0004
Distance from road X_8	0.0003	-0.0065	0.0003	-0.0144	0.0001	-0.0014	-0.0004	0.0014	0.0043
Distance from residential area X_9	0.0003	0.0011	-0.0033	-0.0223	0.0005	-0.1571	-0.1392	-0.0047	-0.0010
Vegetation coverage X_{10}	-2.9888	-0.6348	25.6287	114.0542	5.1558	-1.0185	6.0541	1.5090	-24.2563
Constant	4.9313	1.1928	-16.9324	-205.4083	-16.9483	-8.6652	14.4926	100.8256	24.8889

Table 3. Land use changes before and after optimal allocation of land resources in Fengweihan City, Kaishan, Laos

Land type name	Current situation in 2020		2035 Planning		Difference between planning and current situation	
	Area/km^2	Proportion/%	Area/km^2	Proportion/%	Area/km^2	Proportion/%
Paddy field	152.06	23.38	299.78	46.08	147.72	22.71
Garden plot	1.70	0.26	1.57	0.24	-0.13	-0.02
Crop planting	3.53	0.54	3.53	0.54	0.00	0.00
Other agricultural land	0.61	0.09	0.61	0.09	0.00	0.00
Forestry land	407.48	62.64	221.40	34.03	-186.08	-28.61
Urban construction land	33.25	5.11	69.12	10.63	35.87	5.51
Land use for rural construction	13.12	2.02	16.60	2.55	3.48	0.53
Land of water resources	37.90	5.83	37.90	5.83	0.00	0.00
Other land	0.86	0.13	0.00	0.00	-0.86	-0.13
Total	650.51	100.00	650.51	100.00	0.00	0.00

The change of land use type is mainly the transformation of forestry land and other land to paddy field and construction land (**Table 3**). The land use mode is to develop and utilize sparse barren forest land with good water and soil resources and other land with the development potential of cultivated land and construction land. On the premise that the ecological land meets the requirements of regional ecological protection, improve the land use efficiency, ensure food production, and promote the development of urbanization.

4.2 Three-dimensional visualization of spatial allocation scheme of land resources

Using the digital elevation model data of the study area, through the ArcGIS platform, it is superimposed with the spatial optimal allocation data of land resources to generate a three-dimensional effect map of land use. Through

the construction and analysis of the three-dimensional landscape pattern, it can provide convenient, intuitive, multi perspective and all-round decision-making basis for the planning and design at the micro level and the project layout.

The three-dimensional visualization process of the optimized configuration scheme is as follows: (1) converting the land of each county into vector data composed of regular grids of equal size of 100 ×100; (2) the data center points of the regular grid are extracted and intersected with the results of the spatial optimal allocation of land resources in each county to generate a point layer composed of regular point markers with land use attribute data; (3) this layer is superimposed with the digital elevation model of each county, and the three-dimensional visualization parameters are set to form a three-dimensional effect map of the spatial optimization layout of land resources in Fengweihan City, Kaishan (**Figure 4b**).

4.3 Space optimization results and analysis

The results show that the growth of construction land and paddy field scale and the reduction of forestry land scale are obvious, and the change range of other land is small. Kaishan Fengweihan has natural advantages in natural geography, such as water and soil resources and topography in Savannakhet plain and along the Mekong River, and has great potential for developing agricultural production. At the same time, as the provincial capital of Savannakhet Province, the second largest city of Laos and the economic center of Laos, Kaishan Fengweihan city has policy advantages in urbanization development and economic construction. The construction of grain production base and the development of special economic zones need to make a reasonable layout of its land resources to provide a foundation and guarantee for national and regional development.

In terms of spatial layout, the area where the forestry land in the study area is reduced is sparse trees, and the construction land and agricultural land expand to the undeveloped and sparsely distributed forestry land along the traffic and water system on the basis of the original useful land. The order of expansion space is controlled by the suitability, and the expansion scale is controlled by the results of structural optimization. The expansion area of construction land can be developed into new areas and special economic zones, and the expansion area of agricultural land can be developed into food production bases.

In terms of quantity structure, the planned paddy field area occupies the largest proportion, accounting for 46.08% of the total area of the study area; the second is forestry land, accounting for 34.03% of the total area of the study area; the third is construction land, accounting for 13.18% of the total area of the study area. The planned land use structure is relatively reasonable, which is in line with Laos' industrial development characteristics dominated by agriculture, and is conducive to giving full play to industrial advantages such as rice planting; at the same time, the proportion of ecological land is high. Through planning to improve the quality and ecological service value of the existing forestry land, we can create a good living environment in the region; in addition, appropriately expanding the scale of construction land to provide space for the construction of special economic zones and the development of urbanization is conducive to promoting the development of regional social economy and the improvement of residents' living standards.

In addition, through the three-dimensional visual expression of the results of the optimal allocation of land use space, it can more intuitively guide the micro land use decision-making and facility layout, so as to provide data support for the connection of various plans, and further provide data support for the urban construction and urban service functions of Kaishan Fengweihan City.

5. Conclusions and suggestions

5.1 Conclusion

This study combines suitability analysis, quantitative optimization and spatial optimization, and realizes the optimal allocation of land resources in the study area based on GIS spatial analysis technology, logistic regression analysis method and

CLUE-S model, providing decision support for accurately controlling land layout, preventing land resource waste and ecological environment damage.

Through the optimal allocation of land resources, the construction land and agricultural land in the study area have expanded to regions with better natural and regional conditions based on the current situation, and the scale has increased significantly. The scale of forestry land with poor quality is reduced and used more reasonably, so that the quality of all kinds of land is improved, the efficiency of land use is significantly improved, and it is conducive to the effective management of land resources.

The three-dimensional visual expression of the optimized configuration scheme is conducive to assisting in the construction site selection, industrial layout, transportation planning, engineering pipeline facilities layout, as well as the irrigation and drainage facilities layout of agricultural land, so as to provide a reference for the development of three-dimensional space in land use planning.

5.2 Suggestions

(1) While optimizing the spatial layout of forestry land, agricultural land and construction land in Kaishan Fengweihan City, we need to take into account the protection of the ecological environment. (i) Replan the low and sparse forestry land into street trees and shelter forests; (ii) from the perspective of regional overall planning, while developing special economic zones, food production bases and ecological protection in the region, we should implement the conversion of farmland to forests, afforestation and interregional collaborative planning in other suitable areas outside the region; (iii) draw strict protection red lines and implement special protection. Through the above measures, the current disordered forest land will be transformed into ecological forest dominated by tall trees, so as to improve land use efficiency, achieve the purpose of regional coordinated development, and promote the orderly management and zoning protection of land resources.

(2) Learn from the advanced experience of other countries and regions, establish and improve the planning management guarantee mechanism. With the continuous and in-depth cooperation between China and countries along the “Belt and Road”, the development experience of China’s special economic zones and grain production bases can be used for reference for Laos. At the same time, combined with the development status, characteristics, needs and future development goals of Kaishan Fengweihan City, on the basis of the research on the optimal allocation of land resources, the special economic zones, grain production bases and ecological protection areas should be rationally distributed, and a sound planning, management and guarantee mechanism should be established toromote the coordinated development of regional economic construction, agricultural production and ecological protection, and truly give play to the advantages of the study area as the economic center of Laos.

(3) Develop special economic zones by taking advantage of regional advantages, develop green agriculture and characteristic industries such as rice, coffee and tea by taking advantage of terrain and water and soil resources, and layout irrigation and drainage facilities and transportation facilities. Through the feedback of agriculture, tourism and other industries, we should promote the construction of agricultural modernization and mechanization, change the original agricultural production mode in some areas, improve agricultural production efficiency, liberate productivity, form a benign development model of mutual promotion among land, industry and productivity, and promote the development of regional economy.

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Conflict of interest

The authors declared no conflict of interest.

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ORIGINAL RESEARCH ARTICLE

Exploration of practice and optimization of strategies for conservation of cultivated land resources in contemporary China's rural areas—Centering on black soil conservation and others

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ABSTRACT

Cultivated land resources are the basic elements for rural development and farmers' survival in China. Strengthening the protection of cultivated land is an important measure to ensure national food security and practice the strategy of "storing grain in the land and technology", and it is also an inevitable requirement to promote the high-quality development of agriculture. The protection of cultivated land in contemporary China has gone through three stages: the initial exploration period of reconciliation between economic development and the number of cultivated land, the institutional development period of construction occupation and cultivated land quality management and protection, and the transformation and improvement period of "Trinity" in the new era. In the new era, cultivated land protection has achieved phased results, but it still faces practical constraints from the actors, technical environment, institutional environment and so on. In view of this, we should explore the breakthrough path to further promote cultivated land protection from the aspects of strengthening organizational guidance and technical training, strengthening the top-level design of differentiated cultivated land protection, strengthening the research and development of new technologies and the construction of agricultural technology extension system.

Keywords: Cultivated Land Protection; Practical Exploration; Regional Differentiation; Strategy Optimization

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1. Introduction

Cultivated land is an irreplaceable agricultural production factor to ensure national food security. China feeds 20% of the world's population with 10% of the world's arable land and 6% of the world's water resources. However, the acceleration of industrialization and urbanization and the predatory development and utilization of "reuse and light breeding" for a long time have led to the continuous reduction of the number of cultivated land, the continuous decline of the quality of cultivated land, and the continuous deterioration of rural water and soil resources and environment. On the whole, the situation of China's cultivated land environment is not optimistic. The results of the 2014 National Soil Pollution Survey Bulletin showed that compared with other land types, the over standard rate of cultivated land soil points in China was the highest, 19.4%. On a regional scale, it is mainly reflected in the degradation of black soil in Northeast China, overexploitation of groundwater in North China Plain, increased vulnerability of ecological environment in Northwest China, soil acidification pollution in southern rice region and other problems, which have seriously threatened food

security and sustainable agricultural development[1]. Since the 1980s, the central and local governments have attached great importance to the protection of cultivated land, and "cherish and make rational use of every inch of land and effectively protect cultivated land" has been taken as a basic national policy to implement the strictest cultivated land protection system in the world. However, the early warning of the quantity and quality of cultivated land has never stopped, and the protection of cultivated land still has a long way to go[2].

The existing literature on the protection of cultivated land resources in contemporary China mainly focuses on the following aspects: first, based on the historical evolution perspective, long-term analysis of the evolution and optimization of China's cultivated land protection system[3,4]; second, evaluate the implementation effect of a specific cultivated land protection policy[5,6]; third, analyze the problems and solutions of cultivated land protection in a certain region based on the micro scale of farmers or the macro perspective of ecological protection and food security[7,8]. In fact, cultivated land protection not only has time scale differences, China has a vast territory, and there are also significant regional spatial differences in cultivated land resources and environmental problems. However, the existing literature lacks practical exploration to investigate the protection of rural cultivated land resources in China from the perspective of time and space. In view of this, this paper starts from the dual perspective of time and space, combs the evolution process and stage characteristics of cultivated land protection, takes black soil protection as the core, takes into account other regions, and deeply analyzes the practical exploration, practical constraints and regional differentiation of cultivated land resource protection in different regions, in order to provide decision-making reference for formulating differentiated cultivated land protection policies and supporting measures.

2. Practical exploration and results of cultivated land resource protection in rural China

2.1 Evolution and characteristics of cultivated land resource protection in rural China

At the beginning of the founding of the People's Republic of China, under the background of population pressure and serious food shortage, increasing cultivated land for food production by opening up wasteland, and taking "cultivated land protection" as a way to promote agricultural production increase is the early exploration stage of the awakening of China's awareness of cultivated land protection and the formation of the concept of cultivated land protection policy. The protection of rural cultivated land in China mainly started in the 1980s, which can be roughly divided into three stages: the initial exploration period (1978–2003) of the reconciliation between economic development and the number of cultivated land, the institutional development period of construction occupation and cultivated land quality management (2004–2011), and the transformation and improvement period of the "Trinity" in the new era (2012 to now).

2.1.1 The preliminary exploration period for the reconciliation between economic development and the number of cultivated land (1978–2003)

After the reform and opening up, the implementation of the household contract responsibility system and the progress of modern agricultural science and technology have effectively improved the agricultural production capacity, and the long-term serious shortage of grain in China has been preliminarily reversed. Accompanied by this, the problems of farmers' building houses and township enterprises' disorderly occupation of cultivated land occur frequently, leading to the gradual escalation of the contradiction between economic development and the protection of cultivated land resources. For this reason, since 1981, the basic concept of cultivated land protection has been clarified for the first time in policy texts such as the Government Work Report, the Emergency Notice on Stopping the Occupation of Cultivated Land by rural housing construction, and the Notice of the State Council on Strictly Implementing the Regulations on Land Requisition for National Construction, and it is

proposed to strictly restrict the abuse of agricultural land for building houses or supplementing construction land. The promulgation of the land administration law and the establishment of the State Land Administration Bureau in 1986 marked the beginning of legal basis for cultivated land protection in contemporary China. On this basis, a number of cultivated land protection policy documents have been issued, including the Interim Measures for the Handling of Land Violations, the Regulations on the Protection of Basic Farmland, and the Notice on Further Strengthening Land Management and Effectively Protecting Cultivated Land. Since then, with the acceleration of industrialization and urbanization, a new round of "geothermal use" has been launched. The decline in the number of cultivated land poses a serious threat to food security, and the party and the state have significantly strengthened the protection of cultivated land. In 1998, the State Council established the Ministry of Land and Resources, and assigned the responsibility for the protection of cultivated land use to specially established functional departments. At the same time, the newly revised Land Management Law clarifies the way of land management from the aspects of farmland occupation and compensation balance, basic farmland protection, land use and other content dimensions. In 1999, the Ministry of Land and Resources issued the Notice on Effectively Balancing the Occupation and Compensation of Cultivated Land to implement the cultivated land compensation system proposed in the land management law from the aspects of responsibility, measures, management and monitoring. In 2001, the Notice on Further Strengthening and Improving the Balance of Cultivated Land Occupation and Compensation proposed to control occupation and supplement according to law, and implement the cultivated land supplement plan based on the principle of "occupation and compensation". In 2003, the State Council issued the Notice on Cleaning up and Rectifying All Kinds of Development Zones and Strengthening the Management of Construction Land and the Emergency Notice on Suspending the Approval of All Kinds of Development Zones to investigate the responsibility of sudden approval and sudden establishment of development zones.

In a word, this stage is a preliminary exploration period for the reconciliation of the contradiction between national economic development and the number of cultivated land, and its characteristics are mainly reflected as follows: first, the connotation of the concept of cultivated land protection is gradually deepened; second, the cultivated land protection policy has changed from a single regulation to both economic incentives and legal regulation; third, the cultivated land protection policies and safeguard measures are not perfect, and a systematic cultivated land protection policy system has not been formed.

2.1.2 System development period of construction occupation and cultivated land quality management and protection (2004–2011)

In order to deal with the problems of sharp reduction in the number of cultivated land and compensation for the poor caused by the "land finance" of local governments, the party and the state further strengthen the attention to the protection of the quantity and quality of cultivated land. In 2004, the revised Land Management Law clearly distinguishes the concepts of "expropriation" and "requisition". In 2004, the State Council issued the Decision on Deepening Reform and Strict Land Management, which proposed to "implement the strictest cultivated land protection system". In order to implement the above decision, the Ministry of Land and Resources successively issued several policy texts in 2005, such as the Notice on Carrying out the Basic Work of Converting the Quantity and Quality of Supplementary Cultivated Land by Grade, and the Standard for Investigating and Dealing with Land Violations. At the same time, the State Council issued the Assessment Measures for the Objectives of Provincial Governments Cultivated Land Protection Responsibility in 2005, clarifying the responsibilities of local governments in the protection of cultivated land and basic farmland; in 2006, the Notice on Issues Related to the Establishment of a National Land Supervision System was issued to strictly supervise and inspect illegal

land use. In 2007, the Government Work Report stressed that the red line of 1.8 billion mu of cultivated land should be strictly observed. In 2008, it was proposed to designate permanent basic farmland. In 2009 and 2010, the Ministry of Land and Resources carried out the "double guarantee action" and "double guarantee project", respectively, further deepening the implementation of the policy requirements of the red line of cultivated land.

In short, this stage is the institutional development period of construction occupation and cultivated land quality management and protection, which is mainly characterized by: first, it is proposed to strictly abide by the red line of 1.8 billion mu of cultivated land and delimit permanent basic farmland; second, economic compensation and regulatory constraints work together on cultivated land protection; third, we began to pay attention to the management and protection of cultivated land quality, but the policies and measures for the protection of cultivated land quality need to be further strengthened, and the ecological protection of cultivated land has not been paid enough attention.

2.1.3. The transformation and improvement period of the "Trinity" in the new era (since 2012)

Since the 18th National Congress of the Communist Party of China, under the condition of increasingly tight resource and environmental constraints, the central government has further strengthened the management of cultivated land ecological environment. In 2012, the Ministry of Land and Resources issued the Notice on Improving the Level of Cultivated Land Protection and Comprehensively Strengthening the Construction and Management of Cultivated Land Quality, which marked that China's cultivated land protection has entered a transformation and improvement stage integrating "quantity, quality and ecology". Based on the above policy positioning, China's cultivated land resources protection policies and measures mainly include the following aspects: first, strengthen the construction of high standard farmland. The High Standard Farmland Construction Standard issued by the Ministry of Land and Resources in 2012 and the Opinions on Comprehensively Deepening Rural Reform and Accelerating Agricultural Modernization issued by the State Council in 2014 all emphasize the implementation of the national high standard farmland construction. Since then, the Action Plan for Soil Pollution Prevention and Control issued by the State Council in 2016 and the Opinions on Strengthening the Construction of High-standard Farmland and Improving the National Food Security Guarantee Capacity issued in 2019 have gradually promoted the construction of high-standard farmland from the aspects of standards, management and measures. The second is to establish a system of cultivated land rotation and fallow. After the "13th Five Year Plan" proposed to explore and implement the cultivated land rotation and fallow system, the State Council issued the Pilot Plan for Exploring and Implementing the Cultivated Land Rotation and Fallow System in 2016, emphasizing the problem orientation and implementing zoning and classification policies in heavy metal polluted areas, underground funnel areas, rocky desertification areas and areas with ecological function degradation. In 2020, the pilot area of cultivated land rotation and fallow will reach 1.8 million hectares. Third, balance the occupation and compensation of cultivated land across the country. In 2017, the Ministry of Land and Resources issued the Notice on Improving Management Methods and Effectively Implementing the Balance of Cultivated Land Occupation and Compensation, which proposed to establish a new mechanism for the balance of cultivated land occupation and compensation based on quantity and production capacity. In 2018, the National Integrated Management Measures for Cross Provincial Supplementary Cultivated Land was issued, which clearly pointed out that areas with insufficient reserve resources of cultivated land or poor natural endowment conditions can apply for national integrated supplementary. The fourth is to build a land space management mechanism for cultivated land protection. In 2019, the State Council issued Several Opinions on Establishing a Land Space Planning System and Supervising Its Implementation, which proposed to include cultivated land protection into the land space management system and establish

the corresponding supervision mechanism. Subsequently, the Land Management Law revised in 2019 clarified the above-mentioned high standard farmland construction, rotation and fallow system, balance of occupation and compensation, and land and space management in the form of legal provisions.

In short, this stage is the transformation and improvement period of the "Trinity" cultivated land protection in the new era, which is characterized by: first, the ecological protection of cultivated land is included in the consideration of cultivated land quality; second, the cultivated land protection policy is more administrative and scientific, and has gradually formed a cultivated land resource protection policy system based on the use control as the core, with high standard farmland construction, permanent farmland protection, cultivated land ecological management, land transfer and requisition as the main content.

2.2 Practical exploration and region of cultivated land resource protection in rural China

China has a vast territory, and there are obvious regional differences in natural geographical environmental conditions, resource endowments, agricultural production characteristics and agricultural technology levels in different regions, which leads to significant regional differences in agricultural resources and environment in various regions, mainly manifested in the serious degradation of cultivated land in the black soil region of the northeast, the overexploitation of groundwater in the North China Plain, desertification and salinization in the arid and semi-arid region of the northwest, soil acidification and heavy metal pollution in the rice region of the south, etc. Therefore, it is particularly important to explore the protection technology of cultivated land resources in different regions according to local conditions[9]. This paper focuses on the northeast black soil area as the core, taking into account North China, northwest and South China, to explore the practice and regional differences of rural cultivated land resource protection in different regions.

2.2.1 Northeast black soil area

Northeast black soil area is one of the only "three black soil belts" in the world, and is China's largest commodity grain base. For many years, it has played an important role as a "ballast stone" in ensuring national food security. However, since the 1980s, with the acceleration of industrialization and urbanization, the predatory development and utilization of "reuse and light breeding" for a long time, the increasingly distant planting and breeding relationship, and the single planting system have made the black soil layer "thin", and "hard", resulting in the reduction of soil organic content and the decline of water storage and moisture conservation capacity, which has seriously restricted the potential of grain production in the black soil region of Northeast China[10]. For this reason, since the 1980s, China has introduced and demonstrated the application of subsoiling, no tillage, straw mulching and other conservation tillage technologies. However, restricted by the concept of agricultural production, the conditions of social and economic development and the level of agricultural technology and machines, it was only tested and applied in some areas in this period. Until entering the 21st century, the concept of black land protection began to deepen gradually, entering the early exploration period of black land protection. In order to reverse the deteriorating trend of the ecological environment in the black soil area, since 2002, the Ministry of Agriculture has allocated 170 million yuan of special funds for five consecutive years to support the research of conservation tillage equipment technology and the demonstration and promotion in northern areas (including western Liaoning), which has laid a good foundation for the promotion and application of conservation tillage technology in the black soil area of Northeast China. Since 2003, the Ministry of Water Resources has started to implement the pilot project of comprehensive prevention and control of soil and water loss in the black soil area of Northeast China, with a total investment of about 200 million yuan for three consecutive years. Different control measures such as engineering, technology and ecological restoration have been taken in different prevention and control areas in the black soil area. Since 2005, the Ministry of Ag-

riculture has carried out soil testing and formula fertilization actions and pilot subsidies in Jilin, Liaoning, Inner Mongolia and other five provinces and autonomous regions across the country, and gradually expanded pilot areas and subsidy support. In 2006, the Ministry of Agriculture launched a new round of five-year fertile soil project planning, with northeast black soil region as one of the key implementation areas. As an important part of national cultivated land protection, blackland protection is scattered in various national policies and measures for cultivated land protection, and no policy system has been formulated specifically for cultivated land protection in black soil areas.

In 2007, the Northeast Institute of Geography, the Chinese Academy of Sciences, and the China Agricultural University, with the assistance of the Lishu County Agricultural Committee and the Agricultural Technology Extension Station, took the lead in applying the straw full coverage technology to Lishu County, a major agricultural production county, and launched a long-term experimental demonstration study of the black soil conservation tillage technology and its mechanism and effect for more than a decade, and finally created a mechanized technology system of corn straw coverage suitable for the regional characteristics of black soil areas. A unique "Lishu model" that can be popularized and replicated has been formed, which also marks a breakthrough in the technology and machinery of blackland protection. In addition, the central and local governments began to introduce policies and measures specifically for the protection of black land. Taking Jilin Province as an example, since 2009, Jilin Province has promulgated and implemented the Regulations of Jilin Province on the Protection of Cultivated Land, the Technical Specifications for the Evaluation of Soil Fertility of Black Soil Cultivated Land, and the Technical Regulations for the Monitoring of Soil Fertility of Cultivated Land, which provide strong technical support and legal protection for the protection of blackland. With the improvement of agricultural mechanization and modern agricultural technology, blackland protection technology tends to be mature, and the policy incentives and constraints for blackland protection behavior are increasingly standardized, which has accumulated rich experience for the promotion and application of blackland protection technology in a wider range.

In 2015, the Master Plan for the Treatment of Prominent Agricultural Environmental Problems (2014–2018), issued by the National Development and Reform Commission in conjunction with six departments, included blackland protection into major engineering projects, emphasizing the implementation of blackland protection pilot projects to achieve the integration of blackland use and breeding, and improve the fertility of blackland. In 2015, the country's first academician workstation for blackland protection and utilization was established. From 2015 to 2017, the central government allocated 500 million yuan of special funds every year for three consecutive years to carry out pilot projects for the protection and utilization of blackland in 17 counties (cities) in four provinces (autonomous regions) in Northeast China. In 2017, the Ministry of Agriculture, together with the National Development and Reform Commission and other six ministries and commissions, jointly issued the Outline of the Northeast Blackland Protection Plan (2017–2030), which made specific arrangements of black land protection for the overall idea, key tasks, implementation mode, safeguard measures, etc. In 2020, the Ministry of Agriculture and the Ministry of Finance issued the Northeast Black Soil Conservation Tillage Action Plan (2020–2025), which placed the promotion plan of conservation tillage in the northeast black soil area at the national strategic level, and proposed that the central government should vigorously support the development of conservation tillage in the northeast black soil area and gradually build a conservation tillage policy support system and technology promotion system. In addition, Northeast China has successively launched many projects, such as the pilot of rotation fallow system, the construction of high standard farmland, the prevention and control of agricultural irrigation water pollution, the resource utilization of livestock and poultry breeding waste, and the reduction and replacement of chemical fertilizers, which have played a positive role in the treatment

of agricultural non-point source pollution and the protection of cultivated land in black soil area. At present, the central government has placed blackland protection in a national strategic position. Based on the central and local levels, it has issued a series of policies and measures around the promotion of conservation tillage technology and the treatment of agricultural non-point source pollution in black soil areas, carried out active exploration and attempts on a large scale, and formed a relatively mature blackland protection technology integration demonstration mode and operation mechanism suitable for different regions, and achieved obvious ecological and economic benefits in some areas.

2.2.2. North China

North China Plain is an important major grain producing area and vegetable production base in China, which plays an important role in ensuring the supply of agricultural products. However, over the years, agricultural production in North China has been characterized by high input, high consumption, high output and high pollution, especially the long-term overexploitation of groundwater has made the North China plain the largest groundwater funnel in the world. Therefore, the central government attaches great importance to the control of groundwater overexploitation in this region, and has issued a series of policies and measures. At the end of 2002, the state launched the South-to-North Water Diversion Project, which included Beijing, Tianjin, Hebei, Shandong and Henan into the water receiving area of the South-to-North Water Diversion Project in 2013, and expanded the governance scope to Shandong, Shanxi and Henan provinces in 2018. In 2019, the State Council, together with relevant departments, issued the Action Plan for the Comprehensive Treatment of Groundwater Overexploitation in North China, proposing to gradually achieve the balance of groundwater exploitation and recharge in North China by taking “one reduction” and “one increase” comprehensive treatment measures. By 2020, the cumulative water transfer to Beijing, Tianjin, Hebei and Henan by using the water storage project of the middle route of the South-to-North Water Transfer Project has reached 38.006 billion m^3, and the problem of groundwater overexploitation has been effectively alleviated.

2.2.3. Northwest China

The northwest arid and semi-arid region is not only one of China’s important grain production bases, but also an important ecological function barrier. However, due to its inland location, drought and little rain, and uneven spatial and temporal distribution of water resources, the agricultural ecological environment is fragile. Therefore, during the “12th Five Year Plan” period, the northwest region has effectively curbed desertification in the northwest region by relying on national key projects such as “returning farmland to forests”, “Three North shelterbelts”, “natural forest protection” and the protection of the Yangtze River Basin. Since 2013, many measures have been taken in the northwest region, focusing on saline alkali land treatment through farmland irrigation and drainage, land remediation, soil improvement and farmland forest network construction. In 2017, the Ministry of Agriculture and Rural Areas, focusing on the northwest region, launched and implemented the action of agricultural film recycling, which has a significant effect on the treatment of “white pollution”.

2.2.4. Southern region

Southern China is an important major rice producing region in China, including 16 provinces in the middle and lower reaches of the Yangtze River, Southwest China and South China. However, unreasonable production and management methods such as excessive application of chemical fertilizers for a long time have led to soil acidification and heavy metal pollution in southern rice areas, which in turn affect food production and the quality and safety of agricultural products. In order to solve the problems of soil acidification and heavy metal pollution, in 2014, the Ministry of Agriculture launched the pilot project of heavy metal polluted cultivated land restoration and cultivated land rotation fallow system in Zhutan area, Hunan Province. At the same time, through the promotion of technical measures such as deep tillage, rotary tillage, increased application of organic fertilizer, straw returning to the field and planting green manure, a

"composite" planting and breeding combination model such as rice-fish model was established. According to local conditions, we have explored a comprehensive management system of paddy fields in the south, which integrates "fallow, management and fertilization". In addition, the State Council issued the National Agricultural Sustainable Development (2015–2030) and the Action Plan for Soil Pollution Prevention and Control in 2015 and 2016 respectively, which included the problem of heavy metal pollution in cultivated land into the key content of agricultural ecological environment treatment, and strengthened the prevention and control of soil pollution through ten aspects, such as soil pollution investigation, legislation, management and remediation.

3. Analysis of practical constraints and problems in the protection of cultivated land resources in rural China

As China's economic development enters a new stage, with the strong support of national policies, the protection of cultivated land resources has achieved phased results, but the overall situation of the quantity and quality of cultivated land is still not optimistic, and there are still many challenges and outstanding problems in the practice and exploration of cultivated land protection. This paper summarizes the practical constraints existing in cultivated land protection as "behavioral subject constraints", "technical environment constraints" and "institutional environment constraints".

3.1 "Behavior subject constraint" of cultivated land protection

As the practice subject and benefit subject of cultivated land protection, farmers play an important role in the utilization and protection of cultivated land. However, due to the limitations of their own endowment characteristics and external environment, farmers have many practical problems that are not conducive to their main role, which are highlighted in the following three aspects:

First, farmers' awareness of the main body of cultivated land protection is weak. Based on the survey data in the black soil area of Northeast China, from the perspective of farmers' cognitive characteristics, 85.7% of farmers generally recognize that unreasonable farming methods and excessive application of agricultural chemicals will lead to the decline of cultivated land fertility. However, when asking "who do you think is responsible for cultivated land protection", the proportion of farmers who think they have the responsibility to participate in cultivated land protection is only 39.5%. Most farmers believe that cultivated land protection is something that governments at all levels and village cadres should do, which has little to do with themselves. This dependence psychology and weak subject consciousness of farmers lead to the limited role of farmers in the protection of cultivated land. The possible reasons are that, on the one hand, farmers lack the awareness of modern cultivated land protection due to the limitations of traditional farming ideas and their own endowment characteristics such as older age; on the other hand, the current farmland protection policies and regulations in China have weakened the farmers' environmental protection responsibility, and lack feasible incentive policies and implementation measures, resulting in the implementation of farmers' farmland protection responsibility is often a mere formality[10].

Second, the overall quality of the labor force is low, and the ability to protect cultivated land needs to be improved. Taking the investigation of black soil area in Northeast China as an example, most farmers have realized the importance of cultivated land quality for increasing crop yield and income, and also realized that the current extensive management behavior such as excessive fertilization is an important reason for soil hardening and fertility decline. However, the proportion of farmers who really adopt conservation tillage measures in actual production is only 49.3%. Among them, the proportion of farmers adopting no tillage technology, rotation, straw returning to the field, soil testing and formula fertilization, and applying organic fertilizer is 18.6%, 27.4%, 23.1%, 8.0%, and 25.6% respectively. From the perspective of farmers themselves, the possible reason for the low actual adoption rate of farmers' conservation tillage measures is that

cultivated land protection has high requirements on Farmers' ability to master and apply technology, while China's agricultural labor force generally has problems such as small business scale, weakening aging, low overall cultural quality, insufficient ability to master technology, and farmers' acceptance and demand for new technology are low. And before the conservation tillage technology has not been widely applied and produced ideal benefits, most farmers under the risk aversion attitude hold a wait-and-see attitude.

Third, farmers' short-sighted management behavior was driven by interests. According to Schultz's theory of "rational small farmers", all the behavior activities of farmers, such as resource allocation and production factors, are rational decisions made after comparing and weighing costs, benefits and risks. Under the pressure of survival and development, farmers' pursuit of maximizing short-term income will inevitably lead to their neglect of the rarity of resources and environmental carrying capacity, and take the extensive and short-term management as an important way to increase production and income. There are two main reasons for this behavior: first, institutional factors failed to stimulate farmers' enthusiasm for farmland protection. The implementation of the household contract responsibility system and the agricultural subsidy policy have greatly stimulated the enthusiasm of farmers to engage in agricultural production, but in the early stage, they did not pay attention to and effectively regulate the behavior of farmers to protect the quality of cultivated land. On the contrary, under the agricultural subsidy policy, increasing the application of chemical agricultural materials such as fertilizers and pesticides has become an important way for farmers to obtain land productivity, further accelerating soil acidification and hardening[11]. At the same time, the imperfect land circulation system leads to the instability of the land circulation period, which is very easy to weaken the long-term investment behavior of farmers to adopt conservation tillage measures, and take predatory production behavior for the contracted land. Second, the degree of farmers' part-time employment has increased, and the aging trend of agricultural labor force is obvious. In the process of transition from a planned economy to a market economy, the development of industrialization and urbanization has led to the phenomenon of deinvolution. More and more farmers and families show intergenerational division of labor. The main mode is that "the old, young and women" left behind families are mainly engaged in agricultural production activities, young and middle-aged labor force go out to work during slack seasons and engage in agricultural production activities during busy seasons. Statistics show that the proportion of Chinese farmers' household operating income from agriculture fell from 60.6% in 1996 to 33.5% in 2016. With the improvement of the degree of part-time farming, farmers' non-agricultural income gradually occupies the dominant position in household income. Part-time farmers usually pay less attention to agricultural production efficiency and invest less energy than full-time farmers, even in Northeast China, which has a high degree of affluence of agricultural resources.

3.2 "Technical environmental constraints" of cultivated land protection

Modern conservation tillage technology is the main measure to promote cultivated land protection, which has important value in protecting the farmland ecological environment, improving agricultural production efficiency and enhancing the ability of agricultural sustainable development. Taking the development of conservation tillage in blackland as an example, this paper analyzes the technical environment of cultivated land protection. Foreign research on conservation tillage technology began with the "black storm" event in the United States in the 1930s. Since then, the United States has gradually explored a farming technology model that can replace traditional tillage and conserve water and soil. Now, conservation tillage with straw mulch management as the core has become the mainstream farming method in the United States. China's research on Conservation Tillage Technology for blackland in Northeast China began in the 1980s, such as the pilot no tillage technology for wheat in Heilongjiang state-owned farms, and the develop-

ment of tillage methods combining tillage, loosening and harrowing on the basis of ridge farming. However, under many constraints, conservation tillage technology has not been widely popularized. Since the beginning of the 21st century, the conservation tillage technology of blackland has been gradually improved in basic research and development, demonstration and promotion by relying on a number of projects such as soil testing and formula fertilization, straw returning to the field, and blackland protection pilot projects. According to the natural characteristics of different regions in Northeast China, an integrated mode and operation mechanism of conservation tillage technology suitable for different regions have been formed. Some pilot areas are improving soil fertility and reducing soil erosion. Remarkable achievements have been made in improving the economic and ecological benefits of agricultural production. However, there are still many bottlenecks to be solved in the supporting technology and promotion system, which are highlighted in the following aspects:

First, agronomy is divorced from agricultural machinery, and the corresponding supporting technology is insufficient. Over the years, China's conservation tillage technology has mainly focused on the R & D and application of agricultural machinery and tools such as no tillage sowing, deep scarification and deep ploughing and their corresponding management technologies. For the promotion of modern conservation tillage technology, there is a general lack of theoretical and scientific basis for agronomic technology such as relevant core technology operation principles, standards, scope of application, and a conservation tillage technology system combining practice and theory has not yet been formed. Taking straw returning to the field as an example, the technology of straw returning to the field is relatively mature and has been widely used, but so far, there is no clear scientific theoretical basis for the "how much" of straw returning to the field and what negative effects it will produce after returning to the field, and there is a lack of corresponding normative and authoritative technical guidance, which is not conducive to eliminating the doubts of farmers. In addition, the current conservation tillage technology has not formed an effective configuration combination with conventional cultivation technology and farming technology. For example, under the condition of long-term no tillage, it is likely to have a certain adverse impact on the physical and chemical properties of the soil. However, there is no definite standard for the operation of the rotation tillage technology that can solve this problem, and the corresponding supporting technologies are insufficient, resulting in the obstruction of the large-scale promotion of conservation tillage technology.

Second, the availability of agricultural technology extension is insufficient. Agricultural technology extension system is an important carrier to promote the transformation of agricultural scientific and technological achievements into real productive forces. However, over the years, although China's agricultural technology extension system has been constantly changing, it has not yet made substantive changes, which makes there are many constraints in the promotion and application of blackland conservation tillage technology. Taking soil testing and formula fertilization as an example, the excessive application of chemical fertilizers over the years has not only caused serious agricultural non-point source pollution, but also led to a decline in the yield potential of cultivated land. Since 2005, the Ministry of Agriculture and Rural Areas has launched the soil testing and formula fertilization project and gradually expanded the pilot areas. So far, the soil testing and formula fertilization technology has been relatively mature, and its application scope basically covers every agricultural county-level unit in the country. However, in the survey, it is found that the use and promotion of this technology is not satisfactory. The adoption rate of soil testing and formula fertilization by farmers in the black soil area of Northeast China is only 8.0%. Some surveyed farmers reported that even if department staff tested the farmland, they could not get the final test results most of the time. The main reason for this phenomenon is that China's agricultural technology extension system is not yet mature and perfect, and the effective supply is insufficient. On the one hand, restricted by funds, management

methods, incentive mechanisms and other aspects, China's grass-roots agricultural technology extension practitioners generally show the characteristics of small number, low academic qualifications and single knowledge structure, which can not meet the requirements of modern agricultural technology extension. In addition, the scientific and technological achievements of scientific research institutions have low transformation ability, and a promotion platform combining "production, learning, research and application" has not yet been formed; on the other hand, although the formula fertilizer supply network with dealers as the main body has been established in most regions, in order to sell more fertilizer with high profits, the dealers have led to a low proportion of formula fertilizer sales, and the formula fertilizer is often shoddy, which really goes deep into the production process of farmers, so that farmers make less profits due to the adoption of soil testing formula fertilization technology.

3.3 "Institutional environmental constraints" on cultivated land protection

From the perspective of system, the characteristics of cultivated land protection in developed countries are based on legislative guarantee, economic compensation as a tool, participatory management system, publicity, education and training as a form, forming a scientific, systematic and practical cultivated land protection policy system, which has important reference significance for China's cultivated land protection. Although the funds for research and development of cultivated land protection technology in China are increasing year by year, the effect of cultivated land protection is greatly reduced due to the lack of systematic legislative guarantee and perfect economic compensation policies[11].

First, the legal system related to cultivated land protection is "fragmented". At first, compared with developed countries, China has introduced local laws and regulations indirectly related to cultivated land quality protection since the 1980s. However, in the current Land Management Law, Regulations on the Protection of Basic Farmland, Agricultural Law, Environmental Protection Law and other relevant laws, the legislation on the protection of cultivated land mostly focuses on the protection of the number of cultivated land, and the provisions related to the ecological quality of cultivated land are relatively scattered, and the content is vague or even missing. In 2019, China began to implement the first law specifically aimed at the protection of cultivated land quality, namely the Law of the People's Republic of China on the Prevention and Control of Soil Pollution. The "fragmentation" of laws related to the protection of cultivated land quality and the lack of corresponding implementation measures make it difficult to effectively form a binding force. Second, cultivated land protection involves many departments such as land, agriculture, grassland, forestry and water conservancy. Due to unclear responsibilities and inconsistent regulatory standards among different departments, conflicts between cultivated land quantity and quality protection and ecological conservation land such as forest and grass are very easy to occur. Third, the regulatory measures for the use of blackland are not in place, which is prominently manifested in the acts of a small number of regulators, such as misappropriation, abuse, occupation of the superior and compensation for the inferior, resulting in a double decline in the quantity and quality of cultivated land.

Second, there is a lack of perfect incentive mechanism for ecological compensation of cultivated land protection. At present, China has not yet established a systematic and perfect cultivated land ecological compensation mechanism, which is mainly reflected in the following aspects: first, the current policies on cultivated land compensation mainly aim at ensuring food security and economic and social stability, and pay less attention to the ecological value of cultivated land. Second, although cultivated land compensation appears sporadically, there are still narrow compensation scope, small compensation intensity and single compensation mode. The imperfect compensation fund management system and other issues can not balance and meet the interests of cultivated land protection stakeholders, and ultimately affect the incentive effect of the compensation policy on ecological protectors. At present, the cultivated land subsidy

funds are still distributed to land contractors through the "one card" method, which is not linked to the specific behavior of farmers in the protection and utilization of cultivated land.

Third, there is a lack of education and technical training related to cultivated land protection. Developed countries, represented by the United States, pay great attention to the use of diversified channels such as agricultural associations, agricultural technology extension institutions, scientific research institutions, and mass media in the management and control of cultivated land protection, and publicize the cultivated land protection plan to farmers through conservation tillage technology pilot, field visits, technical training, etc., so as to improve farmers' awareness and ability of conservation tillage, and finally integrate the government's cultivated land protection objectives with farmers' production interests form the endogenous driving force of farmers' cultivated land protection. However, China mainly popularizes and propagandizes cultivated land protection and ecological construction through top-down administrative management, which is prone to the problem of "hot up and cold down", so the mobilization of farmers' enthusiasm for cultivated land protection is extremely limited. Among the surveyed sample farmers, 33.1% had not been exposed to the publicity related to cultivated land protection, and 57.2% had not participated in the training related to cultivated land protection technology. This is also an important reason for farmers' weak awareness of cultivated land protection and insufficient awareness of conservation tillage technology.

4. Promotion strategies for the protection of rural cultivated land resources in China

4.1 Strengthen organizational guidance and technical training, and improve farmers' awareness and ability of main responsibility for cultivated land protection

Aiming at the problems of farmers' weak awareness of cultivated land protection and virtual responsibility, first, transmit the ecological early warning of cultivated land quality degradation to the whole society through television, newspapers, mobile phone networks, village bulletin boards and other forms, and strengthen the publicity of the important strategic significance of cultivated land protection in rural revitalization, national food security and high-quality agricultural development, so as to create a good atmosphere for the participation of the whole society in cultivated land protection, and enhance the sense of responsibility and subject consciousness of farmers' participation in cultivated land protection. Second, farmers are constrained by traditional experience and the original knowledge framework, and it is difficult to form a relatively complete understanding and evaluation of a new agricultural technology in a short time. There is an urgent need to give play to the role of agricultural cooperatives, agricultural technology promotion and other rural grass-roots organizations in cultivated land protection. Specifically, we can strengthen the exchange of experience through on-site lectures, technical training meetings, visits to demonstration bases, popularize the development process, technical types and technical efficiency of cultivated land conservation tillage measures to farmers, especially village cadres, large grain farmers, family farms, etc., improve farmers' cognitive level and adoption ability of conservation tillage measures, and give full play to the demonstration and driving role of new agricultural business entities.

4.2 Strengthen the top-level design of differentiated incentive and regulatory policies for cultivated land protection

Cultivated land is a rare resource. As a "rational economic person", whether farmers choose to participate in cultivated land protection depends on the degree of benefit satisfaction brought by this behavior. Therefore, there is an urgent need to innovate cultivated land protection and collaborative governance policies according to local conditions, coordinate the interests of stakeholders, and balance the supply of government systems with the interests and needs of farmers. First, set up a special compensation fund for cultivated land pro-

tection, and constantly improve the compensation scheme and reward and punishment mechanism. The measures applicable to cultivated land protection, such as less no tillage, straw returning to the field, fallow rotation, soil testing and formula fertilization, and organic fertilizer replacing chemical fertilizer, will be included in the key compensation content, and the performance evaluation of cultivated land protection effect of governments at all levels will be strengthened. It is worth noting that due to the obvious regional differentiation of cultivated land resources and environmental problems in different regions, there are significant differences in the technical attributes and cost-benefit required for the adoption of cultivated land protection measures suitable for different regions. At the same time, under the background of farmers' differentiation, different types of farmers need to be based on regional differences, technical attributes and farmers' types due to the heterogeneity of business scale, production factor allocation and input energy, and formulate differential cultivated land protection strategies. Second, based on the field research and department interviews of large sample farmers, we should scientifically and reasonably build an ecological compensation framework, including compensation principles, compensation standards and compensation methods. Third, support legal protection and regulatory evaluation system. The smooth operation of cultivated land protection ecological compensation policy needs the protection of relevant laws and supervision and evaluation systems. Speed up the formulation of the top-level design of the legal system specifically for cultivated land protection and ecological compensation, and form the laws and regulations of the central and local supporting integration, so that there are laws to follow for cultivated land protection and rules to follow for the distribution of rights and responsibilities of stakeholders.

4.3 Strengthen the research and development of core technologies for cultivated land protection and the construction of agricultural technology promotion system

In 2020, the No.1 Central Document proposed to "promote the application of more scientific and technological achievements to the fields". As the fundamental way to promote cultivated land protection, whether conservation tillage technology can be successfully and large-scale applied to agricultural production practice depends on the technical attributes of the technology itself, that is, whether the technology has the characteristics of cost-saving, labor-saving, high-yield, high efficiency, easy operation and so on, in addition to the constraints of the policy environment and the adoption group. Therefore, first of all, we should combine agricultural technology with agronomy, support the establishment of a research and development and integration platform for cultivated land protection technology with the cooperation of new business entities, scientific research institutions and technology extension institutions, promote the optimization of technical models and the upgrading of machinery and equipment, gradually establish a standard and normative system for the implementation of cultivated land protection technology, and improve the transformation efficiency of scientific and technological achievements of cultivated land protection technology. At the same time, we should strengthen the construction of agricultural technology extension and service system. By deepening the reform of agricultural technology extension system, strengthening the public welfare functions of township agricultural technology extension institutions, optimizing the assessment and incentive mechanism of agricultural technology extension personnel, solving the problems of unqualified professional ability and low enthusiasm of technical personnel in agricultural technology extension work, and further strengthening the construction of agricultural technology extension teams in township grass-roots units.

Conflict of interest

The authors declare that they have no conflict of interest.

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ORIGINAL RESEARCH ARTICLE

Current situation and protection countermeasures of wetland resources in Shaanxi

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ABSTRACT

In order to guide the management, protection and utilization of wetlands in Shaanxi Province, this paper analyzes and summarizes the current situation and existing problems of the protection and utilization of wetland resources in Shaanxi Province, and puts forward suggestions accordingly. There are 4 wetlands and 12 wetland types in Shaanxi Province, 308,500 hectares. The area and proportion of various wetlands are 257,600 hectares of river wetlands, 83.50%; 32,300 hectares of artificial wetlands, 10.46%; 7,600 hectares of lake wetlands, 2.46%; and 11,000 hectares of swamp wetlands, 3.58%. There are 77 families, 207 genera, 341 species and 3 varieties of wild vascular plants in the wetland, including 2 species of key wild protected species at the national level and 4 species at the provincial level. In view of the problems in the protection and utilization, such as the collaborative mechanism has not been established, the resource background has not been completely clear, and the investment is insufficient, we should build a scientific and appropriate wetland evaluation index system in Shaanxi Province, carry out the investigation and evaluation of wetland resources in the province, continue to carry out wetland ecological restoration and reconstruction projects, establish and improve wetland protection management and technical system, and formulate the protection and utilization direction of different types of wetlands.

Keywords: Shaanxi Province; Wetland Resources; Present Situation; Protection; Utilization

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1. Introduction

Wetland refers to natural or artificial, permanent or intermittent marshes, peatlands and water areas, including static or flowing, fresh or brackish water and salt water, as well as sea areas with a water depth of no more than 6 m at low tide[1]. As one of the three major ecosystems of the earth, it is known as the kidney of the earth, the cradle of life, and the paradise of birds[2], and has many functions such as water storage, flood regulation, climate regulation, water purification, and providing habitat for many species. Protecting wetland ecosystem is of great significance to promote the construction of ecological civilization, ensure national ecological security, and achieve carbon peak and carbon neutralization.

Shaanxi Province is located in the northwest of China. It is the only province across the Yellow River and the Yangtze River. Its ecological location is important. The Yellow River is the mother river of the Chinese nation, and the Qinling Mountains are the source of the Chinese nation and the central water tower. Protecting wetland resources is the need of Shaanxi's ecological environment protection and ecological civilization construction. It is not only related to its own development quality and sustainable development, but also related to the overall situ

ation of the national ecological environment.

2. Overview of wetlands in Shaanxi Province

Shaanxi Province is located in the hinterland of China, 105°29"–111°15" east longitude and 31°42"–39°5" north latitude, with a total area of 205,600 square kilometers. From north to south, the terrain is in turn loess plateau in Northern Shaanxi, Guanzhong Plain in the middle, and Qinba Mountain in the south[3]. Different climate, terrain, vegetation and other environmental conditions from south to north breed different wetlands with great differences in resources.

2.1 Wetland types and distribution

According to the second wetland resources survey in Shaanxi Province in 2010, the total area of lake wetlands, swamp wetlands, artificial wetlands with a distribution area of ≥8 hm^2 and river wetlands with a width of ≥10 m and a length of ≥5 km in Shaanxi Province is 308,500 hectares, accounting for 1.50% of the total area of the province. There are 4 wetlands and 12 wetland types, including 257,600 hectares of river wetlands, accounting for 83.50% of the total wetland area; 7,600 hectares of lake wetlands, accounting for 2.46% of the total wetland area; swamp wetland is 11,000 hectares, accounting for 3.58% of the total wetland area; the constructed wetland covers 32,300 hectares, accounting for 10.46% of the total wetland area[4] (**Table 1**).

Table 1. Statistics of wetland area in Shaanxi Province

Wetland type		Northern Shaanxi		Guanzhong		Southern Shaanxi		Total	
		Area/hm^2	Proportion/%	Area/hm^2	Proportion/%	Area/hm^2	Proportion/%	Area/hm^2	Proportion/%
Rivers	Subtotal	49,570.33	16.07	120,979.58	39.22	87,041.44	28.21	257,591.35	83.50
	Permanent river	38,742.27	12.56	49,923.94	16.18	82,850.20	26.86	171,516.41	55.60
	Seasonal river	6,959.18	2.26	11,591.36	3.76	0	0	18,550.54	6.01
	Flood plain	3,868.88	1.25	59,464.28	19.28	4,191.24	1.36	67,524.40	21.89
Lake	Subtotal	7,556.74	2.45	41.18	0.01	0	0	7,597.92	2.46
	Permanent freshwater lake	3,020.21	0.98	41.18	0.01	0	0	3,061.39	0.99
	Permanent saline lake	2,665.50	0.86	0	0	0	0	2,665.50	0.86
	Seasonal saline lake	1,871.03	0.61	0	0	0	0	1,871.03	0.61
Swamp	Subtotal	356.95	0.12	5,484.38	1.78	5,192.83	1.68	11,034.16	3.58
	Herb marsh	73.84	0.02	3,325.86	1.08	4,411.38	1.43	7,811.08	2.53
	Inland salt marsh	0	0	2,158.52	0.7	781.45	0.25	2,939.97	0.95
	Swamp meadow	283.11	0.09	0	0	0	0	283.11	0.09
Artificial wetland	Subtotal	4,943.17	1.60	16,423.00	5.32	10,905.01	3.53	32,271.18	10.46
	Pond	4,943.17	1.60	9,439.78	3.06	10,148.41	3.29	24,531.36	7.95
	Canal/water conveyance river	0.00	0.00	2,957.76	0.96	397.25	0.13	3,355.01	1.09
	Aquaculture farm	0.00	0.00	4,025.46	1.30	359.35	0.12	4,384.81	1.42
Total	62,427.19	20.24	142,928.14	46.33	103,139.28	33.43	308,494.61	100.00	100.00

2.2 Wetland plant resources

Shaanxi has 77 families, 207 genera, 341 species and 3 varieties of wild wetland vascular plants (**Table 2**), including 3 families, 4 genera and 5 species of ferns, 1 family, 1 genus and 1 species of gymnosperms, and 73 families, 202 genera, 335 species and 3 varieties of angiosperms. Among angiosperms, there are 216 species of dicotyledons in

56 families, 142 genera, and 119 species and 3 varieties of monocotyledons in 17 families, 60 genera. There are 2 species of wild plants under national secondary key protection and 4 species of wild plants under provincial key protection[5] (**Table 3**).

Table 2. Categories of wild plants in Shaanxi wetlands

Category	Section	Genus	Species	Variety	National class II protected plants	Provincial key protected plants
Fern	3	4	5	0	0	0
Gymnosperms	1	1	1	0	0	0
Angiosperm	73	202	335	3	2	4
Total	77	207	341	3	2	4

Table 3. Wild protected plants in Shaanxi wetlands

No.	Species name	Family	Genus	Protection level	Distribution location
1	*Glycine soja*	*Leguminous*	*Soybeans*	National class II	Wetlands in the province
2	*Camptotheca acuminate*	*Blueberry family*	*Camptotheca*	National class II	Ningqiang Swallow Bianjin long ditch
3	*Alnus cremastogyne*	*Betulaceae*	*Alder*	Provincial key	Jialing River Wetland
4	*Myriophyllum spicatum*	*Small erxiancao family*	*Sargassum*	Provincial key	Wetlands in the province
5	*Tamarix ramosissima*	*Tamaricaceae*	*Tamarix*	Provincial key	Wetlands in Northern Shaanxi
6	*Ehretia macrophylla*	*Shikoniaceae*	*Pachyderm*	Provincial key	Wetlands in Qinba Mountain Area

Table 4. Categories of wetland wildlife in Shaanxi

Group	Order	Family	Species	National protection level I	National protection class II
Birds	9	24	121	10	26
Fish	6	15	136	0	2
Amphibians	2	7	28	0	1
Reptile	2	5	22	0	1
Mammals	3	4	5	0	1
Total	22	55	312	10	31

2.3 Wetland animal resources

There are 312 species of wetland wildlife in Shaanxi Province (**Table 4**), including fish, amphibians, reptiles, birds, mammals, shellfish and shrimp. Among them, there are 9 orders, 24 families, 121 species of birds; fish 6 orders, 15 families, 78 genera, 136 species (including subspecies); amphibians 2 orders, 7 families, 14 genera, 28 species; reptiles 2 orders, 5 families, 17 genera, 22 species; mammals 3 orders, 4 families, 5 species[4]. According to the newly revised list of national key protected wildlife[6], there are 10 national level I protected animals and 31 national level II protected animals in the wetland wildlife of Shaanxi Province, including 36 species of birds, 2 species of fish, 1 species of amphibians, 1 species of reptiles and 1 species of mammals[7-9] (**Table 5**).

2.4 Wetland tourism resources

Shaanxi has numerous river systems and complex landforms, forming a variety of wetland landscapes with unique charm, and rich tourism resources. These include the river beach landscape represented by the Yellow River, Weihe River and Han River; alpine swamp landscapes represented by Zibai Mountain in Liuba, Hanzhong, and congtan in Mian County[9]; wetland and lake landscape represented by Yulin Hongjiannao Lake; wetland pond landscape represented by Ankang Yinghu Lake; and the wetland cultural landscape represented by Hukou waterfall, Longmen, and the clear-cut of Jinghe River and Weihe River.

3. Achievements of wetland protection in Shaanxi

3.1 Wetland protection is gradually legalized and institutionalized

Shaanxi province attaches great importance to

wetland protection. In 2004, the general office of the people's government of Shaanxi Province issued the *Notice on Strengthening Wetland Protection and Management*, which puts forward specific requirements for wetland protection and management and planning in the province; in 2006, the Standing Committee of Shaanxi Provincial People's Congress issued the *Regulations of Shaanxi Province on Wetland Protection*, which is the first wetland protection regulation in Shaanxi Province; in 2008, the Shaanxi Provincial People's government issued a notice, announcing the *List of Important Wetlands in Shaanxi Province*, clarifying the four boundaries and subordinate relationships of 55 important wetlands, and requiring the relevant municipal (county and district) people's governments and relevant departments to thoroughly handle the work of wetland protection and management; in 2017, the general office of Shaanxi Provincial People's Government issued the *Provincial Wetland Protection and Restoration System Plan*, which pushed the wetland protection work in Shaanxi Province to a new height. As the competent department of wetlands, the Provincial Forestry Bureau has formulated *The 13th Five Year Plan for the Protection of Wetlands and Biodiversity in Shaanxi Province*, *The Protection and Planning of Wetlands in Qinling Mountains in Shaanxi Province*, and *The Planning of Wetland Protection Projects in Shaanxi Province (2009–2030)* since 2008, and issued the ten innovative actions for the management of ecological space in Shaanxi Province, the ten actions for the management of ecological space in the Yellow River Basin in Shaanxi Province, and the ten actions for the management of ecological space in Qinling Mountains in Shaanxi Province. The above laws and policy documents provide an important basis for wetland protection, restoration and reconstruction, popularization of science education, scientific research monitoring and rational utilization.

Table 5. Wild protected animals and their distribution and habitat in Shaanxi wetlands

No.	Species name	Protection level	Resident	Distributive type	Distribution location	Habitat
1	*Ciconia boyciana*	I	P	U	Ningqiang, Pingli	Water area and farmland
2	*Ciconia nigra*	I	S	U	Zhouzhi, Xi'an, Huayin, Ningshan, Zhashui, Chang'an, Yulin, Shenmu, Yan'an, Huangling, Tongchuan, Luonan, Danfeng	Waters
3	*Nipponia nippon*	I	R	E	Yang County, Chenggu, Foping, Xixiang, Ningshan, Zhouzhi, Hantai	Water area, forest land, farmland
4	*Aquila chrysaetos*	I	R	C	Foping, Zhouzhi, Yangxian, Meixian, Liuba, Ningshan, Ankang, Hantai, Xi'an, Taibai, Zhashui, Shiquan, Chang'an, Ningqiang, Xixiang, Pingli, Wugong, Fufeng, Zhenping, Yan'an, Shenmu	Grassland
5	*Aquila heliaca*	I	W	O	Xi'an, Taibai, Tongchuan, Weinan	Forest land and water area
6	*Otis tarda*	I	P	O	Zhouzhi, Dingbian, Yulin, Shenmu, Dazheng, Yan'an, Tongguan, Huayin, Xi'an, Heyang, Weinan	Water area, farmland and grassland
7	*Larus relictus*	I	S	D	Yulin, Shenmu	Waters
8	*Grus japonensis*	I	W	M	Dali, Tongguan, Heyang	Farmland, grassland, reed
9	*Falco cherrug*	I	W	C	Martial arts, Yulin, Weinan	Woodland and grassland
10	*Mergus squamatus*	I	W	U	Yang County, Foping	Waters
11	*Pelecanus crispus*	II	P	O	Weinan	Waters
12	*Platalea leucorodia*	II	P	O	Shenmu, Zhouzhi, Shiquan, Heyang, Hantai	Waters

Table 5. (*Continued*)

No.	Species name	Protection level	Resident	Distributive type	Distribution location	Habitat
13	*Anser albifrons*	II	W	C	Weinan	Water area, farmland and grassland
14	*Cygnus columbianus*	II	P	C	Yulin, Shenmu, Xi'an	Water area, reed
15	*Cygnus cygnus*	II	W	C	Heyang, Hengshan, Shenmu, Dali, Yulin, Foping, Xi'an	Water area and farmland
16	*Cygnus olor*	II	P	C	Weinan	Water area and farmland
17	*Aix galericulata*	II	P	E	Foping, Dali, Tongguan, Hanyin, Huayin, Shiquan, Huaxian	Waters
18	*Buteo buteo*	II	P	U	Shanyang, Shiquan, Liuba, Yang County, Zhouzhi, Foping, Xixiang, Feng County, Dingbian, Yulin, Shenmu	Farmland
19	*Circus melanoleucos*	II	P	M	Ningqiang, Weinan	Water area, farmland and grassland
20	*C. cyaneus*	II	P	C	Zhouzhi, Xi'an, Hantai, Ankang, Ningqiang, Weinan	Water area, farmland and grassland
21	*Falco peregrinus*	II	P	C	Xi'an, Taibai, Weinan	Woodland and grassland
22	*F. naumanni*	II	P	U	Hantai, Shenmu, Weinan	Water area and grassland
23	*F. amurensis*	II	S	U	Mei County, Xi'an, Huayin, Yang County, Taibai, Foping, Zhouzhi, Zhashui, Xixiang, Chang'an, Dingbian, Yulin, Shenmu, Tongguan	Grassland
24	*F. columbarius*	II	P	C	Yulin, Yan'an, Foping, Taibai	Woodland and grassland
25	*F. tinnunculus*	II	R	O	Zhouzhi, Xi'an, Huayin, Yang County, Foping, Shanyang, Taibai, Hantai, Ankang, Liuba, Zhashui, Xixiang, Chenggu, Chang'an, Pingli, Dingbian, Yulin, Shenmu, Ningshan, Weinan, Liquan, Tongguan, Shiquan, Baoji, Binxian	Grassland
26	*F. subbuteo*	II	S	U	Meixian, Zhouzhi, Xi'an, Huayin, Yang County, Nanzheng, Liuba, Foping, Taibai	Woodland and grassland
27	*Pandion haliaetus*	II	S	C	Xi'an, Ankang, Hantai	Woodland
28	*Grus grus*	II	P	U	Xi'an, Huayin, Hantai, Chang'an, Dingbian, Yulin, Shenmu, Weinan, Dali, Qianyang	Water area and farmland
29	*G. vipio*	II	P	U	Weinan	Water area and farmland
30	*Anthropoides virgo*	II	S	D	Zhouzhi, Chenggu	Water area and farmland
31	*Asio flammeus*	II	W	C	Foping, Xixiang, Weinan	Forest land and farmland
32	*Athene noctua*	II	R	U	Zhouzhi, Huayin, Ningqiang, Nanzheng, Ankang, Yang County, Foping, Ningshan, Taibai, Pingli	Forest land and farmland
33	*Glaucidium brodiei*	II	R	W	Zhouzhi, Liuba, Yang County, Foping, Taibai, Weinan	Forest land and farmland
34	*Otus bakkamoena*	II	R	W	Yang County, Foping, Zhouzhi, Taibai, Liuba, Ningshan, Weinan	Forest land and farmland

Table 5. (*Continued*)

No.	Species name	Protection level	Resident	Distributive type	Distribution location	Habitat
35	*Glaucidium cuculoides*	II	R	W	Zhouzhi, Huayin, Chenggu, Yang County, Foping, Shanyang, Danfeng, Taibai, Ningqiang, Nanzheng, Shiquan, Hanyin, Ankang, Liuba, Ningshan, Zhashui, Chang'an, Xixiang, Pingli, Zhenba, Hantai	Farmland
36	*Ketupa flavipes*	II	R	U	Zhouzhi, Liuba, Foping, Taibai, Pingli, Zhenping	Woodland
37	*Hucho bleeke*	II			Ningqiang, Zhenba, Nanzheng, Taibai, Longxian, Lueyang	Mountain streams and rivers
38	*Brachymystax tsinlingensis*	II			Taibai, Meixian, Zhouzhi, Foping, Longxian	Mountain streams and rivers
39	*Andrias davidianus*	II			Shangnan, Ningshan, Foping, Taibai, Zuoshui, Danfeng, Yang County, Ningqiang, suigao, Liuba, Luonan, Lueyang	River deep pool
40	*Lutra lutra*	II			Longxian County, Taibai, Foping, Yang County, Nanzheng, Liuba, Zhashui, Zhen'an, Ningshan, Shiquan, Pingli, Shangnan	Stream and river
41	*Palea steindachneri*	II			Pingli	Mountain streams and rivers

Note: residence type: R—resident bird, S—summer migratory birds, W—winter migratory birds, P—migratory bird, V—straggler. Distribution type: C—all north type, U—palaearctic type, W—oriental type, M—northeast type, D—central Asia type, P—Highland type, H—himalaya-hengduan mountain type, S—south China type, X—Northeast-North China type, B—North China type, E—monsoon type, O-hard to be classified type. Protection level: I is national level I, and II is national level II.

3.2 Continuous improvement of wetland protection management and scientific research institutions

After the institutional reform, the provincial forestry bureau established the wetland, grassland and desertification management office, the wetland and grassland institute of Shaanxi Academy of Forestry Sciences, and the wetland and grassland monitoring center of Shaanxi Forestry Investigation and Design Institute. The municipal and county forestry departments also clarified the wetland management department when adjusting and optimizing the institutional functions, providing the organizational guarantee for promoting wetland protection.

3.3 Preliminary formation of wetland protection system

Through years of efforts, a wetland protection system based on nature reserves and national wetland parks has been initially established. So far, the province has established 9 nature reserves of various wetland types at all levels; establish 43 national wetland parks (including pilot projects)[10]. The protection system has played a great role in maintaining the health and function of the wetland ecosystem in the province. The protection of Crested Ibis, a national first-class protected animal, has become a model for the protection of endangered species in the world. The number of Crested Ibis in the province has increased from 7 at the time of discovery to more than 4,000 now[11].

3.4 Strengthen publicity and create a good atmosphere for wetland development

Wetland authorities at all levels, based on major activities such as "World Wetland Day", "Wildlife Publicity Month" and "Bird Preservation Week", make full use of various media to widely publicize the great and irreplaceable role of wetland protection in improving environmental quality, maintaining biodiversity, regulating climate, promoting education and scientific research, which improves the public's awareness of wetland knowledge and im-

portance.

4. Problems in wetland protection in Shaanxi

4.1 The contradiction between wetland protection and social development is becoming increasingly intense

With the continuous development of society, illegal occupation and reclamation of wetlands often occur in industrial and agricultural production and life; chemical fertilizers, pesticides and domestic sewage used in agricultural production not only cause water pollution and eutrophication, but also pose a serious threat to biodiversity; the engineering measures taken in the construction of water conservancy projects, such as cutting bends and straightening, damming and blocking water, and cement hardening, not only directly reduce the wetland area, but also destroy the original shape of the river, hinder the connection of water systems, and have a great impact on the wetland ecosystem.

4.2 The collaborative cooperation mechanism for wetland protection has not been established

As the wetland administrative department, the forestry department has the main responsibility of organizing and coordinating the wetland protection and management and giving overall considerations. However, since the wetland law at the national level has not yet been issued, the Forestry Department of Shaanxi Province mainly carries out wetland protection and management according to the *Regulations on Wetland Protection and Management*, *the Scheme of Wetland Protection and Restoration System* and the *Regulations of Shaanxi Province on Wetland Protection*, which are department regulations of the State Council, official documents of the central government and local regulations respectively. Their legal effect is low, and they do not have the nature of universal national law[12]. There is no applicable binding force for the relevant departments of wetland protection such as agriculture, water conservancy, land and so on, and they still need to obey the provisions of national laws and regulations when applicable[13], which makes it difficult for the forestry department to effectively coordinate the law enforcement and management work of relevant departments, which is not conducive to the smooth development of wetland protection work.

4.3 Insufficient scientific and technological support, and the background of wetland resources is not completely clear

The institutions engaged in wetland research in the province have been established for a short time, the scientific research force is weak, and there is a lack of professional teams engaged in wetland research in colleges and universities. The scientific research on Wetlands in the province is scattered and unsystematic, only partial research on wetland animals and wetland plants has been carried out, and the scientific research achievements supporting wetland protection and management are scarce. The data of the second wetland resources survey in the province completed in 2010 cannot accurately reflect the current situation of wetland resources in the province, and cannot meet the needs of ecological environment protection.

4.4 Insufficient investment in wetland protection and management

Shaanxi Province has only provincial wetland protection special funds. Compared with other provinces, there is a lack of stable investment mechanism for wetland protection funds at the city and county levels. For example, the *Regulations of Qinghai Province on Wetland Protection* and the *Regulations of Henan Province on Wetland Protection* clearly stipulate that people's governments at or above the county level should incorporate wetland protection into national economic and social development planning, increase wetland protection investment, and include wetland protection and management funds into the financial budget at the same level. The insufficient investment in wetland protection and management in Shaanxi Province has seriously restricted the development of wetland restoration construction and protection.

5. Suggestions on wetland protection and utilization in Shaanxi

5.1 Carry out wetland ecological restoration and reconstruction projects

Deeply implement the concept of "lucid waters and lush mountains are invaluable assets", adhere to the "put ecology and conservation first", focus on ecological restoration, and gradually repair and rebuild damaged wetlands; continue to strengthen the work of returning farmland to wetlands and returning fishpond to wetlands in wetland nature reserves and wetland parks, and constantly improve the wetland protection rate; carry out comprehensive treatment of water pollution, strictly supervise and severely crack down on illegal acts such as pollution, destruction and occupation of wetlands according to law, so as to effectively protect wetlands.

5.2 Establish and improve wetland protection and management system

Carry out the revision of the *Regulations of Shaanxi Province on Wetland Protection*, and further clarify and refine the specific responsibilities of relevant departments. As the administrative department in charge of wetland protection, the forestry department should effectively communicate and coordinate with other departments, establish a wetland protection coordination mechanism, strengthen the overall planning of work, form a joint force of work, and constantly promote the development of wetland protection in the province. Implement the territorial management responsibilities of wetland protection, establish a working mechanism for wetland protection assessment, and incorporate the effectiveness of wetland protection into the assessment of governments at all levels.

5.3 Carry out the investigation and evaluation of wetland resources in the whole province

Carry out the investigation of wetland resources in Shaanxi Province, and comprehensively grasp the types, area, spatial distribution and current situation of wetlands in Shaanxi Province. Carry out research on applied technologies such as wetland protection, restoration, monitoring and sustainable utilization, formulate the *Measures for the Management of Provincial Important Wetlands*, the *Measures for the Evaluation and Identification of Provincial Important Wetlands*, the *Technical Regulations for Wetland Monitoring in Shaanxi Province*, and the *Technical Regulations for the Evaluation of Wetland Ecological Status in Shaanxi Province*, and build a wetland evaluation index system suitable for the ecological environment, wetland resources, socio-economic status and future development direction of Shaanxi Province, carrying out wetland evaluation in the whole province. On this basis, we should reasonably divide the wetland protection level, implement graded protection management, and establish a provincial wetland classification management system and technical framework.

5.4 Increase wetland protection capital investment

Actively strive for more investment of central financial funds in wetland protection and management. Increase the support of local financial funds for wetland protection and management, include wetland protection and management funds into the financial budget, and establish a stable capital investment mechanism. At the same time, in accordance with the principle of "who uses, who benefits, who compensates"[14], social capital is encouraged to join wetland protection and establish diversified investment channels.

5.5 Protection and utilization of different types of wetlands

5.5.1 Effectively protect and improve the ecological benefits of provincial-level important wetlands and wetland nature reserves

Provincial important wetlands and wetland nature reserves have important ecological location and rich biodiversity, which are of great significance in maintaining ecological security. We should adhere to the "put the ecology and protection first", protect in strict accordance with the *Regulations of Shaanxi Province on Wetland Protection*, put an end to the development of industries that have adverse effects on resources and environment, such as fisheries, leisure and entertainment, tourism and cater-

ing, and constantly improve and optimize the functions of wetland ecology, culture and education.

5.5.2 Give full play to the demonstration role and social benefits of wetland parks

Wetland parks should adhere to the principle of "protection first, supplemented by utilization", and give full play to their exemplary role in expanding the protected area of wetlands, restoring degraded wetlands, carrying out scientific research, science popularization and education. At the same time, we should thoroughly implement the concept of "a good ecological environment is the most inclusive benefit for people's well-being", constantly meet the people's demand for good ecological products, and make the wetland park a good place for the people to share green scenery, giving full play to its social benefits.

5.5.3 Coordinate the relationship between development, utilization and protection, and improve the economic benefits of artificial reservoir wetland

The artificial reservoir wetland should adhere to the principle of "combination and mutual promotion of protection and utilization, keep a balance between exploitation and protection", organically integrate with rural revitalization and village appearance, adjust measures to local conditions, develop industries with local characteristic and advantageous species and ecological leisure tourism, constantly explore development paths, promote the advantages of ecological environment and landscape resources into economic advantages and benefits, and form a win-win situation of protection and exploitation.

Conflict of interest

The authors declared no conflict of interest.

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