

# Exploring the paths of ecological transformation of mining wastelands under the market-oriented model: A case study of the remediation of Lingshan Mining Wasteland in Jiangxia District, Wuhan, China

**Y Zhu** *China University of Geosciences, The People's Republic of China*

**JW Zhou** *China University of Geosciences, The People's Republic of China*

**DH Su** *China University of Geosciences, The People's Republic of China*

**HB Feng** *China University of Geosciences, The People's Republic of China*

**QQ Hou** *China University of Geosciences, The People's Republic of China*

**CX Feng** *China University of Geosciences, The People's Republic of China*

## Abstract

*In the context of market mechanism reform, this study addresses the challenges of ecological security, industrial discontinuity and policy gaps in the process of promoting mine ecological restoration through market-oriented means, and explores new methods and paths for the ecological transformation of mining wastelands. By applying the “resource-asset-capital” theoretical framework, this study analysed the market operation mechanism in mine ecological restoration, integrated market incentives and government regulation measures into the holistic process of governance, development and operation to formulate a market-oriented model for the ecological transformation of mining wastelands. Through an empirical study of the transformation design of Lingshan industrial and mining wastelands in Jiangxia District, this study considers fundamental concepts, including the incorporation of social capital investment, advanced technological support, and actively explores new governance models. This study proposes optimisation pathways from three aspects: mine ecological restoration, industrial spatial reconstruction and land regulation policies. These pathways include optimisation of the national spatial layout with ecological security reconstruction as the guiding principle, promoting industrial transformation and upgrading through the regeneration of industrial and mining land, and supporting diverse operational mechanisms through the implementation of land policy regulations. Under the market-oriented model, a collaborative design and management platform is established to ensure project implementation effects and achieve local environmental improvement and regional ecological transformation. This project not only restores the damaged environment, but also transforms it into an ecological cultural tourism complex, adding land index benefits and providing a new paradigm for current mine restoration and transformation design.*

**Keywords:** *Mining wastelands restoration, ecological transformation, land rehabilitation, market mechanism, property rights incentive*

## 1 Introduction

China is a major mining country and while resource extraction has made a great contribution to social and economic development, it has also caused serious ecological problems such as geological instability, land destruction, vegetation damage, environmental pollution, soil erosion, and biodiversity reduction. Since the damage caused by mining activities is usually extensive, deep and difficult to manage, mine ecological restoration needs to be realized in the progress of closure planning, trials during the life of a mine. Mine ecological restoration refers to relying on natural forces or artificial measures to intervene to repair the geological safety hazards, land destruction and vegetation damage caused by mineral resources mining

activities, so that the geological environment of the mine is stabilized, the damaged land is reclaimed and used, and the ecosystem function is restored and improved (Li et al. 2020).

According to China Mineral Resources Report (2020), remote sensing monitoring data show that in 2019, there are 480 km<sup>2</sup> of the national new mine restoration and treatment area, 288 km<sup>2</sup> of the new restoration area of abandoned mines, accounting for 60% of the whole 480 km<sup>2</sup>, the national capital demand for mine restoration in more than 900 billion yuan (Zhou et al. 2020). Therefore, in the context of the country attaches more importance to the construction of ecological civilization and the realization of the double carbon goal, mine ecological restoration is imperative (Hu & Zhao 2021). In 2019, the Ministry of Natural Resources issued the Opinions of the Ministry of Natural Resources on Exploring the Use of Market-oriented Approach to Promote Mine Ecological Restoration which encourages comprehensive restoration and utilization of mine land, implements differentiated land supply, encourages the use of vacated construction land indicators, and more comprehensively proposes incentive policies to promote mine ecological restoration in a market-oriented approach, and promoting mine ecological restoration in a market-oriented approach has become an important way to solve the problem of shortage of restoration funds. This is an important way to solve the problem of shortage of restoration funds (Liu et al. 2021).

## 2 A market-oriented model for ecological transformation of mining waste sites

Most of the mining abandoned land is located in the border area between urban and rural areas or independent industrial and mining areas, and it includes not only the areas damaged by mining that need urgent treatment, but also the subsidiary industrial and mining land, production and processing facilities and office and living space. Due to its special environment and diversified spatial connotations, mining abandoned land often has multiple attributes of ecology, production and life. Traditional mine ecological restoration emphasizes environment management and greening and beautification projects, while brownfield regeneration emphasizes redevelopment and reuse of land resources (DCLG 2006), each with its own focus and inseparable from the other. The construction of ecological civilization respects natural values and focuses on people-oriented, reflecting the dialectical unity of environment and development, ecology and society (Chen et al. 2019). The ecological transformation of mining abandoned land is the synergistic process of mine rehabilitation, mine land regeneration and mining reconstruction in the context of ecological civilization construction. Through the integration of multiple regulations, the ecological and construction space is laid out in an integrated manner, the stock of industrial and mining land is revitalized, and the industrial structure and layout are optimized to achieve sustainable regional development (Dixon et al. 2007).

The early sprout of ecological restoration marketization in China appeared in the field of land reclamation in mining areas, with agricultural industry integration as the main component. In 2012, since the 18th Party Congress proposed to accelerate the improvement of the socialist market economy system and strengthen the construction of ecological civilization, relevant documents have been issued one after another to encourage public participation, diversified investment, and market-oriented operation to promote ecological restoration. In 2017, since the 19th Party Congress, the reform of ecological civilization system and market mechanism has been accelerated, and the relevant theories and practical explorations have shown diversified trends, mainly in two aspects. One is the operation of the market mechanism of ecological restoration, which is mainly reflected in the capitalization of natural resources (Li 2020; Jing et al 2019), including natural resource trading, waste resource utilization and comprehensive development models. The second is the regulation mechanism of ecological restoration market behavior (Zeng 2015; Li 2019), including ecological funds, property rights incentives and land policies.

Government-led mine ecological restoration focuses on mine treatment itself, which has low resource utilization rate and high financial pressure, while the restoration under the role of market mechanism alone ignoring the ecological value tends to pursue economic benefits and emphasize land value, which will increase ecological risks. The market-based model emphasizes the integration of the two, introducing market

mechanisms while strengthening the government's supervisory function and effectively regulating and controlling market behavior, and striving to find the optimal solution between ecological risks and economic benefits, market returns and public interests. On the one hand, market-based means should be used to expand the capitalization path of natural resources, realize the diversified utilization of stock resources, play the role of property rights incentive, improve the income of ecological restoration projects, attract social capital participation, and comprehensively solve the financial problems of governance projects. On the other hand, it is important to restrain the market-based behavior, maintain regional ecological security, realize the balance of benefits of all parties and sustainable utilization of resources, and guarantee regional Long-term development.

The market-oriented model of ecological transformation of mining abandoned land is to integrate market incentives and government regulation mechanisms into the whole process of treatment, development and operation, and to maximize the comprehensive environmental, social and economic benefits through the optimization of the paths of mine ecological restoration, industrial space reconstruction and land regulation policies (Kepe & Tessaro 2014) (Figure 1).

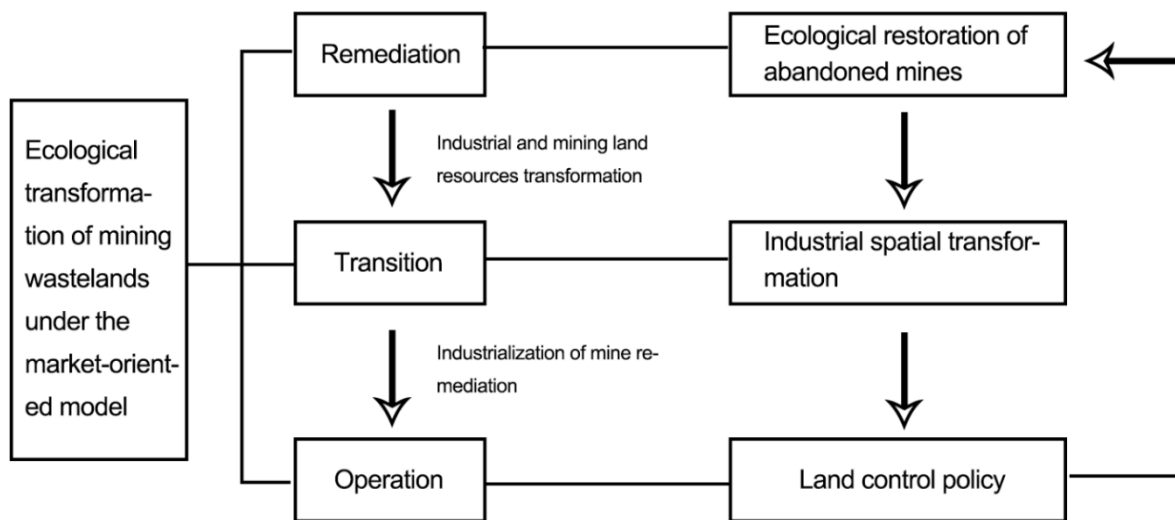


Figure 1 Analysis of market mechanism for ecological transformation of mining wasteland

### 3 Current status and transformation goals of Lingshan Mining Wasteland in Jiangxia District

#### 3.1 Current situation analysis

Jiangxia District is located in the southern part of Wuhan City, the northern part of the border with Wuhan City East Lake New Technology Development Zone and Hongshan District, the east through the Liangzi Lake and Ezhou City, the south through Jiayu County, Xianning City, the west and Wuhan Caidian District and Hannan District across the river. Lingshan is located at 10 km in the direction of 155° in the central part of Jiangxia District, involving three administrative villages, Lingang Village, Lingshan Village and Xingfu Village (Figure 2).

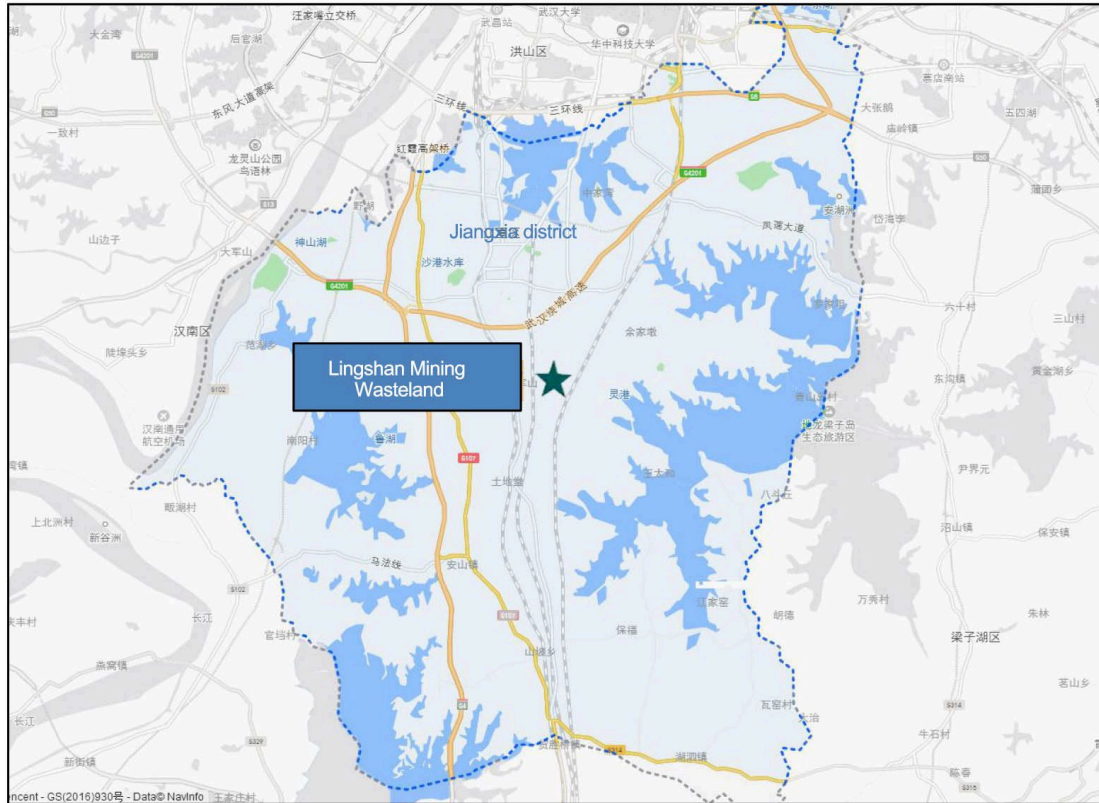


Figure 2 Location of the project in Wuhan City and Jiangxia district

The total area of the Lingshan Mining Wasteland is about 139 km<sup>2</sup>, the industrial and mining land is about 84 km<sup>2</sup>, and there are three main mining pits in the area (Figure 3).

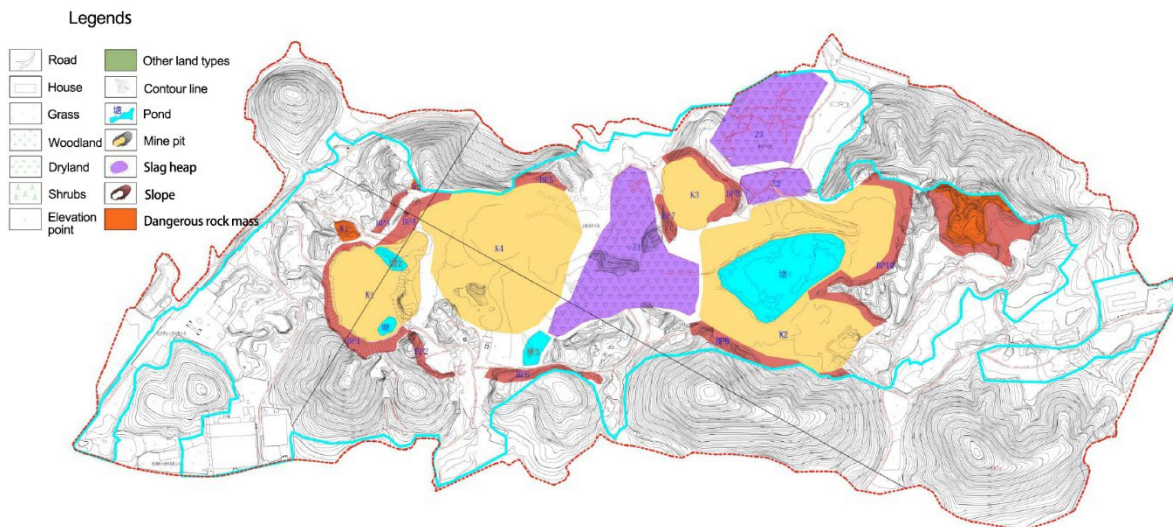


Figure 3 The general situation of mine wasteland in Lingshan

### 3.2 Transformation objectives

The problems brought about by the abandoned industrial and mining land in Lingshan are:

1. Multi-factor destructive geological phenomena, here including collapse, landslide, mudslide, cave-in, etc.

2. Environmental pollution, including air pollution, water pollution and soil pollution.
3. Destruction or damage of ecosystem, biodiversity and ecological balance.
4. Fragmentation of spatial structure, the abandoned land of mines fragments and destroys the original order of local spatial structure, destroying the geographical environment.

In 2019, Wuhan Natural Resources Bureau issued a land use plan for the abandoned industrial and mining land in Lingshan, with a total area of 92.2 hectares for treatment and an area of 10.2 hectares for reserved construction land. Of this 10.2 hectares, reclaimed forest land area is 19.2 hectares, reclaimed arable land area is 45.3 hectares, and water conservancy area is 9.2 hectares.

## **4 Market-oriented model for ecological transformation of Lingshan Mining Wasteland**

The ecological restoration of mines should firstly be planned from regional ecological security, and the systems of regional hydrology, geological hazards, biodiversity, industrial cultural heritage and transportation connections should be overlaid and analyzed to form a comprehensive security pattern to maintain the stability of the regional ecosystem, and the site development boundary should be determined in conjunction with the site suitability evaluation (Zhang 2019).

Subsequently, the mine management project was carried out in conjunction with the layout of land use planning to repair the mountainous ecosystem and ensure the safety of construction land. The design was based on the hydrological analysis of the watershed, using topographic preparation, soil improvement and other technical means to eliminate geological safety hazards while repairing the damaged mountain corridors, enhancing the ability to store rainwater and floods, providing suitable space for vegetation to grow and restoring mountain biodiversity. The overall restoration and virtuous cycle of the terrestrial ecosystem was realized, and the comprehensive utilization of the stock of industrial and mining land and ecological space was guaranteed (Maczkowiack & Smith 2019).

Finally, through landscape treatment design, we created characteristic landscape space and planned for rational use of ecological resources.

### **4.1 Geomorphological remodeling**

In the natural landscape restoration of the abandoned industrial and mining land in Lingshan, the existing topography was used as the basis for the remediation of imitation natural landforms, trying to approach the original landforms and landscapes. Using methods such as cutting high and filling low, earth hauling, land leveling, slope leveling, etc., the high soil and rock body threatened by geological disaster were cut and filled to low land level. The natural landscape also played an important role in micro-topography on the ecological restoration of Lingshan mining area. Some small-scale micro-topography such as shallow ditch, slow platform and steep hill in the mine area were conducive to the establishment and growth of vegetation, and some suitable micro-topography could be constructed during the construction process, such treatment and re-greening played an important role in the soil composition, precipitation infiltration, recovery of vegetation community and ecological service function of the mine area to a large extent (Figure 4).





Figure 4 Before the remediation of Lingshan Mining Wasteland

## 4.2 Soil reconstruction

The severe soil degradation in the abandoned industrial and mining sites of Lingshan was mainly manifested by soil erosion and soil impoverishment in the mine area, and was accompanied by little vegetation and slow growth in the mine area. Large soil animals such as termites, earthworms, and ants were placed in the soil of the Lingshan mine site, and they created more pore space for the soil through their life activities to promote nutrient and water infiltration and improve soil quality (Sun 2020). Micro soil animals, mainly nematodes, affected plant competition through inter-root effects, thus influencing plant succession and reducing soil erosion (Wang 2020). Bioaugmentation technology was applied to the abandoned industrial and mining sites in Lingshan to introduce microorganisms with specific functions by screening from indigenous microorganisms, which can improve the permeability of the soil in the mining area, thus preventing soil erosion and promoting soil quality improvement and hydrological conditions.

## 4.3 Vegetation reconstruction

The mining area of Lingshan has a subtropical monsoon climate with abundant rainfall and light, an average annual temperature of  $16.7^{\circ}\text{C}$ , a rainy season from April to July, and rich and diverse native plant resources. In the mining environment, plants with strong resistance to adversity and salinity tolerance were selected, and native plants were mainly used, combining grass, irrigation and trees to form multi-level vegetation planting and promoted the biodiversity recovery of vegetation communities. Some common garden plants in Wuhan Jiangxia also had obvious ecological functions, such as hibiscus, plum blossom, and daylily are highly adaptable and tolerant of barrenness, wisteria and magnolia can purify air and resist pollution, iris, calamus and reed can purify water, combined with imitation of natural landforms and microtopography treatment means, so that all kinds of plants in the mine area combined with natural landform and microtopography remediation, all kinds of plants played the role of soil fixation and water retention, improved soil fertility, improved environmental pollution and restored biodiversity in the suitable spatial environment.

## 4.4 Market-oriented model operation and revenue analysis

The industrial spatial reconstruction of industrial and mining abandoned land is a key path to realize the functional conversion of industrial and mining land under the market mechanism and enhance the value of the stock of land and its accessories (Kivinen 2017). Under the market-oriented model, the core of this path optimization is the balance of short-term and long-term benefits. Thus, it is necessary to play the role of government regulation and incentive to optimize the industrial structure, but also to tap the value of stock resources and encourage the innovative development of diversified industries (Bowie & Fulcher 2017). While guaranteeing the balance of short-term funds, it leads to sustainable regional economic growth and social and livelihood improvement, and realizes the market-oriented development of mining abandoned land.

Optimize industrial structure configuration, build a composite industrial system, and improve land use efficiency and industrial value. Government investment behavior focuses on the comprehensive development of local social economy and favors operation and service industries. Market-oriented

investment behavior, focusing on capital turnover efficiency and risk control, favors sales-oriented industries. The industrial allocation should take into account the local industrial development needs and the background resource conditions of the mining area, consider the industrial added value, job supply and ecological environment impact, take into account the market-oriented development needs, reasonably determine the ratio of composite industries, and achieve a balance between the near-term land revenue and the long-term operation revenue.

Combining the development demand of tourism industry in Jiangxia District and the characteristic cultural landscape resources and location advantages of Lingshan mining area, it built an industrial culture tourism complex industrial system with mining theme park cluster as the core, theme tourism service facilities as the support and theme life neighborhood as the extension. With the theme of industrial and mining culture experience, it also built the first mine park in Wuhan, developed four leading industries of ecological restoration, sightseeing agriculture, outdoor sports and study and vacation, form the highlight project of Jiangxia's whole area tourism and drived the regional industrial transformation.

The project operation mode was led by the local government, and social capital participates in the investment and operation. The main responsibilities of each party: the local government was responsible for the overall management and the completion of project approval and other work; the social investment and construction body, as the main body of investment and implementation, was responsible for undertaking the investment and financing, construction, operation and later management of the project. For details, see Figure 5 operation mode.

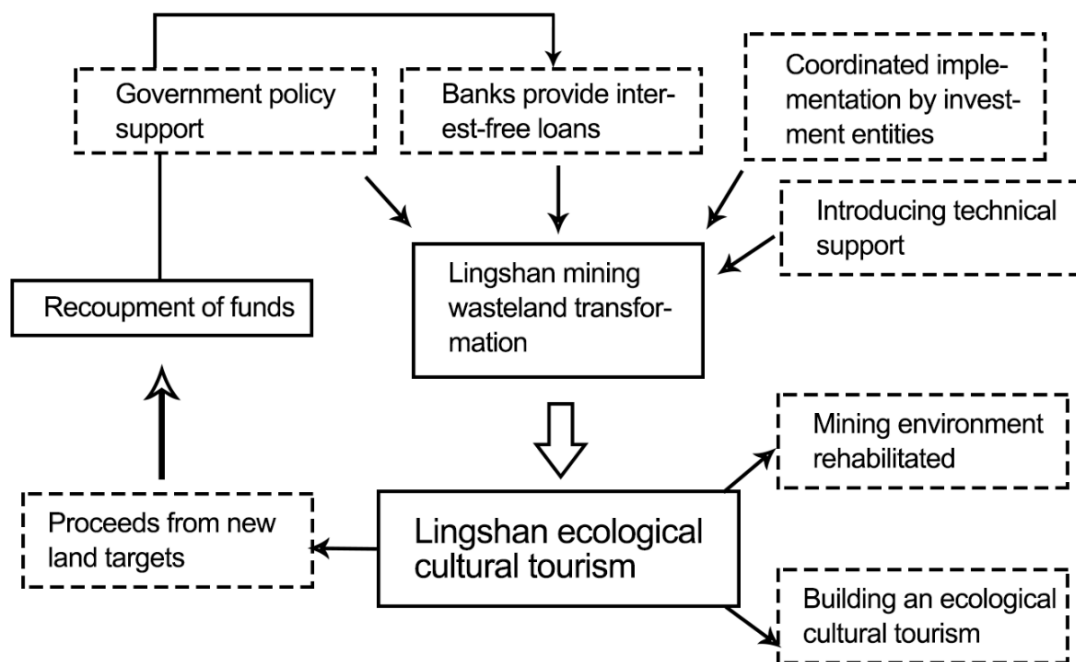


Figure 5 Operation model schematic

According to the figure 5 operation mode, the key paths for Lingshan mining wasteland transformation are divided into 3 parts:

(1) Introducing social capital investment

Introducing state-owned enterprises in the district, applying for interest-free loans from banks for restoration funds, as the main investor in the restoration of abandoned mines (which is linked to the part 4.4).

(2) Introducing advanced technology support

Through the cooperation with domestic first-class universities, advanced mine management technology is introduced to provide targeted program design for difficult problems such as high and steep rocky slopes, land reclamation in mining areas and irrigation and drainage (which is linked to the part 4.1,4.2 and 4.3).

(3) Exploring new modes of governance

After the restoration of industrial wasteland is transformed into arable land, the new land index is transferred to produce economic benefits, and the restoration funds are again replenished, forming a closed loop of investment returns (which is linked to the part 4.4).

Table 1 Achievements and benefits of Lingshan Mining Wasteland rehabilitation

Completion of the Lingshan Ecological and Cultural Tourism	Rehabilitation of arable land, forest land and other agricultural land			Benefit of transformation land
Restoration area: 92.2 hectares	Restoration of arable land: 51.9 hectares	Restoration of forest land: 27.7 hectares	Restoration of other agricultural land: 12.6 hectares	USD 0.6 million / 1 hectare

According to the table 1, the economic benefits of industrial and mining abandoned land reclamation and utilization are evaluated using inputs and outputs. Mine inputs mainly refer to the financial inputs of mine reclamation and management, and output benefits can be divided into two parts: one is the economic benefits of food cultivation directly generated by reclaiming arable land, and the other is the output benefits of adjusting the use of new construction land.

There are 92.2 hectares of abandoned industrial and mining land transformed into new arable land, forest land and other agricultural land. Among them: arable land is mainly used for rape, sweet potato and wheat cultivation; forest land is mainly used for acacia cultivation. According to the flow of new arable land indicators, the proceeds from the sale of governance indicators amounted to USD 55.32 million, with a cost investment of USD 30.1 million and a gross profit of USD 25.22 million (According to the exchange rate on 23 August 2023, USD 1 = CNY 7.29). And the before and after comparison of Lingshan mine ecological restoration is shown in Figure 6 and 7.



Figure 6 Before and after rehabilitation of Lingshan Mining Wasteland





Figure 7 Before and after rehabilitation of Lingshan Mining Wasteland

## 5 Conclusion

The market-based model of ecological transformation of abandoned mining sites is a new approach to solve the comprehensive problem of ecological restoration and transformation of mining abandoned sites under the dual role of market mechanism and government regulation and control. Integrating market incentives and market regulation into the whole process of management, development and operation of mining abandoned land, and optimizing the implementation path of ecological restoration, industrial reconstruction and land regeneration are the keys to balance ecological, social and economic benefits and realize the ecological transformation of all elements of mining abandoned land.

Applying the market-oriented model, the ecological transformation of the abandoned industrial and mining land in Lingshan, Jiangxia District, has achieved initial results. By the end of 2022, the total area of governance is 92.2 hectares, the area of reclaimed forest land is 27.7 hectares, the area of reclaimed arable land is 51.9 hectares, the area of other agricultural land is 12.6 hectares. Through the transfer of land use rights and construction land indexes after the ecological restoration of mines, the balance of mine management funds is more than USD 25.22 million. The ecological transformation of mining abandoned land has not only improved the local ecological environment and landscape appearance, but also provided sustainable impetus for regional economic and social development.

Facing the game of multiple interests and the reconstruction of multiple elements in the market-oriented mode, a multi-disciplinary collaborative work platform should be established to consider the needs of governance, development and operation under the role of market mechanism, and supervise and manage the whole process to ensure the effective connection of project design, implementation and operation, and reduce construction and management costs. The core of the market-based operation mechanism is the reuse of stock land resources, which has certain limitations in the face of ecological transformation projects of mining abandoned lands with restricted land development, such as those located in ecological regions and the severe lack of stock construction land indexes. In the follow-up study, the funding sources and implementation paths for various types of mine treatment with constrained development conditions need to be further deepened.

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