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Practical Exploration of Ecological Restoration and Management of the Mountains-Rivers-Forests-Farmlands-Lakes-Grasslands System in the Irtysh River Basin in Altay, Xinjiang

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Abstract: The Irtysh River Basin refers to a water conservation area and a vital ecological barrier in Xinjiang and also partially in Central Asia. Here, the technical solution for the ecological protection and the restoration of the Mountains-Rivers-Forests-Farmlands-Lakes-Grasslands system (MRFFLGs) pilot project in the Irtysh River Basin is refined, by complying with the core concept, i.e., "mountains, rivers, forests, farmlands, lakes and grasslands are a community of life". The solution stresses the specific characteristics of ecologically protecting and restoring MRFFLGs in the Irtysh River Basin, which aim to reduce ecological water use, soil erosion, forest and grassland degradation, the ecological destruction of mines, water environment pollution and other issues. With overall protection, system restoration, district policy, and problem orientation as the overarching ideas, 162 sub-items of 44 major items with seven categories have been designed and implemented in the project. In addition, some highlights of the management experience that are worth promoting when the pilot project is being implemented are also summarized (e.g., the use of laws to solve historical problems, scientific argumentation and third-party evaluation, proactive guidance for the engagement of people, modern information technology support, and integration with local sustainable development). Lastly, four policy suggestions are proposed: (1) Building a model of systematic protection and restoration by using basins as the basic geographic unit; (2) Establishing and optimizing key weak links of systems and mechanisms; (3) Focusing on remedying the shortcomings of regional talents, technology and capital; and (4) Promoting the MRFFLGs project to integrate "industry, city, people, and tourism" for carrying out a large-scale system project.

Key words: Mountains-Rivers-Forests-Farmlands-Lakes-Grasslands system; ecological restoration; functional zoning; management model; Irtysh River Basin

1 Introduction

As society and the economy are leaping forward, the adverse effects of human activities on the natural ecosystem are increasing, resulting in varying degrees of damage to the ecological environment in many parts of the world (Krittika, 2016; Tu et al., 2019). The ecosystem process is hindered, the normal functioning of the ecosystem is restricted, and even the service capacity of the natural ecosystem is seriously reduced or lost (Ge et al., 2016; Borrelli et al., 2017; Wunder et al., 2018; Liu et al., 2019a), which is especially true for the case of China's development. For a long time, China's economic development has relied mainly on inputs

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of production factors (e.g., land, capital, labor, and technology) (Wang et al., 2009; Wang and Huang, 2015; Fan et al., 2019), while the role of ecological factors in economic growth are inadequately considered. High-intensity resource development has led to a series of serious ecological problems (e.g., environmental pollution, land degradation and biodiversity loss) (Liu and Diamond, 2005; Zhou et al., 2021), and the carrying capacity of resources and the environment continues to decline (Li et al., 2019a). To cope with the issue of increasingly severe ecological degradation, China has successively deployed and implemented a series of ecological restoration projects in areas with more serious ecological degradation (Shao et al., 2017; You et al., 2017; Gao et al., 2020). Though these projects have achieved certain results, most of them focus on individual ecological elements (e.g., water and soil), or only one single natural process (e.g., soil erosion) (Xu et al., 2014; Cheng and You, 2019; Peng et al., 2019). For systemic deficiencies, only these superficial problems are solved without addressing the fundamental problems.

To strengthen ecological protection and restoration in an integrated and systematic manner, the Chinese Central Government proposed the idea of "mountains, rivers, forests, farmlands, lakes and grasslands are a community of life" along with overall planning and policy implementation in 2016. "The protection and restoration of Mountains-Rivers-Forests-Farmlands-Lakes-Grasslands system (MRFFLGs) should be unified" in areas with a damaged ecological environment, important ecological function areas, ecologically fragile areas and ecologically sensitive areas. By 2019, China had organized and implemented three batches of the ecological protection and restoration of MRFFLGs pilot projects. On the whole, the current implementation of the ecological protection and restoration of MRFFLGs pilot project mainly highlights land remediation and soil pollution remediation, mine environmental remediation and restoration, watershed water environmental protection management, biodiversity protection, etc. (Zhao et al., 2017; Wang et al., 2018; Kong et al., 2019; Li et al., 2019b; Luo et al., 2019b; Niu et al., 2019; Zhao et al., 2019). China has a vast territory, the causes of MRFFLGs degradation exhibit obvious spatial differentiation characteristics, and the required restoration and management technologies and sustainable management models vary considerably (Huang et al., 2018; Yu et al., 2018; Luo et al., 2019a). Therefore, for any given pilot area, explaining its general idea, project deployment and management mode, summing up the experience and methods, and innovating institutional mechanisms will also be important research contents of the ecological protection and restoration.

In 2018, the ecological protection and restoration of MRFFLGs in the Irtysh River Basin in Xinjiang was successfully selected as part of the third batch of national pilot projects. The Irtysh River Basin in Xinjiang displays a unique natural geographical pattern, a fragile ecological environment background, and an important ecological security status (Liu et al., 2019b). In addition, the ecological protection and restoration of its MRFFLGs should more significantly highlight the integrity, coordination, system and sustainability. Based on an investigation of the technical solution of the ecological protection and restoration project in the Irtysh River Basin, the management model and practical experiences of MRFFLGs can help clarify the ecological construction of MRFFLGs in the arid and semi-arid regions of Northwest China. This study forms a set of highly operable, scientific and reasonable watershed ecological protection and restoration systems to provide a reference, as well as replicable and popularized experiences for the ecological protection and restoration of MRFFLGs in other similar regions.

2 Study region and ecological issues

2.1 Study region

The Irtysh River originates from the southern slope of the Altai Mountains in the Altay region, flowing northwest along the southern foot of the Altai Mountains, and entering Kazakhstan to the west of Habahe County. It is an international river, flowing through China, Kazakhstan and Russia. The Irtysh River is an important tributary of the Ob River, the sixth largest river in the world, and the only river in China that flows into the Arctic Ocean. In terms of administrative divisions, the Irtysh River in China is all located in the Altay region of Xinjiang. Moreover, the spatial scope of the pilot program of the MRFFLGs project is the entire Altay region in China. For this reason, the Irtysh River Basin in our study is recognized specifically as the river in the Altay region (Fig. 1).

The Altay region is located in the northern part of Xinjiang, covering a total area of 1.18×10^5 km^2 and including 7.14% of the total area of Xinjiang. It includes six towns, one city and one scenic area under its jurisdiction. In 2019, it had a regional GDP of 3.3916×10^{10} yuan, a population of 6.57×10^5, and an urbanization rate of 38.97%. The basin is rich in water resources, nourishing an area of 3.53×10^5 km^2 and more than 7 million people in China. To be specific, the GDP of the covered area represents 60% of the entire Xinjiang. It acts as an important and strategic water resource reserve area in northern Xinjiang, so it is recognized as a water tower and "life river" of Xinjiang (Fu et al., 2016). The basin is one of the 25 significant ecological function zones in China, which involves all of the ecological elements of the MRFFLGs. It includes a distribution in Jimunai Glacier, Altai Mountains and forests, plains and desert grasslands, Irtysh River, Ulungur Lake, oasis and Gurbantungut Desert. The Irtysh River Basin exhibits the very typical characteristics of a life community of MRFFLGs, which is of high demonstration significance for exploring the formation of a technical model for the protection and restoration of MRFFLGs.

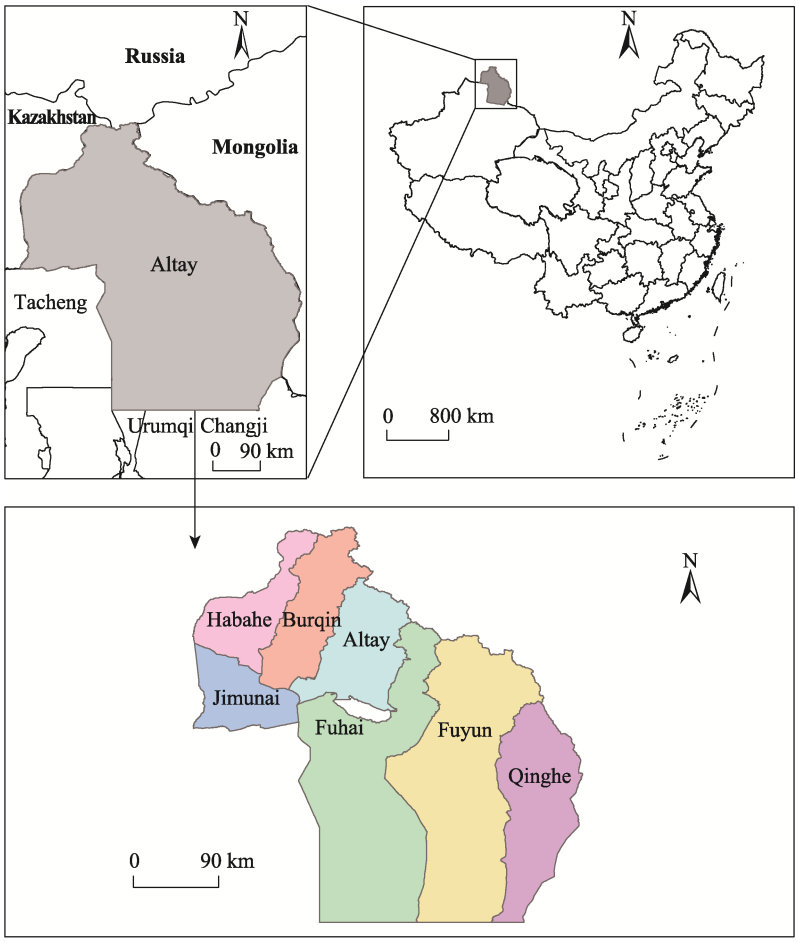

Fig. 1 Scope and location of the Irtysh River Basin in Altay, Xinjiang

2.2 Vital ecological issues

The ecological protection and restoration projects of MRFFLGs should aim at ecological functions and environmental issues (Fu, 2021). The analysis of the status and trends of changes in the ecosystem, and the classification of the significant problems faced by various elements of the ecological environment can underpin ecological protection, restoration and management.

2.2.1 Ecological water reduction

Under the increasing intensity of human activities, the water volume of the Irtysh River has displayed a clear decreasing trend. In the summer of 2007, a historic dry-flow phenomenon was reported; the Ulungur River was dry-flowed for 167 days in 2008, and it is currently dry. This flow situation has nearly become the norm. Numerous wetlands in the basin have shrunk to varying degrees. The Kekesu Wetland, the largest marsh wetland in the Gobi Desert in northern Xinjiang, achieved a total decrease in wetland area of 27.6% from 2000 to 2010, reaching 40.6 km^2, and wetland fragmentation has increased significantly. With the significant drop in the water level in the basin, the degradation and loss of fish spawning grounds have occurred in the lower reaches of the Irtysh River.

2.2.2 Soil erosion

With the rapid economic growth in the Altay region, numerous industries have sprung up to engage in economic activities, including the establishment of factories, the development of industrial parks and the large-scale reclamation of land for planting crops, which has caused serious soil erosion problems. The significant and severe situation of soil erosion is particularly noteworthy in the central area of Altay, where plantation farms, industrial parks, and most of the populations are located in the central plains and low-mountainous areas. Since the area of damaged surface vegetation and bare areas have expanded, floods have carried away considerable amounts of surface soil during the flood seasons and heavy rains. As suggested from the continuous actual sediment measurement data, the average sediment concentration of the Irtysh River from 2010 to 2015 increased significantly compared with that of the 1980s.

2.2.3 Forest aging and degradation

The vast forests are important part of maintaining the ecological functions of the Altai Mountains. According to the second-class forest survey data in the Altai Mountains in 2010, the area and accumulation of mature forest age groups

in mountainous areas reached up to 76.8% and 81.76%, respectively. The proportions of young, middle-age and near-mature forests are extremely low, and the proportion of forest resource age groups is seriously unbalanced. For several factors (e.g., overload grazing and disorderly felling), the aging trend of forest tree ages, the death of forest trees and serious windfalls have caused the forest communities in valleys to decline rapidly. Moreover, through the mining of mineral resources and man-made engineering, the original ecology has been destroyed, which has reduced the ability of the forest ecosystem to resist the invasion of foreign species.

2.2.4 Mine ecological environmental destruction

The Altay region abounds with a wide range of non-ferrous metals, such as sand gold and precious gems. In the 1980s and 1990s, tens of thousands of people entered the forest area to mine sand gold and gems in a very disorderly manner. Large-scale machinery mining and ordinary mining have continued for over two decades. Though the government had imposed restrictions on mining since 2000, scattered gold, gem, and mica mining have continued to be widespread. Mining development has imposed tremendous damage on large areas of bare land and mountain vegetation. A large area of exposure along the river banks and a large amount of sand and rock have caused the river to be diverted. As revealed by preliminary calculations, the exposed area of sand and rock attributed to gold mining alone amounts to 4000 ha, and the amount of sand and rock reaches at least 9.84×10^7 m^3.

2.2.5 Water pollution

Affected by the discharge of pollutants from industrial and mining enterprises, as well as urban and rural residents, the water bodies in some sections of the river are seriously eutrophicated, and the river water quality is poor. Most rural areas lack the facilities to collect and treat domestic garbage and sewage, and sewage and garbage are directly discharged into the river. The extensive use of chemical fertilizers, pesticides, and land films has given rise to soil and water environmental pollution. The areas of towns and oases continue to expand. Besides the increase in sewage discharge, excessive interception, especially the construction of large-scale water diversion facilities, has also resulted in several environmental problems, including the shrinking of lakes and wetlands (e.g., Ulungur Lake), salinization of water quality, swamping, etc. In 2018, four sections of the three rivers of Shuimo River and other rivers were polluted to varying degrees; Lakes and reservoirs in the lower reaches of Lake Aibi and eight other cities were classified as Class IV and Class V. The factors present in excess primarily included total phosphorus, fluoride and COD.

2.2.6 Grassland degradation

The land cover of Altay is dominated by grassland and desert steppe, and it is one of the vital animal husbandry bases in Xinjiang. However, the Altai grassland has been seriously degraded for a long time across a broad range of factors, e.g., overgrazing, improper reclamation, illegal digging of medicinal materials, and mining. Soil erosion and vegetation degradation lead to the loss of plant retention of precipitation, water conservation and transpiration which increase air humidity. Moreover, this is superimposed with rising temperatures and climatic droughts, thereby leading to an increase in catastrophic rainfall, e.g., heavy rains and hails. As revealed from the survey data of grassland resources in Altay region, over the past two decades, 73% of the natural grasslands in Altay have been degraded, of which 40% are seriously degraded.

3 Implementation project for ecological protection and restoration

3.1 Basic ideas and goals

The Irtysh River Basin is a typical mountain-oasis-desert complex ecosystem. The project has analyzed the current status and existing problems of the ecological environment of the river basin, complying with the concept of "mountains, rivers, forests, farmlands, lakes and grasslands are a life community", which is theoretically guided by the principles of ecosystem service balance and coordination mechanisms. Based on system-level thinking, an overall perspective and the watershed landscape, watershed health and function improvement are taken as the core of the project to achieve regional ecological protection and restoration. The emphasis is placed on improving vital ecosystem services (e.g., river cleaning, windbreak and sand fixation, soil conservation, product supply, and biodiversity protection) in the river basin in a coordinated manner, as well as on repairing the ecological process of the river basin with water as the link. This will be accomplished by analyzing the processes of formation and supply of ecosystem services in the river basin, the Irtysh River Basin located on the southern slope of the Altai Mountains, as well as forming a north-to-south coupling system of material flow, energy flow, information flow and service flow with the rise and fall of the terrain. Accordingly, the project has established a regional governance pattern for forests, grasslands, desert grasslands, farmland, as well as rivers, lakes and wetlands. Following the principles of unity, system, and integrity, from a goal-oriented and problem-oriented perspective that has been developed, the plan has formed various measures, which consist of conserving the river and lake water source areas, enhancing river and lake water storage areas, treating the sources of river and lake pollution, restoring of lifelines of rivers and lakes, as well as constructing barriers (e.g., desert protection, penetration of ecological corridors, improvement of governance capabilities and functional restoration).

Taking 2018 as the base year for rolling out the ecological protection and restoration of MRFFLGs pilot project, as of 2021, the key issues to be solved have been suggested as serious ecological damage and outstanding ecological risks in the mines, low ecological health of the Irtysh River, the

Ulungu River and the Ulungu Lake (two rivers and one lake), degradation of ecological conservation functions in the Altai Mountains, the overloading of the carrying capacity of farmland and grassland, the serious artificial fragmentation of ecosystems, and the decline of biodiversity. Efforts will be made to significantly improve the ecological environment of key regions, to noticeably increase the regional ecological safety water, and to substantially increase the supply and guarantee capabilities of regional ecological products, all in an attempt to build an ecological security pattern system in China's northwest border. Furthermore, a relatively complete system and mechanism for ecosystem protection, restoration and management should be built, as well as a set of replicable and extendable ecological protection and restoration technology models for the community of life in the arid area of Northwest China. The specific indicators consist of 22 items in five categories, as listed in Table 1.

Table 1 Performance indicators of the ecological protection and restoration of the MRFFLGs pilot

Target	Index	Current value	Target value
The ecological health of the "two rivers and one lake" has improved significantly	Water quality of the Irtysh River	Reach or better than class III	Not degenerate
	Water quality of Ulungur River	Reach or better than class III	Not degenerate
	Ecological water replenishment of Ulungur Lake (average for many years) ($\times10^8$ m^3)	5.51	8
	Water quality of Ulungur Lake	Reach or better than class III	Not degenerate
The ecological service functions of Altai Mountain have been significantly improved	Comprehensive management area of mine environment (km^2)	9.4015	50.46
	Forest cover rate (%)	22.65	22.76
	Forest stock volume ($\times10^8$ m^3)	1.16	1.17
	Returning farmland to forest area ($\times10^4$ mu)*	47.97	56.77
	Soil erosion control rate (%)	14.8	16
The ecological well-being of farmers and herdsmen has greatly improved	Living environment improvement village (unit)	–	190
	Recovery rate of waste mulch film in farmland (%)	60	⩾80
	Newly improved and restored area of degraded grassland ($\times10^4$ mu)*	–	75
	Water quality compliance rate of centralized drinking water sources (%)	⩾90	100
	Grassland comprehensive vegetation coverage (%)	38.8	42.2
The ecological risk of human activities is significantly reduced	Centralized treatment rate of urban sewage (%)	51.79	98
	Centralized disposal rate of domestic waste (%)	19.2	100
	Compliance rate of the Irtysh River into the river section (%)	100	100
	Ecological migration/household	–	413
Effective protection of the ecological safety of the Silk Road	Natural wetland protection rate (%)	49	55
	Ecological environment monitoring and early warning capabilities	Initially available	Significantly improved
	Water quality of the section going abroad	Class II	Class II
	Construction of national ecological civilization demonstration zone	Started	Completed

Note: * 1 mu is equal to 0.0666667 ha in the Table.

3.2 Ecological function division and key content

Based on the identification of vital ecological areas and the analysis of vital ecological processes, a comprehensive consideration is made for the ecological types and functional positioning of different basin areas, vital ecological processes and ecological relationships, as well as the main ecological and environmental problems faced and their causes. The Irtysh River Basin can be divided into three major ecological protection and restoration areas. The first is the ecological function conservation area of the northern Altai Mountains, which primarily aims to improve the ecological functions of the source runoff-producing areas in the mountains. The second is the ecological security maintenance area of the "two rivers and one lake" in the central area, which emphasizes maintaining the ecological security of the clear water production area and the river and lake storage area. The third is the southern desert grassland ecological conservation area, which is focused mostly on ensuring the ecological security of the inflow regulation area.

3.2.1 The ecological function conservation area of the northern Altai Mountains

This area spans 43183 km^2, occupying 36.68% of the land area of Altay. On the whole, the spatial distribution comprises the mountains and hills in the northern part of the Altay, which are the source areas of the "two rivers and one lake", and are capable of achieving water conservation, biodiversity maintenance and soil and water conservation. The

main ecological and environmental problems are ecological damage attributed to mining of mineral resources; forest ecological functions are reduced, manifested as forest aging and degradation; soil erosion and habitat fragmentation, and the mountain rivers often turn turbid yellow-brown or even dark-brown. To tackle these problems, three key tasks for ecological protection and restoration are implemented in the region: 1) Increasing ecological restoration and governance in mines to lower regional ecological environmental risks; 2) Increasing forest and grass vegetation restoration to improve soil and water conservation and biodiversity maintenance functions; 3) Accelerating the restoration and comprehensive utilization of tailings in order to expedite the simultaneous improvement of ecological protection and restoration as well as ecological development.

3.2.2 The ecological security maintenance area of the "two rivers and one lake"

This area spans 39633 km^2, covering 33.67% of the land area of Altay. The spatial scope mainly covers the central area of the Altay region, including the national vital ecological function area. This area plays a prominent role in regulating the ecological buffering of the "two rivers and one lake". Moreover, it is the main area for the supply and production of ecological products (e.g., water, animal husbandry and agriculture), and the intensity of human activities here is relatively high. The main ecological problems facing this region consist of wetland retreat, Ulungur Lake water pollution, natural grassland degradation, river valley forest degradation and weak ecological environment governance. Furthermore, the pollution and destruction in towns that are caused by human activities, and those in agricultural and pastoral areas, are rising. Thus, the key tasks of ecological governance comprise the following four aspects. First, the ecological restoration of rivers and lakes should be strengthened to elevate the level of ecological safety of the "two rivers and one lake". Second, the ecological restoration of grasslands should be strengthened to enhance the carrying capacity and regulation capacity of the grassland. Third, the ecological restoration and governance of oases should be deepened, and various pollution sources should be reduced. Fourth, overall protection should be stressed, and the improvement of ecological governance capabilities should be greatly enhanced.

3.2.3 The southern desert grassland ecological conservation area

This area covers 34901 km^2, occupying 29.65% of the land area of Altay. Distributed in the low mountain and hilly desert area in the southern part of Altay, it is recognized as a vital area for desertification prevention and biodiversity protection. The water resources here are scarce, the ecological environment is significantly fragile, and the intensity of human activities is low. A number of problems are currently evident, including a decrease in the groundwater level attributed to farmland reclamation, an increase of desertification, and the ecological damage, desertification, and threats to biodiversity attributed to the development of mineral resources. The vital tasks in this region consist of desertification control, ecological restoration of mines, farmland oasis management, ecological management and protection capabilities, and improving the monitoring and early warning capabilities.

3.3 Major project deployment

Specific to the three major ecological function areas and their key problems, and fully considering the rationality, feasibility, importance and benefit of the project, the ecological protection and restoration tasks of the MRFFLGs pilot project in Altay fall into seven categories, which include 44 major items and 162 sub-items, with a total investment of 5.827 billion yuan.

(1) Improvement of the ecological conservation function of Altai Mountains

Overall, seven major items are involved, with the primary distribution in the ecological barriers of the northern Altai Mountains. These items stress several problems, e.g., ecological damage left by mining, restoration of the geological environment damaged by man-made engineering, as well as the degradation of forest vegetation. The main contents of these items cover the treatment and restoration of the ecological problems left over by mining, the restoration and treatment of the damaged geological environment of the project, forest tending and conservation, as well as the construction of the source area of the shelterbelt.

(2) Grassland ecological restoration and comprehensive utilization

On the whole, five major items are included, which are mainly distributed in the arid desert area in the southern part of the northern Altai Mountain ecological barrier. For the construction content, subsidies and rewards for natural grassland ecological protection, natural grassland restoration of grasslands, settlement of nomads and grassland ecological protection are involved. With the improved self-repair of degraded natural grasslands, grass and livestock can be ensured to basically reach a balance in the natural grasslands of the northern mountainous areas.

(3) Enhancement of oasis ecological function and improvement of the human settlement environment

Eleven major items are included in total, with the primary distribution in the oasis area of the "two rivers and one lake" ecological safety maintenance zone in the middle section. To address the key problems (e.g., poor urban and rural water pollution prevention and control capabilities, outdated infrastructure, and poverty of residents), efforts have been made to promote the construction content, such as oasis towns, improvement of rural human settlements, ecological improvement of oasis agricultural land, and eliminating oasis ecological poverty.

(4) Ecological protection and restoration of the "two riv-

ers and one lake"

Eight major items are included in total, which show the major distribution in urban built-up areas and agricultural areas in central Altay. The items are implemented around the Irtysh River, Ulungur River and its tributaries, Ulungur Lake, Azike Wetland, Yilemu Lake and other wetlands. Vital tasks comprise ecological migration of important wetlands, returning farmland to wetland, and returning grazing land to wetland. Supplemented by appropriate artificial management and strengthened management and protection, the aim is basically restoring and maintaining lake wetlands.

(5) Biodiversity protection and desertification control

A total of three major items are included. By building protection stations, enhancement and releasing, and the construction of breeding loops and workshops, the effects caused by human interference in the protection area are eliminated. The artificial protection of important species and the education regarding biological diversity have both been strengthened, in an attempt to effectively maintain the natural reserve habitat and protect the biological diversity. To protect and manage the land under desertification, comprehensive measures have been adopted, such as closing hills for afforestation, artificial tending, artificial construction of sea-buckthorn forests, and reasonable irrigation.

(6) Improve the governance capacity of the life community

Overall, six major items are involved. To eliminate at the problems of the Irtysh River's ecological environmental monitoring and low management capabilities, items such as climate change monitoring and early warning and manual regulation, big data platforms, and key scientific issues of the life community have been implemented. The technological support and monitoring and emergency response capabilities of MRFFLGs will be significantly improved, as well as the ability to respond to climate change and ecological environmental governance.

(7) Transformation and development of resource-exhausted mines

On the whole, four major items are covered. The damaged area around the Keketuohai Mine was repaired. Specific measures cover clearing and transporting industrial solid waste, sealing low-grade ore, shutting down old silicon carbide factories, conducting remediation of pollutants, as well as ecological restoration of the factory area. Moreover, the farmers and herdsmen in the mining area will be transferred to resettlement areas and ecological poverty will be alleviated, and the grassland ecological breeding base will be formed.

4 Highlights of project management experience

4.1 Ensuring the implementation of the project with legal methods

First, the historical problem was solved through legal means. The pits left by the large-scale mining of sand and iron resources in Qinghe County cover an area of more than 1100 ha. However, due to a major disagreement between a company and the government in the negotiation of compensation for closure, the ecological improvement project is difficult to start. Finally, both parties resorted to the law. Through a court ruling, the differences between the company and the government have been resolved. Subsequent placer mining companies have been closed and written off one after another, which cleared the historical obstacles to the environmental improvement of the sand iron mine. Second, violations of regulations and disciplines discovered during bidding and implementation should be seriously dealt with. Bid rigging was discovered during the bidding process for the water reuse project in Habahe County. The government cleared one bidding company that operated in violation of regulations, and filed a case for the review of 11 bid-rigging companies. For the environmental assessment of two landfills in Qinghe County, an administrative penalty of 0.34 million yuan was imposed for the issue of "construction before approval". Third, the accountability mechanism for leading cadres has been implemented in an orderly manner. Responsibility shall be investigated for issues such as ineffective promotion of ecological protection and restoration projects, non-compliant use of project funds, and non-compliant project construction procedures. As of October 2020, eight violations have been fully investigated and dealt with, and two main county leaders have been warned. Seven relevant persons in charge of the construction company and the supervision company were punished, with a total fine of 0.35 million yuan.

4.2 Ensure the objectivity and reasonableness of the project with scientific argumentation and third-party evaluation

(1) Before the project was implemented, experts were organized from authoritative institutions, e.g., the Chinese Academy of Sciences, the Chinese Academy of Engineering, the Chinese Academy of Environmental Sciences, Tsinghua University, as well as the Ministry of Ecology and Environment. Through repeated demonstrations, field investigations, and project-by-project discussions with experts, targeted revisions were made to the plan. Experts took full responsibility to ensure the quality of the project; for individual key items, academicians personally participated in the demonstration and bid evaluation of the project to ensure the plan was scientific and feasible.

(2) The "double audit" mechanism has been established. Twenty third-party companies have been selected by bidding to focus on tracking and auditing the entire process of project planning goals, capital investment and project implementation. The audit results lay an important basis for project budgeting and fund payment.

(3) The fund performance assessment of the project is innovative. Third-party institutions have been selected to

participate in the full-cycle fund performance assessment of the project. This changes the previous internal government evaluation method in which the competent department in charge of fund use carried out self-evaluation, and then the financial department evaluated the quality of the self-evaluation. The establishment and monitoring of annual performance goals have been completed, emphasizing the professionalism of the evaluation methods and the authority of the evaluation results, as well as elevating the efficiency of the use of financial funds.

4.3 Encourage and guide people to participate in ecological protection and restoration actions

By recruiting laborers, renting agricultural tools, purchasing fertilizers and other supplies, local farmers and herdsmen have been guided to actively participate in the ecological protection and restoration of the MRFFLGs pilot project. As it stimulates the increase in people's income, it also raises the awareness of environmental protection, thereby creating an atmosphere where the people take the initiative to maintain, conspire, build and share. Qinghe County has exploited local farmers and herdsmen's machinery to participate in geological restoration projects, collected farmers and herdsmen's cow and sheep dung, and organized poor households to participate in grass seeds harvesting and sowing. Local labor accounted for 51%, leading to an increase in the income of local farmers and herdsmen by approximately 10 million yuan. Fuyun County has recruited local migrant workers to participate in the work of sowing grass seeds, planting trees, and transporting soil residues in the construction of mine pits and ecological restoration, which increased the income of residents by nearly 4 million yuan. As people are increasingly engaged, the ecological civilization concepts of "green water and green mountains are golden and silver mountains" and "mountains, rivers, forests, farmlands, lakes and grasslands are a community of life" have been promoted via household visits, national flag raising and other methods, so the people are progressively shifting from being "bystanders" to "masters" of ecological environmental protection and restoration.

4.4 Use modern technology to improve project implementation efficiency and supervision

Modern digital information technology is capable of significantly supporting project implementation. The Altay MRFFLGs life community ecological cloud platform has been developed based on three cores, i.e., project life cycle management, remote sensing analysis of ecological environment, and comprehensive business support of the ecological environment. In this platform, a database and four sub-platforms are involved, i.e., MRFFLGs pilot project database, full life cycle project management platform, ecological remote sensing analysis platform, visualization display platform, and ecological environment business management platform. On the whole, constructing the "integrated cloud platform" has allowed scientific, efficient, comprehensive and sensitive information collection, as well as systematic, networked, and intelligent information management and services to be conducted. Accordingly, information collection and processing capabilities, comprehensive evaluation capabilities, timely monitoring capabilities, rapid response capabilities, and predictive and early warning capabilities have been improved overall, and the progress of the ecological governance projects has been dynamically monitored in real time.

4.5 Promote the integration of ecological protection and restoration and regional sustainable development

The Altay government presses ahead with the combination of ecological protection and restoration with regional high-quality development. By combining principles and flexibility, the MRFFLGs pilot project is coordinated with industrial development and rural revitalization strategies, as well as the improvement of rural human settlements. A wide range of models have advanced steadily, and the first is the "ecology + industrial development" model. After having rolled out the geological environment treatment and the ecological restoration, Qinghe County has revitalized nearly 933.3 ha of land to develop and expand the sea-buck- thorn and donkey industries. Fuyun County combined the MRFFLGs pilot project with the Happy and Beautiful New Village construction project. Among them, the "Ertys River First Village" Talat Village achieved tourism income of more than 9.7 million yuan in 2019. The second model is the "ecology+rural revitalization" model. A total of 316 villages have been renovated in the entire region, making up a completion rate of 166%. The infrastructure construction of rural domestic sewage, garbage disposal and sanitary toilets has been accelerated, and the living environment in farming and pastoral areas has been optimized. The water quality compliance rate of centralized drinking water sources has reached 100%. Altay City has exploited the reclaimed water reservoir project to expand and green, to build a 666 ha nursery base, as well as to turn the reclaimed water reservoir into a tourist base that integrates hiking, cycling, leisure and tourism, and environmental education. The model of "maintaining reservoirs with forests" has been explored and practiced. The third model is the "ecology+education+tourism" model. Qinghe County, Fuhai County, and Fuyun County have built ecological civilization practice demonstration bases, e.g., geological environment restoration, wetland system restoration and biodiversity, and mine restoration. With the horizontal publicity of the indoor exhibition hall and the vertical visual comparison of the outdoors, the effect of ecological restoration is presented, and the idea of ecological civilization has been further deepened. Furthermore, Altay City used waste rock left over from the black and

white granite mining area in Chemurcek to build mazes and "stonehenges", turning the abandoned and messy mine into a popular tourist attraction.

5 Discussion and suggestions

In the Irtysh River Basin, the ecological effects of the MRFFLGs pilot project have a relatively long period as impacted by the high latitude, large span, long winter, cold climate, short effective construction period, and low rainfall. Thus, an in-depth implementation should be urgently carried out. In the scenario of novel development, the continued implementation of the ecological protection and restoration of the MRFFLGs project in the Irtysh River Basin critically impacts the ecological security of Central Asia, the One Belt One Road Initiative, local high-quality development, and the exploration of typical ecological governance models. Due to some problems which exist in the implementation of the pilot project, the mentioned significance and goals remain incompletely achieved, which should be addressed and improved during the in-depth implementation. The plans have continuously focused on the restoration of individual projects, and lack a holistic and systematic construction. Besides, evaluation management, ecological compensation and other institutional mechanisms remain relatively weak. Moreover, obvious deficiencies remain in talents, technology and funds. Furthermore, the projects are mostly limited to the planning documents themselves, and linkage with regional high-quality development is lacking.

The protection and restoration of MRFFLGs is integral, long-term and complex. Combined with the problems of project operation, technical systems, capital and management encountered in the ecological protection and restoration of the MRFFLGs pilot project in Altay, Xinjiang, the following four suggestions are proposed for an in-depth implementation.

(1) A model of systematic protection and restoration should be formed, with river basins as the basic geographic unit. The theoretical research on the ecological protection and restoration of MRFFLGs in the natural geographical units of the river basin should be deepened, and the key point that only highlights the ecological protection of water should be changed. All four attributes of water resources, ecology, environment and disasters should be considered comprehensively, and the conversion process between these four attributes should be explored.

(2) The key weak links of the system and mechanism should be identified and improved. The adaptive management of ecosystems should be strengthened. Implementation and management are required to stress regional ecological ownership and damage, and an evaluation system should be built for ecosystem restoration. First, the inspection system should be improved, ecological legislation should be explored, and the provincial and municipal levels of local ecological environmental protection and restoration legislation should be elevated.

(3) A professional team of experts in ecological restoration management, technology and engineering should be organized. An ecological restoration fund should be established, and ecological protection and restoration funds should be more deeply institutionalized. The cooperation with relevant scientific research institutes and universities is required to establish a typical regional ecological protection and restoration center in Altay.

(4) The MRFFLGs project should be pressed forward to integrate "industry, city, people and tourism" in order to organize a large-scale system project. The MRFFLGs project should be transformed from the design and implementation of ecological engineering to the planning of regional high-quality development. At the national level, the ecological governance project will be upgraded to national planning, e.g., the One Belt One Road Initiative, border and sub-regional cooperation. Moreover, at the regional level, the MRFFLGs project should be integrated with industrial development, urban construction, human settlements and eco-tourism as an important means for regional high-quality development.

6 Conclusions

"Mountains, rivers, forests, farmlands, lakes and grasslands are a community of life" is a novel concept of ecosystem protection and restoration, and new approaches and new methods should be continuously explored during its implementation and practice. To mitigate several issues in the Irtysh River Basin (e.g., ecological water use, soil erosion, forest and grassland degradation, mine ecological environment destruction and water environmental pollution), the improvement of the health and function of the river basin is suggested as the core. Following the general ideas of overall protection, system restoration, zoning policy implementation and outstanding problem orientation, the ecological protection restoration and environmental management plan design has been launched. By combining regional function positioning for spatial identification, the Irtysh River Basin falls to three functional areas, i.e., the ecological function conservation area of the northern Altai Mountains, the ecological security maintenance area of the "two rivers and one lake" in the central area, and the southern desert grassland ecological conservation area. The design has implemented 162 sub-items of 44 major items in seven categories, which cover the enhancement of ecological conservation function, the ecological restoration of grasslands, the improvement of human settlements, the protection of biodiversity, as well as the transformation of resource-exhausted mines. As the project is being implemented, Altay has formed several characteristic management experiences from engineering planning to project implementation and achievement promotion. Specifically, the following aspects are included: The use of the rule of law to solve historical problems, scientific argumen-

tation and third-party evaluation, proactive guidance for the engagement of people, modern information technology support, and integration with local sustainable development. Other regions can refer to the technical system and management model of Altay ecological protection and restoration for their ecological protection and restoration of MRFFLGs. Finally, combined with the great ecological significance of the Irtysh River Basin in China and Central Asia and some problems in the implementation of the pilot project, in order to further the in-depth and effective implementation of the MRFFLGs project, we have put forward some suggestions in terms of repair units, institutional mechanisms, element shortcomings, and regional high-quality development.

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新疆阿勒泰额尔齐斯河流域山水林田湖草生态保护修复与管理实践

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摘　要：阿勒泰额尔齐斯河流域是新疆乃至中亚地区的水源涵养区和重要的生态屏障。基于“山水林田湖草是一个生命共同体”理念，聚焦额尔齐斯河流域“山水林田湖草”生态保护与修复试点的特殊性，针对生态用水减少、水土流失、森林和草地退化、矿山生态破坏、水环境污染等问题，提炼了额尔齐斯河流域山水林田湖草生态保护与修复的技术路线。以整体保护、系统修复、分区施策、突出问题导向为总体思路，设计并实施了 7 大类 44 个大项 162 个子项的工程方案。总结了在项目实施过程中的若干值得推广的管理经验，包括运用法治手段解决历史遗留问题、科学论证与第三方评估、积极引导百姓参与、现代信息技术支撑、与地方可持续发展融合等。最后文章提出应形成以流域为基本地理单元的系统性保护修复典范，建立健全体制机制的重点薄弱环节，着力弥补区域人才、科技和资金等短板，推进“山水林田湖草工程”融合“产城人游”构成大系统工程等建议，以期为其他地区系统开展山水林田湖草生态保护修复工作提供借鉴。

关键词：山水林田湖草；生态修复；功能分区；管理模式；额尔齐斯河流域