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Ecological Management and Land Rehabilitation in Mining Areas from the Perspective of Actor-Network Theory—A Case Study of Lizuizi Coal Mine in China

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Abstract: Ecological damage in mining areas largely affects the regional ecological environment and ecological security. In China, ecological restoration in mining areas is urgent, as its environmental protection lags behind economic and social development. Recent studies on environmental governance in China focus on each participant's logic of action. It suggests that cooperation among each participant is important. Thus, a fundamental question arises: how can we effectively organize various actors in environmental governance? Unlike theories that focus only on human factors, the actor-network theory considers both human and non-human actors. Within the framework of ANT, ecological restoration governance can take good care of both people and nature. To the best of our knowledge, the actor-network theory has not been used to analyze ecological restoration and land rehabilitation in mining areas. In this paper, the Lizuizi Coal Mine in Huainan of China is taken as a research object. By using the actor-network theory, we analyze the stability of the actor network and governance problems in different stages of ecological restoration of Lizuizi Coal Mine. It is concluded that the participation of the residents in ecological restoration is insufficient, and should be improved. Suggestions are provided accordingly. Our paper provides a theory basis for ecological construction in other ecologically damaged areas and resource-based cities. Further in-depth studies are necessary to strengthen the participation of social forces and the bundling collection of interests in governance.

Keywords: ecological restoration; coal mining subsidence area; actor network; land rehabilitation; China

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1. Introduction

Ecological damage in mining areas is a major factor affecting the regional ecological environment and ecological security. The economic development policy of "mining fast and flowing fast" encourages rapid exploitation of natural resources such as mines and waters as soon as they are discovered. This has led to the excessive and disorderly exploitation of mineral resources, and caused serious damage to regional ecological functions [1–3]. In China, the area of destroyed land is increasing year by year, and it reached about 120,000 km^2 in 2020 due to production, construction and mining activities [4]. By the end of 2018, more than 8.9 million acres of land had been destroyed by mining nationwide, of which more than 5.6 million acres had been occupied by historical mines [5]. Some coal mines have been closed and more will be closed in the future. In 2020, the number of abandoned coal mines in China reached 12,000, and it is expected to reach 15,000 by 2030 [6]. Due to the long-term path dependence of rapid socio-economic development on coal resource utilization, the coal mining subsidence area is still increasing. Consequently, it brings a continuous increase of construction land and a significant reduction of ecological land. This shows that the implementation of ecological restoration in mining areas with serious ecological damage has a realistic urgency.

Ecological restoration is an important means to improve polluted and damaged ecosystems [7]. Knowledge of how to carry out ecological restoration projects scientifically and effectively has gained great attention from various countries, including China. Since the

beginning of the 20th century, European and American countries have been protecting damaged mountain, forest and grassland resources. They have accumulated rich experience in ecological restoration practices and policies. The pioneering law of mine land rehabilitation is the "Rehabilitation Act" issued in 1939 in West Virginia, USA to restore the ecological environment of mining areas. It aims to restore the mined land to a natural or economically usable state [8], marking the beginning of a new stage of law-based ecological restoration of mining land. The UN has developed a ten-year plan for ecosystem restoration for 2021–2030 to promote large-scale restoration of degraded and damaged ecosystems. Ecological restoration work has become a central issue of global ecological environment governance [9]. The Common Agricultural Policy (CAP) is one of the most important agricultural policies in the EU. Although the initial main objective of CAP is to stimulate agricultural production, it also pays great attention to ecological and environmental issues, and established subsidies and compensation measures. A series of programs have been formulated by the EU to let arable fields lay fallow. These measures have effectively balanced the contradiction between food supply and demand. The implementation of the Conservation Reserve Program (CRP) in the US has achieved positive results in reducing soil erosion, improving water quality and protecting wildlife habitats [10].

In recent years, ecological environment governance and land rehabilitation in China's mining areas have achieved unprecedented results. Data released by the Ministry of Natural Resources show that by the end of 2017, financial expenditures of China's all-level governments for mine environmental management had accumulated more than CNY 100 billion. In total, 9200 km^2 land in mining areas has been rehabilitated, with a mine restoration rate of 28.75%. President Xi Jinping (2020) has made a series of important statements on the construction of ecological civilization, such as "green water and mountains are also golden mountains" and "improving the ecological environment is developing productive forces" [11]. These statements emphasize the coordinated and sustainable concept between economic development and environmental protection. The "13th Five-Year Plan (2016–2020)" makes ecological protection and restoration of mining areas a priority and promotes the geological environmental restoration and land rehabilitation in mining areas. In general, environmental protection in China still lags behind its economic and social development. Due to great complexity, serious impacts and insufficient investments, ecological environmental management is difficult, and the ecological safety in mining areas is severe.

In recent years, the relationship between subjects of ecological environment governance has been discussed from different perspectives, trying to find participants' action logic and explain this gap. As China's environmental governance system and regulations are becoming better, local governments have more dominated influence on environmental governance. In particular, grassroots governance directly communicates with the public in either conventional or unconventional ways (e.g., voluntary rescue, donations). However, in existing studies, only the action logic of each participant is explained. The interactions between different subjects are less addressed.

In this scenario, the "actor-network" theory can provide a new theoretical viewpoint on eco-environment governance. In recent years, actor-network theory has been widely used in rural geography, urban geography, economic geography, tourism geography and other fields, and has produced a great academic impact [12], such as its applications to the rural space commercialization [13], the development of country houses [14] and the spatial transformation of traditional villages [15]. These studies show that internal logic of actor-network theory is suitable for studying cooperative governance. Therefore, it is natural to consider an important issue of environmental cooperative governance in mining areas that was less studied before. Several questions can be raised: how can we organize the various actors of environmental governance effectively? Who are the actors of ecological protection and environmental governance? Answering these questions are essential to improve ecological management. However, so far, no researchers have yet exploited the

actor-network theory to explore ecological environment restoration and land rehabilitation in mining areas.

This paper takes the Lizuizi (L) Coal Mine, a typical resource-depleted mining area in China, as the research object. By using actor-network theory, we analyze the stability of the actor network and governance problems in different stages of ecological restoration in L Coal Mine. The case study reveals that in the process of ecological restoration, the participation of local residents in the L Coal Mine area is insufficient. Based on the results and analysis, suggestions are proposed to improve the environmental management policy in the mining area. Our case study also provides a theory basis for ecological civilization construction in other ecologically damaged areas and resource-based cities. We hope this encourages the individual social actor to construct ecological civilization.

2. Literature Review and Theoretical Framework

2.1. Research Related to Ecological Environment Management in Mining Areas

China has raised the bar for sustainable development in resource-based regions, and has taken many measures to restore the damaged land and its ecology. Research by the scientific method complements social disciplines. For example, Landsat remote sensing data were used to analyze changes of land utilization and landscape ecology in mining areas [16,17]; TM satellite data were used to monitor lakes due to collapse after lignite mining in eastern Germany, providing the direct environmental impact of open-pit lignite mining [18]. As reported by Liu et al., land rehabilitation is an effective way to restore the ecology of subsidence areas; however, in China there exist several problems in land rehabilitation, such as low rehabilitation rates and less-efficient development [19].

Although great achievements have been made in ecological environment management, more than 70% of the mine environment has yet to be effectively restored [20]. So far, research on the ecological environment of mining areas has mainly focused on establishing the index evaluation system for transformation indicators of specific areas [21,22]. Scholars have carried out research based on the governance idea of sustainable development, and believe that the establishment of an environmentally friendly coal mining system will continuously seek industrial transformation and upgrading [23].

There is generally a gap between policy goals and actual environmental situations in ecological management, referred to as the "implementation gap" or the "implementation deviation" [24]. A dilemma of implementing ecological management projects in mining areas has been reported. In China, environment management relies mainly on the government, both as a policy maker, and as an executor and supervisor. Therefore, there exists a governance contradiction between the limited nature of government functions (expansion) and the infinite growth nature of society (governance issues) complexity [25]. Ge (2004) analyzed the obstacles to the management of subsidence areas from the perspective of the economic conditions of coal enterprises [26]. He argues that the cost of disaster management in coal subsidence areas is not clarified by the country. This leads to many unresolved issues of compensation, and post-treatment in coal mine subsidence-affected areas. In China, the surrounding area of mining areas is generally rural, and the rural ecological environment is governed by a single subject with a weak sense of community. It is therefore difficult to build an ecological management community with management and cooperation of various actors [24]. Chinese people's willingness and actions of participation in environmental governance are both low [27]. In addition to economic and social factors, there are also technical difficulties in ecological management. Johimsen (1996), using experimental data, argues that ecological restoration in subsidence areas is a long and difficult process [28]. The management process involves ecological restoration, migration and compensation for lost land, which is complicated and difficult to carry out because satisfying the needs of all residents is not easy. Based on literature and government public documents, we summarize the current steps for the treatment of mine subsidence areas in China (see Figure 1). The steps mainly focus on land rehabilitation and compensation for residents who have lost their land and houses due to subsidence. Land rehabilitation

is an activity that aims to restore various kinds of land destroyed by human and natural factors to a state that can be reused as expected by society. Nowadays, it mainly includes the mixed cultivation model based on aquaculture, an eco-model based on afforestation; the model of development agriculture which aims to grout and re-soil the gangue land; a model of simply leveling agricultural land; the model of reclaiming agricultural and forest land by the dredging method; the model of reclaiming basement ponds or eco-agriculture and the model of reclaiming eco-farms.

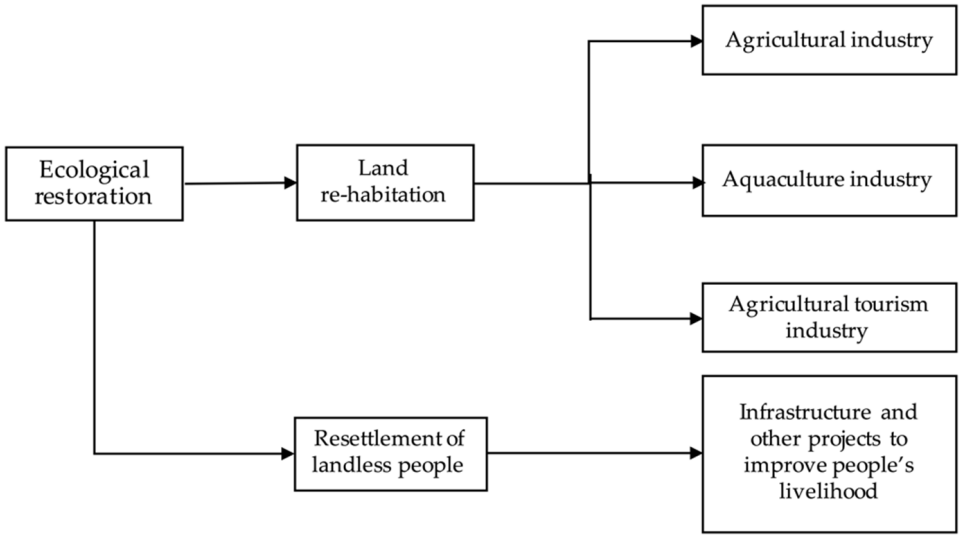

Figure 1. Steps on the control of coal mining subsidence area. Source: Organized by the authors.

There are also theoretical contradictions in how to conduct environmental governance. Natural environmentalism emphasizes the "originality" of nature, i.e., the human non-interference in nature [29]. This approach separates humans from nature and is not operable in regions with large populations and small land areas. In the 1980s, Japanese environmental sociologists proposed living environmentalism, which advocates promoting environmental governance by respecting and relying on local people's wisdom. The opinion emphasizes that environmental policies should be developed based on local history, culture and the needs of the residents [30,31]. Local people understand regional culture and customs better, and thus policy formulation needs to respect residents' demands and adjust environmental protection strategies accordingly [32]. When studying how to effectively implement the energy efficacy policy in Shanxi Province during the 11th Five-Year Plan period, Kostka et al. found that the local government mainly used three strategies, namely, interest bundling, policy bundling and policy framing [33]. Kostka et al. mainly saw that the superposition of different policies enhanced the pressure and legitimacy of the implementation of a certain policy [33]. In this article, we are more interested in how local governments can use the policies to bundle enterprises into the network.

It is difficult for any single entity to ensure sufficient resources and capacity to independently deal with ecological governance issues in the long term [34]. On the whole, environmental governance is still carried out mainly based on government decisions, with few opinions from local communities. The government-centered supply model is unable to meet people's needs for a high-quality ecological environment. Everyone is a protector, builder and beneficiary of the environment [11]. We believe that researchers need to pay attention to these conflicts and conduct in-depth studies on mining subsidence areas, such as the mechanisms of repairing the relationship between people and nature and the mechanisms of adopting residents' opinions. Currently, environmental governance has become a major political task, so China needs to fulfill its commitment as a responsible power [35]. Since social capital is an important resource that exists among people and enables them to participate in collective activities [36], ecological environment governance

can guide the interest relationship between individual and collective from the acquaintance social relationship.

2.2. Actor-Network Theory and Analysis Framework

The concept of "actor-network" originates from the "actor-network theory" (ANT) proposed by the sociologists of scientific knowledge (the Paris School of Thought, represented by Latour [37], Callon [38] and Law [39]) in the mid-to-late 1980s. Because the ANT can objectively and accurately describe the method of collective action of human beings, it is often used as an analytical tool for organization and social governance problems. It highlights the importance of a "network" consisting of multiple "actors" in solving complex and dynamic social issues. Pels (1996) argues that the most attractive aspect of actor-network theory is that it accepts the agency of each actor [40]. The main feature of the ANT is that each actor in the network node can play a role, and its essence is cooperation and openness. ANT focuses on actors whose power originates from their operations [41]. "Actor", "Heterogeneous network" and "Translation" are three core parts of the ANT. According to Callon's (1986) actor-network theory, actors can be either "human actors", or "non-human actors" such as institutions, ideas and technologies [37]. Any factor that is related to the system or contributes to its change is called an actor. These "non-human actors" are both an important part of the actor network and the "glue" that links other heterogeneous networks [42]. Translation is a process of interpreting all actors' interests and converting them into a consistent goal, based on which the role of each actor in the actor network is defined, namely a process of transforming actor attributes. Specifically, the translation process includes four basic parts: problematization, interest, enrolment and mobilization [8]. The above steps do not occur one after another, but repeat randomly. A "problem" can be understood as a gap or contradiction between reality (what it is) and the ideal (what it should be) that needs to be solved by actions now or in the future. Presenting the "problem" is the first step to be determined in the translation phase of ecological management. Therefore, how to recognize the problem should be first addressed by the key actors. Using the tram case, Callon analyzed the "translational" mechanisms that link human and non-human actors and sustain the network of actors. He also pointed out that translation is a way for both human and non-human actors to interact with each other [43]. All actors are in the process of translating and being translated until they pass the "obligatory passage points (OPP)". Once some actors in the translation process do not trust the OPP, the actors will exit the network and the connection may break down. This is called "dissidence". The key actor needs to notice the dissidence of the heterogeneous actors in a timely manner, remove it and retranslate it. According to Latour, an actor network is a description of a connection method, rather than a physical or technical network, such as the internet [37]. Latour also defined that "any actor is an escaper, not an intermediary, and any information and conditions will be transformed by the actor". This definition is emphasized by Czarniawska [44].

In the actor-network, each heterogeneous actor has its own "problem" or "obstacle", and in the process of translation they will have single or multiple "problems", thus creating multiple "objections". Dissenting actors will respond differently to close the gap in the "problem"; if the gap cannot be closed and key actors cannot identify the cause of the gap and eliminate the "objection" in time, the actor-network will be in an unstable state of complete collapse or on the edge of collapse because some heterogeneous actors realize that their interests or goals cannot be achieved. A heterogeneous network is a network of actors, each of whom is a node, that together form a seamless network. In this network, each node is a subject or an actor with equal footing. As can be seen, the three core concepts in ANT are independent but also connected to each other. Actors and networks are linked and extended by means of the translation.

As a national key project of environment management, ecological restoration requires the cooperation of multiple governance actors, not only between humans, but also between heterogeneous actors of human and natural elements. Therefore, unlike theories that focus

on human behavior, such as stakeholder theory, game theory and the opportunity cost approach, ANT focuses on non-human actors such as water, soil and air. The concept of a "network" in ANT is used to describe the dynamic relationship between human and non-human actors, which is a combination for actors to share information and coordinate their actions [45]. From this perspective, humans are no longer the only subject of ecological governance, and focusing on natural elements will make us reconsider the relationship between humans and nature. There are no predefined rules for a network, and only by following the actors can a network be drawn. From the analysis of "actors" and "networks", it is clear that ANT focuses on experience description rather than explanation [46]. This helps the concept of harmony between people and nature to be integrated into ecological restoration governance. On the other hand, environmental governance processes undergo cyclical changes and adjustments. However, ANT can track the changes in governance stages because it focuses on the linkages of heterogeneous actors in dynamic processes and analyzes the translation process of heterogeneous actors in different governance stages. In the ANT perspective, the actors cannot be interpreted by each other, nor can they be considered as unrelated. The relationship between them is a power relationship, a "translation" process of mutual influence. Here, "translation" is to clarify roles. It is only through "translation" that actors can be linked together as an actor network. Stable relationships are expected to be established between actors in the network [47].

The specific analysis process is shown in Figure 2. First, declare the main human and non-human actors and key actor involved in ecological governance. Second, analyze each heterogeneous actor's own problems (obstacles) and goals (interests). Third, establish an actor network and analyze the various translational aspects of the ecological restoration project. The key actors mobilize each heterogeneous actor successively and assign them interests, identities and responsibilities. The key actor takes strategic actions to remove the obstacles in the restoration process. Afterwards, the goals and interests among the heterogeneous actors are translated. Finally, the stability of the actor network and the problems in each stage of ecological restoration governance are judged. Suggestions are given by focusing on the analysis of the dissension process.

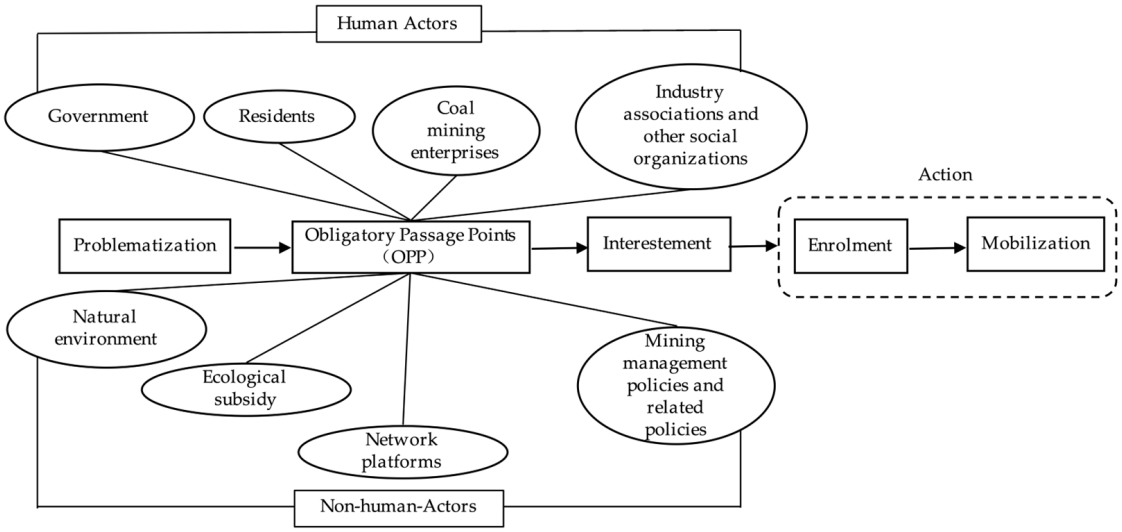

Figure 2. Actor-network analysis framework. Source: organized by the authors.

3. Selected Case and Data Sources

3.1. Selected Case

Huainan is located in the middle course of the Huaihe River, in the middle of the Anhui Province, between the longitude of 116°21′21″~117°11′59″ and the latitude of 32°32′45″~33°0′24″. Huainan is a new energy base city in China and is very rich in coal resources, being one of the 14-billion-ton coal bases in China. It is also an important coal-

grain composite area in China. As a traditional coal city in China, the problems involved in the ecological restoration of Huainan are representative to some extent. Since the 1960s, frequent mining of coal resources has brought serious damage to the geological landscape and ecological environment, which has affected the development of the city. The most serious problem is the large area of ground collapse caused by coal mining (coal subsidence area). Studies have shown that mining millions of tons of coal will result in 0.03–0.05 km^2 of sinking land and relocation of one village [48]. Villagers in mining areas gradually lose their arable land and houses, and are forced to become "landless farmers", a special group with "no land and no houses". In such a case, the land subsidence not only destroys the soil directly, but also causes new arable land to be occupied by villages that are forced to resettle. This poses a threat to "the red line of 3 billion acres of arable land" in China, and also seriously damages the regional infrastructure and ecological environment. In Huainan, there are subsidence areas in 30 towns and 623 villages. The coal mining subsidence area covers about 176 km^2, of which arable land accounts for about 141 km^2. There is a large waterlogged area of about 2.78 km^2 in L Coal Mine due to land subsidence after coal mining (see Figure 3). Before ecological restoration and its closure, L Coal Mine had an annual production rate of 90,000 tons per year.

Figure 3. Ecological environment status of subsidence area. (**a**) Current situation of subsidence water; (**b**) a road caused by subsidence; (**c**) farmland irrigation before restoration; (**d**) farmland irrigation after restoration. Source: Figures are from the studied coal mining enterprise.

In this paper, the L Coal Mine in Huainan is selected to study the ecological management of mine subsidence areas for the following reasons. (1) Although it is required that ecological restoration should be carried out in parallel with mining activities, many treatment projects can only be started when the mine area has entered the stabilization stage, since mines are initially not stable. According to the Evaluation Report on Mining Impact Stabilization (Institute of Mining Damage and Protection, China University of Mining and Technology, August 2017), the subsidence area of L Coal Mine was stabilized in 2019. This can provide suggestions for ecological management of closed mines in other areas. (2) Due

to years of mining activities, large areas of mining collapse and ground subsidence have occurred in the mine area. The coal mines in Huainan are all underground, as is the L Coal Mine. The occupation and destruction of land resources, as well as the collapse of mining areas have caused geological environmental problems in mines. The main types of destroyed land are arable land, pond surfaces and mining land. At the time of its closure, L Coal Mine had a total subsidence area of about 12.2 km^2, and the maximum subsidence depth is about 20 m. L Coal Mine is a representative area for ecological restoration and management of mining areas, and the problems involved in its management are somewhat general. (3) Coal mining enterprises have carried out a series of treatment projects for mining geological environment and land rehabilitation which have improved the arable land area of 3.88 km^2 and cost more than CNY 265 million. These treatment projects have yielded good results, making it possible to discuss their actor networks.

3.2. Data Sources

For the field research, we organized an interview with eight people from villages, the coal mine enterprise, and residents in June 2022. We chose village cadres as the government actor. As the heads of the related government departments did not accept an interview, we obtained information mainly from the official websites of corresponding departments. Our information also comes from policy documents, statistical yearbooks and internal reports of the coal mine enterprise. The authoritative sources of our research data ensure the reliability of our conclusions. Different information sources can also support each other. Here, the involved government departments include the Administrative Department of Environmental Protection, the Natural Resource Management Department and the Integrated Management Department. At the county level, there are approximately 20 departments responsible for mining activities. In our paper, the mentioned representative of the local government is village cadres.

4. Case Study: Actor Network in Ecological Restoration Management

4.1. Actor Identification and the Problem Statement

There are multiple actors involved in the ecological restoration and management of the mining area, as detailed in Table 1. Actor 1 is the municipal leadership group for ecological treatment of coal mining subsidence areas and is the first key actor in the network. The "leadership group" is a political organization with Chinese characteristics, usually led by a person or department at a higher level of power, uniting multiple departments and pooling political resources [49]. Actor 1 is an example of the integration of organization, policy and platform, which is essentially a government actor role. The establishment of the leadership group can focus on handling the major issues. It has an important role in top-level leadership and coordination, and has unparalleled superiority in complex issues [50]. It makes the appearance of an actor-network possible. In China, the fragmented design of environmental governance functions has created a dilemma where government departments make decisions individually and without collaboration. For example, the administrative department of environmental protection is responsible for overall supervision; resource management departments of land, forestry and water are in charge of environmental protection, meanwhile, integrated management departments of development and reform, finance, science and technology are sometimes involved in the environmental management of mining areas. This means that at least five departments have responsibilities. Each government at the county level and above establishes an average of about 20 functional departments. In this way, the environmental management functions of mining areas are distributed into dozens of government agencies. China's decentralized governance structure has provided poor incentives for environmental policy implementation and regulatory enforcement [51].

Table 1. Actors of the ecological restoration actor network.

Type	Category	Actor
Human actors	Individual	Mining area residents
	Organization/Group	Municipal leadership group for ecological treatment of coal mining subsidence areas; coal mining enterprises; news media; industry associations and other social organizations
Non-human actors	Traditional pattern	Natural environment; ecological subsidy; mining management policies and related policies
	New pattern	Weibo; WeChat, Circle of Friends, BBS, and other network platforms

Ecological restoration and management projects require a large number of human resources and supporting funds. The establishment of a municipal leadership group in Huainan allows for the mobilization of resources and the organization of other actors to take action, constituting an existing actor at the governmental level (see Figure 4). The mining ecosystem is typically a public good that can lead to "free-rider" behavior, whereby other actors who are not involved in the treatment will also benefit from the restored mining ecosystem. Government actors need to be proactive in finding "problems". For example, regarding the compensation policy for land subsidence in mining areas, by levying mineral resource taxes and ecological compensation fees, government actors can effectively raise funds for ecological compensation. Mining tax has become an important policy in most countries around the world to address ecological damage by mineral resource development [52].

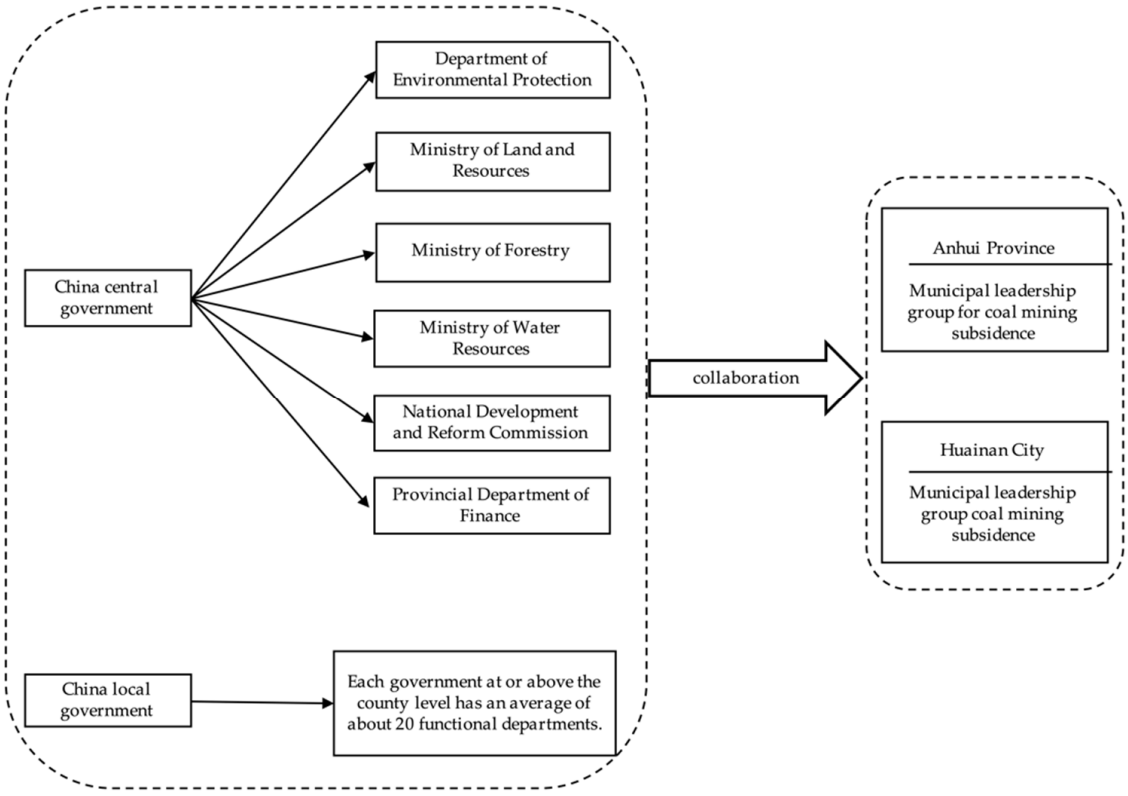

Figure 4. A network of government actors in ecological restoration of subsidence area. Source: Organized by the authors.

Actor 2 is coal mining enterprises. As the main body directly to blame for the environmental damage for profit, its attitude largely determines the effectiveness of environmental protection in mining areas. Because ecological restoration projects require large amounts of money, the government budget alone is totally insufficient, and thus additional sources of financing are essential. As the first key actor, the government needs to initially find the mining enterprise as the second key actor. Based on the principle of "who benefits, who treats", the mining enterprises are responsible for most of the environmental treatment costs of the whole subsidence area, which reduces the government's financial burden. However, enterprises usually consider their own economic interests first, and it is questionable whether they can consider the public interests. There is also a reality: the Chinese government's "de-capitalization" policy for the energy sector has caused some mining companies to lose revenue. In the meantime, their revenues fluctuate with the price of coal and are therefore unstable. Many coal mining companies are insolvent and cannot afford the responsibility of dealing with the subsidence problem.

Actor 3 is residents of the mining area. As direct victims of ecological pollution, mine residents play an important role in monitoring policy implementation, timely reports of environmental violations in mines and restraint of mining enterprises' pollution behavior. Through interviews in the resettlement villages of mine residents, we learned that mine residents are generally less educated and less motivated to participate in environmental protection. This has resulted in a general lack of their understanding of environmental protection policies in mining areas, and the governance project has become difficult to promote in practice.

Actor 4 is a social actor, such as an industry association. The role it can play in environmental protection in mining areas cannot be underestimated, but for this group of actors, there is also the problem of low motivation to participate. For example, industry associations and communities rarely organize public participation in community life.

Actor 5 is the policies of environmental management and land rehabilitation in mining areas. In terms of existing laws, the Environmental Protection Law, Soil and Water Conservation Law, Solid Waste Pollution Prevention and Control Law, Mineral Resources Law, Coal Law and Land Management Law, which are at the same legal level, provide regulations on environmental issues in mining areas from different perspectives. For example, the Mineral Resources Law, as one of the core laws regarding the environmental management of mining areas, establishes the basic system of mineral resources exploration and exploitation. However, the law focuses on the development and utilization of mineral resources, and only a few clauses provide principal provisions for environmental protection in the development of mineral resources. It is clear that the environmental protection laws for mining areas are either too general, not comprehensive enough or contradictory, making it difficult to ensure mandatory enforcement of the law.

Actor 6 is the natural environment. The mining area is flat and its main part is arable land. The human activities there are mainly agricultural production, consisting mainly of planting and farming. Due to the impact of coal mining subsidence and farming, there is little natural vegetation cover and the village has consequently been relocated collectively to resettlement villages.

It is worth noting that with the development of internet technology, social media such as microblogs, WeChat and forums provide new communication platforms for social forces to participate in environmental governance. They can be seen as Actor 7. Traditionally, rural residents only learn about ecological management policies through village cadres or their neighbors. This limits the effectiveness of their participation in ecological management and sometimes even their voice. Therefore, digital platforms, as one of the new non-human actors (e.g., TikTok and WeChat), can provide an effective way for rural residents to better understand policies of ecological management. As also reported by Kostka et al., due to the Chinese government's tighter control over civil society organizations, individual citizen-based participation in environmental governance is more welcomed by local governments [53]. In this case, individuals can objectively play a greater role in ecological

governance with the help of digital platforms. These new non-human actors, to some extent, have accelerated environmental management change.

With the formation and stabilization of the actor network for managing the ecological environment, the ecological governance union is built. The action phase can only begin when the problems in ecological management are clearly determined. The municipal leadership group for ecological management of coal mining subsidence areas is a key actor. It works with other actors to carry out ecological management of the L Coal Mine subsidence area, focusing on a joint OPP, which enables each actor to obtain predictable benefits (see Figure 5).

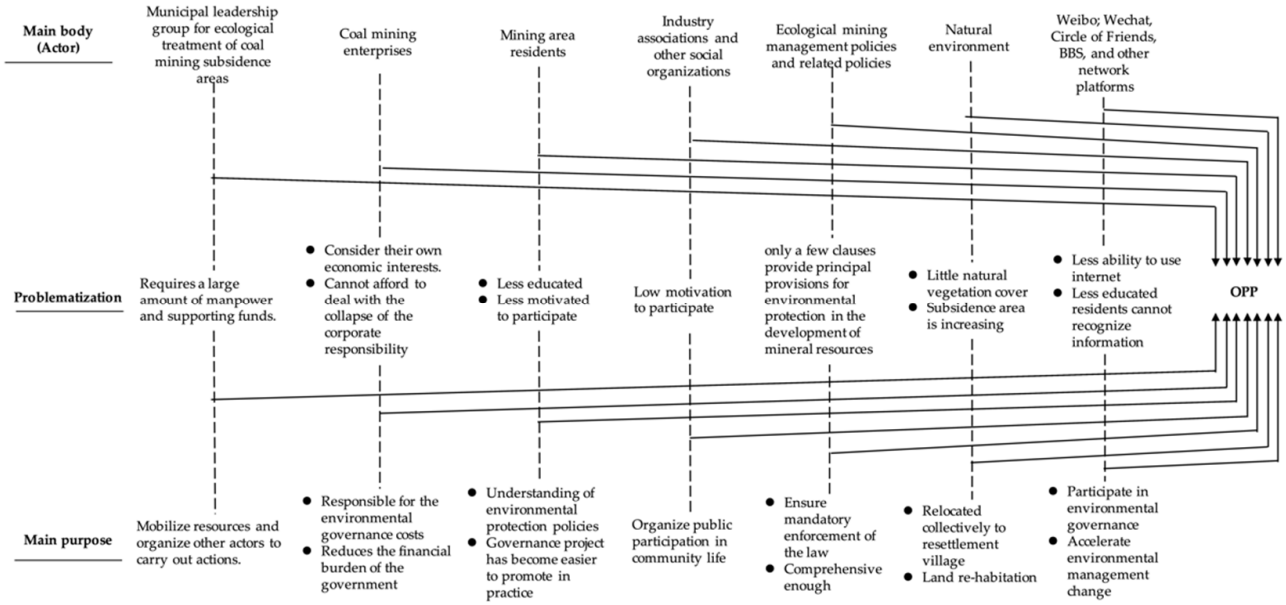

Figure 5. Problems, purposes and OPP of various actors: Participation in governance. Source: Organized by the authors.

4.2. Interest Satisfaction and Mobilization by Enrolment

As interests are the main driving force for actors to group together, it is important to fully understand the interests of each actor and the existing obstacles. At this stage, various strategies should be used to maintain the stability of actors' roles and to form a good cooperation mode of interests. When economic interests conflict with ecological interests, public interests' conflict with private interests and individual interests' conflict with overall interests, the "coordination of interests" will become a problem in the ecological governance. Therefore, we need to pay attention to how to fulfill the demanded interest, and how to share the cost of governance by various subjects.

In recent years, China has been putting forward high requirements for the environmental management of mining areas. In particular, the reduction of arable land caused by the subsidence of mining areas has been of high concern. In order to reduce the management process and to improve efficiency, the land authority has started a reform that requires mining enterprises to combine the "Mine Geological Environmental Protection and Rehabilitation Program" and "Land Rehabilitation Program" (referred to as "two programs" below). The government cares about communication with state-owned enterprise (SOE) and is willing to imply compensation benefits [33]. In this case, the mining companies are asked to complete the requirements of this program (e.g., land rehabilitation or relocation compensation). In return, local officials will cooperate in the interests of the company by granting compensatory benefits of land and other funds, and enterprise managers are offered opportunities with economic and political interests, which vary according to enterprise ownership. These benefit exchanges would not appear in policy documents. When the public interests' conflict with the enterprises' private interests, local governments

can punish enterprises using a common policy referred to as "cut water cut electricity" [33]. However, in this case, the government cannot do the same, because coal mining companies need to be running all year round, even during an epidemic. Our field research has shown that when interests conflict, the most common means of a government to restrain companies is through environmental policies or by pressuring banks to slow down loans to mining enterprises. The official procedure diagram has only six steps, as shown in Figure 6. Although the "two programs" have been merged, the first step requires the coordination of multiple management departments and the coordination of interests between local governments, mining enterprises and society. If the local governments' interests are not well balanced, the rational choice of the local governments will easily lead to the "prisoner's dilemma" in the joint management of ecological and environmental problems.

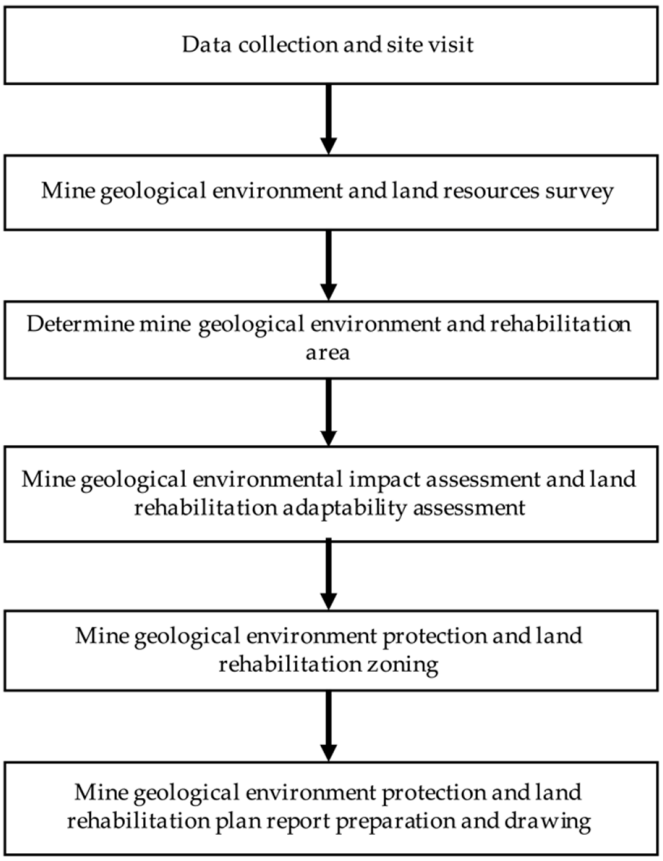

Figure 6. Program diagram of mine geological environment protection and land rehabilitation scheme. Source: Guidelines for Preparation of Mine Geological Environment Protection and Land Rehabilitation Plan, Ministry of Land and Resources of the People's Republic of China, December 2016.

The recruitment phase is mainly to find suitable actors for the alliance of ecological restoration and governance. Only by rigorous selection and recruitment, and by choosing the right coalition among the actor elements, can we ensure that future actions will be fast, accurate and complete. The municipal leadership group of the ecological management project has adopted a series of administrative conscription strategies. This is mainly for the compensation of arable land and resettlement of farmers who lost their land in the subsidence area due to the ecological restoration treatment. According to the Land Management Law of the People's Republic of China, Notice on the Announcement of the Comprehensive Land Price Standard for the Acquired Area of the Anhui Province, there are detailed official regulations on compensation for residents of coal mining areas. Farmers receive compensation for house collapse and crop seeding costs from mining enterprises after land subsidence. The compensation of crop seedling is CNY 1800 per year.

In our field research, we found that after losing farmland, each household only receives compensation of CNY 3000 to 5000 per year. This makes their livelihood insecure, and they showed dissatisfaction. However, what is interesting is that it is not the "loss of arable land" that the public is dissatisfied with, but the low compensation. Thus, it is evident that the dependence of traditional Chinese farmers on the land is decreasing. However, the question of whether it is limited only to the residents around the mining area still requires a follow-up study.

The resettled villages in the subsidence area of L Coal Mine involve 11 administrative villages. These villages are to be relocated to four communities. This shows that there are a large number of affected residents, and the task is difficult. As the relocation mode in recent years is collective moving, most of the residents need to be relocated off-site. The resettlement progress is affected by the long time taken for the submission and approval of relocation sites. Field research found that many residents in the subsidence area need to rent a room first with the compensation money, and then wait for the resettlement community. In the actual resettlement process, it is difficult to resettle local residents prior to ecological treatment. In contrast, resettlement of landless residents is the last step after land subsidence and land loss has occurred.

4.3. Actor Potential Disagreement and Dissipation

The impact of ecological pollution in mining areas is extensive and long-lasting, which makes its management an extremely complex project. Therefore, it often requires a large amount of investment and has slow effectiveness. Multiple governance actors, such as government representatives, coal mining enterprises and society, have different interests and value preferences, which lead to different governance "behavior combinations" and disagreements between the actors. For example, driven by economic interests, local governments tend to use their information advantage to make "adverse choices", i.e., to focus more on the short-term goal of rapid economic growth than on the long-term goal of good environmental governance. This is particularly common under the "GDP top-priority" incentive mechanism of government performance assessment. Actor network has a respect for the rights of social subjects [54]. In other words, the actors are their own spokespersons and are able to bring each governance subject of the network nodes into the "governance field". The heterogeneous network is then a useful tool that describes the linking process between the actors as well as the actual operation of the network, allowing the actors in the network to frequently discuss problems. The ecological management project of mining subsidence area is also similar, which is carried out under the cooperation and supervision of each actor.

The detailed flow chart of the project is shown in Figure 7. It is also not difficult to see that the design, implementation and final examination of the project did not involve the residents around the mining area, and that social capital was not sufficiently involved. This may be the reason why residents have doubts about whether the treatment project has expropriated the arable land afterwards. When searching for "subsidence area management" on the Huainan government official website, we found that many complaints were related to the expropriation of the arable land. Of course, the general concern of the public is neither the progress of land rehabilitation nor the obsession with the land, but still the policy related to seedling compensation fee. As the area of subsidence increases year by year, the coal mining enterprises need to pay increasing amounts of seedling fees to the residents. In the current situation of severe economic downturn of coal, if coal mining enterprises cannot pay the seedling fee in time, it will inevitably lead to major social problems and safety risks.

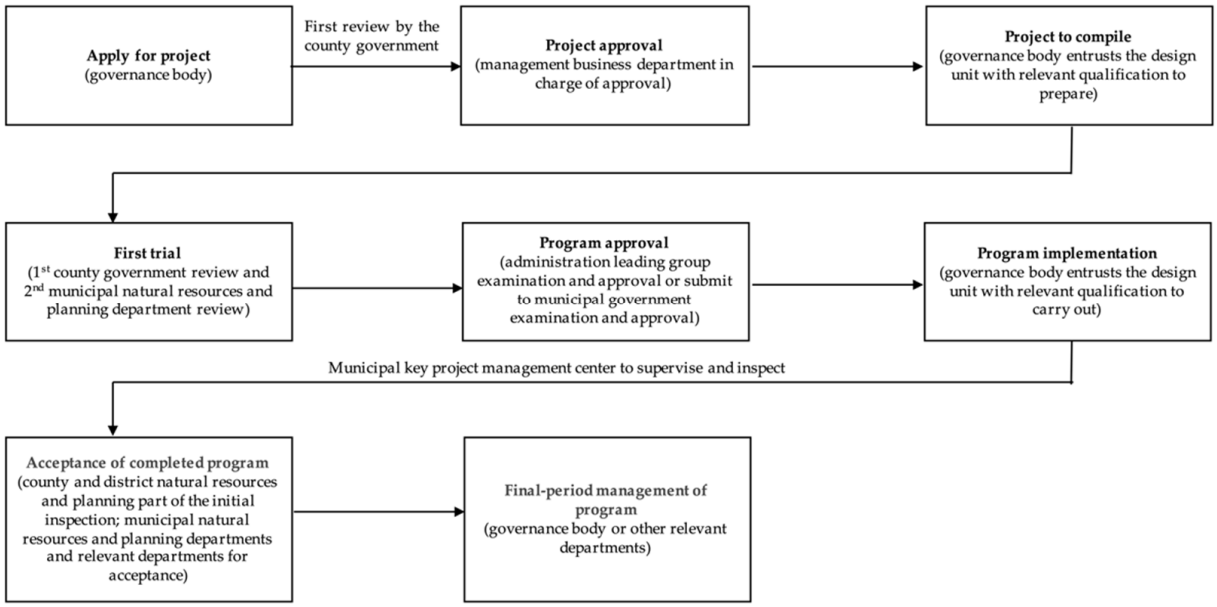

Figure 7. Flow chart of construction of ecological restoration and control project in subsidence area. Source: Organized by the authors according to research data.

5. Benefits after Ecological Restoration of L Coal Mine

The ecological restoration of the L Coal Mine is based on the following principles: "people-oriented, site-specific, minimizing new damage, and comprehensive management". In this process, the municipal leadership group for ecological restoration and governance is the key actor. It relies on coal mining enterprises to enlist, mobilize and exclude dissent from human actors (e.g., town governments, village committees, mining villagers) and non-human actors (e.g., natural environment, land and environmental policies). The heterogeneous actors are mutually embedded and interact with each other, forming a relatively stable complex heterogeneous actor network. Through the implementation of the ecological restoration project, the function of damaged land in the coal mining subsidence will be restored, the topographic landscape will be improved, and valuable arable land and woodland resources will be acquired. These improvements can promote the sustainable development of local economy and society, and are in line with the overall plan of the city. From the perspective of the actor network, sustainable development in mining areas is supported by government policies, village committees and green industries.

(1) Social benefits

The ecological restoration project is in line with China's basic state policy on "population, resources and environment". It is also of great significance for resource-based cities to promote the construction of a resource-saving and environment-friendly society. After restoring its land function, the sustainable development of the mining area will be enhanced through land rehabilitation. The development and construction of the ecological restoration project will help optimize the allocation of local resources. The rehabilitation project will, to a certain extent, solve the unemployment of the remaining labor force. Meanwhile, the local district government holds recruitment sessions exclusively for residents of coal mining subsidence areas, building a two-way exchange platform and making it possible for landless farmers to find a job. After the residents of the subsidence area have been moved into the community via the resettlement project, it will be easier to carry out assistance services for the elderly low-income group, and free medical examinations and haircut services for the elderly group. The community can also improve the construction of rural leisure and fitness points. For details of specific livelihood projects, please refer to Table 2.

(2) Economic benefits

Table 2. Year 2020 people's livelihood projects involved in L Coal Mine ecological restoration.

No.	Project Name	Details
1	Rural toilets and waste resources utilization	• 30 toilets were upgraded.
2	Promotion of employment and entrepreneurship	• Create 340 public welfare jobs; • Provide employment services; • Implement relevant subsidy.
3	Skills training and upgrading	• Skills poverty alleviation training; • Pre-job skills training for new employees of enterprises; • Systematic training for new technicians
4	Minimum living allowance for rural residents	• Dynamic management • Ensure the basic living standards
5	Basic medical insurance for urban and rural residents	• Improve the unified basic medical insurance system for non-working urban and rural residents; • Participation rate of basic medical insurance for urban and rural residents shall be above 95%; • Implement the financing policy; • Deepen reform of medical insurance payment methods; • In 2021, the individual contribution of medical insurance for urban and rural residents will be raised to 280 RMB. • By 2020 November 27, 93.58% of urban and rural residents had participated in basic medical insurance.
6	Shantytowns transformation & Renovation of old residential areas	• Reconstruction of run-down urban areas was started per unit, and 932 units were basically completed. • 14 old residential areas in cities and towns were renovated, with a floor area of 91,300 square meters, involving 1,536 households.

Source: The author organizes the information according to the official website of Huainan government.

After the implementation of the ecological restoration project, 169,554.40 m^2 of arable land and 2204.41 m^2 of forest land were increased. The economic benefits after the project implementation are directly manifested in the arable land. The local crops in Huainan are "rice-wheat", which are harvested twice a year. The annual income from the new arable land is CNY 635,800, showing good economic benefits. At the same time, the implementation of the mine geological environment management project also has great indirect potential economic benefits. The waters in the area are capable for large scale aquaculture (see Figure 8), including fish, shrimp and crab, and poultry. This is an important income source for local people.

(a) (b)

Figure 8. After restoration of the water area. (**a**) The land was converted into fish ponds after subsidence; (**b**) the subsidence area can be restored for raising geese. Source: Figures are from the studied coal mining enterprise.

The government also focuses on the economic benefits of non-agricultural production. The electricity company of the coal mining enterprise pioneered the construction of a photovoltaic power generation in 2016. The project has a total investment of CNY 146 million. After completion, it is expected to have a cumulative power capacity of 446,162 MW over a 25-year life span. It is the first photovoltaic power generation project built on the abandoned site of coal mining subsidence. In the L Coal Mine subsidence area, another wind energy project was built in 2017, with a total investment of CNY 800 million, an estimated total capacity of 100,000 kilowatts and a planning area of about 300 acres. All the above are of great significance to discover new ways of comprehensive utilization of resources in subsidence areas and promote the transformation of resource-based cities.

(3) Ecological benefits

The damaged land function in the coal mining subsidence area is restored and valuable arable land resources are obtained. At the same time, the vegetation coverage rate is increased and the air is purified. It greatly improves the environmental quality in and around the coal mining subsidence area, which creates good conditions for future development. The subsidence land can be reclaimed, developed for rural tourism, and restored into an ecological park, etc. (see in Figure 9).

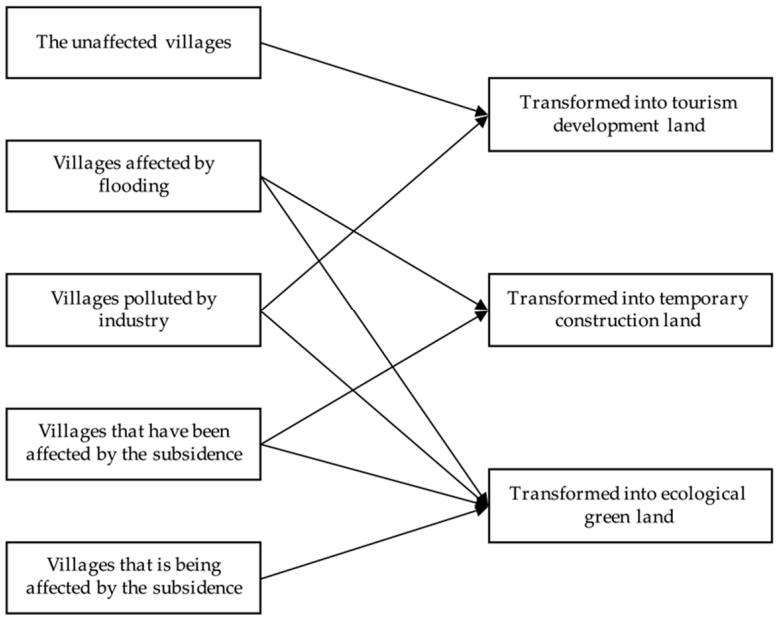

Figure 9. Land use pattern in coal mining subsidence area. Source: "Conceptual Planning for Ecological Governance of Coal Mining Subsidence Area in Western Huainan City".

6. Discussion and Policy Suggestion

6.1. Discussion

Studies on L Coal Mine show that due to difficult political tasks of environmental treatment in the subsidence area, the large number of participating subjects and the complex interests, it is difficult for the local government to balance people's well-being and the economy. The unique feature of ANT is that it highlights the agency of actors (human and non-human) in science formation [55]. In this study, the leadership team, as the "key actor", needs to acknowledge the people's environmental interests, and guide the social forces through "moderate regulation" to express their demands in a procedural way. As one of the founders of the actor network theory, Callon (1984) believes that "forming an alliance with us you will have more opportunities to get what you want" [38]. Non-human actors are involved in technology transfer, mediating benefit allocation, and technology itself even becomes a stakeholder. Meanwhile, key actors should use policies to engage social, economic and political groups of both human and non-human actors to participate in ecological governance. Popular policy includes permits, licenses and best available technology [53]. Once actors know their own interests, the interests of the participants should be "bundled" to build a joint community. From the perspective of ANT, benefit allocation is the effect of a network composed of interest declaration and interest negotiation [46]. The ecological restoration project in the subsidence area of L Coal Mine reveals that the participation of the residents is insufficient. The resettlement in the project is one of the major complaints of the public. Dissatisfaction in translation through "uncultivated" anger and violent confrontation is often because there is no way to protect their own interests, thus seriously disturbing the social order. In order to reduce resettlement costs, municipal governments usually plan and build large resettled communities in the distant suburbs of the city. However, once the poor families in the collapsed area are marginalized and centralized, there will be a combination of social disadvantage and spatial disadvantage, referred to as "social space disadvantages" [56]. This tends to lead to the continuation and the transmission of poverty from one generation to another, and will have a negative impact on the spatial balance and sustainable development of urban society. Few livelihood-related policies in ecological governance (more detail in Table 2) have been carried out. The landless mining residents can enjoy the welfare of urban development. ANT focuses on actors whose power originates from their operations [41] so key actors have more control over governance and can better achieve ecological restoration.

6.2. Policy Suggestion

Ecological restoration is an important guarantee to guard the safety boundary of natural ecology and promote the overall quality of natural ecosystems. China has a large historical environmental problem in mining areas. Despite some achievements, ecological restoration is still in great demand, and the following recommendations are made.

(1) Further improve the legal system

The height and seriousness of the law requires that enterprises must be responsible for the environmental impact of the mining, adhere to the "protection first, systematic restoration" rule, and establish an awareness of "restoring the environment after development". It is necessary to strictly approve mining, increase the content of mine land rehabilitation, and clearly define the responsibilities and obligations of the central and local governments and the mine enterprises. Establishing and improving the legal system of mine environmental protection is also a necessity to protect China's ecological environment and realize the sustainable development of its mining industry.

(2) Building a governance system with multiple subjects and collaborative participation

The path of eco-environmental governance relying solely on the government should be changed, and a governance pattern of collaborative participation by multiple actors should be explored and established. As beneficiaries of environmental governance, residents of mining areas should actively participate in activities of ecological and environmental

protection. For example, they should enhance environmental protection awareness and understand their responsibilities and obligations in rural environmental governance. Further, they are encouraged to participate in various ecological restoration activities and thus provide better suggestions for rural environmental improvement. If they can fully understand their rights and government policies, they can avoid some irrational "uncultivated" antagonism. Meanwhile, environmental organizations initiated by the government, private volunteers and various student associations, respectively, are all important contributors to rural ecological and environmental governance. Various grass-roots public welfare organizations and social capital have an important role in environmental protection publicity and education, participating in environmental governance and carrying out environmental protection supervision. To build a governance mode of collaborative participation by multiple subjects, it is not only necessary to establish multiple subjects on an equal footing, but also to clarify the responsibilities and boundaries of various subjects. It is important to focus on the collaboration of the environmental governance community.

To reach their scientific action goals and successfully treat a project, decision makers must know how to translate their interests into others' interests and simplify complex problems. This facilitates the enrollment of members, and engages them in common actions, building a committed coalition.

(3) To reasonably resettle residents in subsidence areas and pay attention to their mental health

Optimize the demolition compensation and resettlement policy for residents in subsidence areas. For example, the scope and standard of compensation for demolition and relocation should be raised for low-income groups with no jobs and no working ability. New models of housing supply such as "shared ownership" and "rental and sale" should be explored to relieve the economic pressure of poor groups. Meanwhile, the mental health and social issues of the resettled residents need to be addressed. This includes both the psychological change of "losing farmland" and the unwillingness to leave the old house. If not handled properly, it will easily lead to various social problems. In order to solve these problems, on the one hand, resettlement needs to be as close to their homes as possible. It is important to avoid building large resettlement communities in areas that are seriously lacking urban support facilities and which are far from employment centers. This reflects the concept of not only "building new houses" but also "creating new life". The quality supply of external transportation, hospitals, schools, banks, grocery stores and other residential facilities needs to be guaranteed so as to enhance the residents' happiness and sense of ownership. On the other hand, it is necessary for the government and voluntary organizations to carry out communication, dialogue and consultation work. The government needs to sufficiently listen to people's voices, investigate public sentiment, and through sample surveys and visits, effectively understand the social problems of moving-in residents, coordinate and resolve social conflicts, maintain social security and local stability. These measures can greatly enhance residents' sense of security.

7. Conclusions

For the transformation of resource-based cities and the construction of ecological civilization, ecological environmental treatment is urgent and necessary. The ecological management strategy of subsidence areas is clearly demonstrated by the decision makers. Although land rehabilitation has achieved some success, it is more of a government-oriented act to manage the ecological environment of mining areas. This is due to the fact that coal mining inevitably causes subsidence, but mining enterprises are less aware of protecting the ecological environment based on profit considerations. Government as a key actor should use policies to engage social, economic, and political groups of both human and non-human actors to participate in ecological governance. The important step is "translation", through which interests of the participants could be "bundled" to build a network. It is evident that ecological environment management is not only an engineering and technical task, but also the result of the participation by people and objects together. It is a collective and co-constructive behavior, where the benefits and responsibilities that come with coal mining

are shared. Human and non-human actors need to work together to make a scientific governance strategy for the benefit of humanity. The municipal leadership group needs to maintain good cooperation with social forces and thus maintain the stability of social order. Only by incorporating public participation into the existing system and regulating the rights with power in a reasonable, legal and appropriate manner can we promote the orderly public participation and thus improve the performance of environmental governance.

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