Research of mining wasteland reclamation and regeneration modes in Shendong Mining Region

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Abstract. Mining resource is one of essential fundamental energy resources in China. In recent years, mining exploitation activities have been more frequently, which plays an important role in protecting the economic and social development of mining areas. However, it has led to severely destroyed land resources and environmental pollution. Considerable amount of mining wastelands have been appearing accordingly. Therefore, it is necessary to reclaim the mining wastelands and do the regeneration project. In the study, Shendong Mining Region across Shaanxi Shenmu and Inner Mongolia Erdos is the research site. The paper discussed the ecological restoration engineering measures suitable for the landform reconstruction, soil improvement, vegetation restoration and ecological restoration of the abandoned mining areas in Shendong Mining. Three new modes of development and utilization, including ecological agriculture model, construction land mode and mine park model, are proposed in order to rehabilitate the land resource and make a reference to the economic, social and ecological sustainable development in Shendong Mining Region.

1. Introduction
As one of the basic energy sources for the development of the national economy, the coal industry is an important part of the industrial and agricultural production and the social and economic development [1-2]. According to statistics, more than 95% of the basic energy, 80% of the industrial raw materials and 70% of the raw materials of agricultural production come from the coal industry. The importance of the coal industry is evident [3]. Since the 1980s, the coal industry and other heavy industry has been unprecedented prosperity, but sustained high intensity mining activities caused serious damage to the land (such as surface subsidence, solid waste pollution, geological disasters) and destruction of natural environment (soil pollution, water pollution, air pollution, etc.). Even if the mining operation is over, the destruction of the large area of the land in the mining area still exists.

The development history of the developed countries in the world (including Britain and Germany) has also experienced similar “industrial diseases". Through land consolidation and reclamation, the land that has been polluted and destroyed can rejuvenate the vitality [4-5]. In order to reduce the environmental pollution and protect the ecology of the mining area, many mining areas in China have carried out the land renovation and reclamation work [6-8]. With the development of social economy in Shendong mining area, the demand for construction land is increasing gradually. Actively promoting the abandoned mining land reclamation, improving the local natural and ecological conditions can improve the social, economic and ecological benefits at the same time, and provide protection for the local intensive and efficient and sustainable land resources [9-10].

2. The general situation of the research area and the land use status

2.1. Socioeconomic and natural conditions

Shendong mining area operated by China Coal Enterprises - Shenhua Group, Shenhua Group reached 23 billion 605 million yuan of commercial coal sales revenue in 2009, and its revenues increased significantly to 2013. Shendong mining area as a core area of Shenhua coal industry, there are total reserves of about 200 billion tons of coal resources. It is regarded as one of the eight coal field of the world [11-12]. Shendong mining area built coal production base in the first hundred million tons of modern large, and it included 19 high-yield and high efficiency coal mines, the annual production capacity of is over 2 tons, and the production capacity ranks the first in China [13-14]. With the development and construction of Shendong mining area, it greatly promoted the rapid development of the regional economy, and Shenmu and Yijinhuoluo have become the fastest growing economy in the county, and made great contribution to national economic development.

Shendong mining area is located in border area of the northwest area of Yulin city in Shaanxi Province and the southern Ordos of the Inner Mongolia Autonomous Region City (Figure 1), located in the complex transition zone of the Loess Plateau, Inner Mongolia grassland and the Mu Us Sandland. It is located in the east longitude 109 degrees 30 '30" to 38 degrees north latitude 30 '32 ", above 1000 m [15]. The geomorphic units is the Loess Hilly and gully region, parts of the surface is mostly covered by the quaternary wind sand and sandy loess; It is semi-arid continental monsoon climate, and the annual rainfall is 402.7 mm, however, evaporation is as high as 1753.8 mm–1978.7 mm, and wind erosion and water erosion are very strong [16,17]. Because of the effects of climate and sand area with sparse vegetation, drought tolerance and drought Psammophyte plants mainly showed
sparse shrub vegetation landscape; regional ecological environment is very fragile, so it is the national key water and soil erosion monitoring area.

![Figure 1. Geological location map of Shendong Mining Region.](image)

2.2. Situation of reclamation project area

Shendong mining area contains large amounts of high quality coal, and it is shallow burial. After the coal mining, it is easy to form the ground collapse pit [18]. With the increase of coal mining intensity, the goaf gradually becomes larger and more, and the collapse is gradually expanded, and a large number of cracks [19] are developed around it. The large-scale exploitation of coal resources not only destroyed the original topography, landforms and natural landscapes, but also left barren mining fields, tailings and collapsed goaf and waste rock sites. In the large coal mine area of Dalinta mining in Shenmu County, the surface area of the goaf and subsidence area is seriously deformed. The surface cracks are as wide as 2m, and the longitudinal depth is 10–18m. The overall subsidence of some parts of the area is 2 to 3m, and the maximum collapse depth is tens of meters [20-21], as shown in Figure 2.

![Figure 2. Surface collapse fracture and desert sandy land.](image)

On the other hand, with the large-scale exploitation of the mining area and the widespread disturbance of the surface, the vegetation has been severely damaged, and the accumulation of the waste residue has reached 68 million 580 thousand tons, and the land desertification has intensified.
Due to the shallow coal seam in the mining area, the drainage and mining caused by artificial draining and groundwater cause a large and large scale decline of groundwater. The water supply of farmland is insufficient, and the surface vegetation is withered. At the same time, the discharge of coal chemical wastewater has seriously polluted the water resources. See Figures 3 and 4 in detail.

![Figure 3](image1.png)  ![Figure 4](image2.png)

**Figure 3.** Scarce plants and destroyed grassland.

**Figure 4.** Polluted water from industrial and mining sites.

3. **Theory and method of ecological restoration of mine wasteland**

3.1. *Basic principles of land reclamation and ecological restoration*

According to the law of mineral resources, there are complete plans for waste disposal and land ecological restoration and corresponding technical measures and evaluation indicators after mining or mining activities. Land reclamation is taking remedial measures for the production and construction activities and land damaged by natural disasters, to restore to the desired state of available activities, and its purpose is to restore the ecological balance of land use, recycling, the production and construction for the healthy development of the land resources at the same time, and also protect the land resources and make it sustainable [22-23].

Ecological restoration is a local ecosystem that restores the ecosystem destroyed by human disturbance and restored into biological diversity and dynamic balance. The essence is to restore or rebuild the damaged regional environment into an ecosystem that is compatible with the local nature. It includes [24] Re-vegetation, Reclamation and Reconstruction. Among them, the key to ecological
reconstruction is to restore the necessary structure and function of the ecosystem, so that it can be self-sustaining [25].

3.2. Objectives and principles of ecological restoration

Ecological restoration is an important measure to restore the natural ecological landscape and improve the regional environmental quality in the abandoned mines. The determination of ecological restoration targets is based on the [26] Physicochemical properties of discarded land, natural conditions and social needs. Physicochemical properties is based on the analysis of sampling and investigation, and topography, landforms and geological stability; natural conditions needs to consider the climate, landscape, flora; social needs to consider the subject of wasteland ecological restoration, environmental protection and economic development needs. The ecological restoration in the mining area follows the following basic principles:

(1) The principle of combination of qualitative and quantitative. Methods of combination of qualitative and quantitative evaluation is research on the comprehensive analysis of soil, climate, topography, biological and other natural factors and economic conditions, planting habits and other social factors, considering the extent of damage and the type of garden, and determine the direction of [27] mine ecological restoration reasonable.

(2) The principle adheres to local conditions. According to the different block failure characteristics, ecological environment conditions, it needs economic, reasonable and effective methods, and strictly control the exploitation of mineral resources in the mining area environment disturbance and damage to the protection and keep the utilization of the original vegetation and land reclamation, and minimize the affection of the development activities on the ecological environment [28].

4. Engineering measures for ecological restoration of abandoned in Shendong Mining Area

4.1. Landform remolding and soil improvement

The remodeling of landform and soil improvement in mining area is the basic project of ecological reconstruction in mining area. In Shendong mining, the first work is to open pit filling and soil leveling work. Filling and reclamation technology refers to the use of coal mining waste (such as fly ash and coal gangue, etc.) as filling material to repair the damaged land. Among them, burned coal gangue is a strong acid substance, which can neutralize the basic components of the soil, so it is used for filling agriculture and forestry reclamation. The unburned coal gangue can consolidate the foundation, and can build up the capital construction land [29]. Reclamation of fly ash is suitable for dry land. Its use is soil improvement, which can change soil texture, increase soil water holding capacity, improve soil pH value and increase soil fertility. The technology of reclamation and reclamation in wasteland of mining area is shown in Figure 5.

When filling the abandoned area land in Shendong mining reclamation, firstly complete stripping soil (the surface soil thickness of about 30cm and 30 ~ 60cm thick subsurface soil) needs to be taken, collected and placed in the designated area. Coal gangue and fly ash are used as filling materials in order to fill in open pit. According to the shape and size, the large coal gangue is arranged in the bottom layer, and the small pieces of coal gangue are loosely placed on the surface. After filling, the
spare soil is covered in the surface of reclamation area, and restores the physicochemical characteristics and nutritional status of the soil, to provide growth conditions for the reconstruction of vegetation in mining area.

**Figure 5.** The process of filling reclamation at the opencast mining area.

Soil improvement of Shendong mining wasteland include physical properties improvement, pH improvement and nutrition improvement and other aspects [30-31]. The goal of physical properties improvement is to increase soil porosity, reduce soil bulk density and improve soil structure. It can be used to plough, farmyard manure and other methods [32]. Soils with low pH value can be repeatedly applied to phosphate rock, controlling pH value over a long period of time, and acid soils with low pH value can use lime to regulate acidity, reducing soil pH and promoting microbial activity, and improving soil structure.

4.2. Restoration of vegetation and ecological reconstruction

The ecological environment is vulnerable in Shendong mining area. After exploitation of coal resources, environmental damage and ecological imbalance is more serious, therefore, the vegetation restoration and reconstruction of ecological engineering measures are necessary. Vegetation restoration is not only meant to plant crops on abandoned land, but to create a biological community [33], which is self-sustaining natural environment. Vegetation restoration and reconstruction projects, is the general to improve the site conditions through manual intervention, which can adapt to the biological characteristics of plants; the vegetation root has a fixed role, it can control soil erosion and soil evaporation in a certain extent, increase microbial activity and improve microclimate. Therefore, vegetation restoration has become an important means of reclamation of coal mine waste land and environmental protection measures [34].

The selection of plant species is very important in the initial stage of land reclamation and ecological restoration. Using the local crop varieties in the reclaimed area, planting such plants can quickly adapt to the growing environment of reclaimed land and can grow and reproduce well [35]. Based on the principles of restoration ecology, landscape ecology and vegetation community theory, the composition, structure and density of vegetation communities are designed to create suitable living space and avoid interspecific competition [36]. The simulation of natural vegetation structure of vegetation community structure, the implementation of mixed planting of deciduous trees, shrubs, using a small amount of soil with planting of evergreen trees in the soil ball transplant, herbaceous plants should be dipped in mud or soil mix seeding planting [37]. In addition, by distinguishing the advantages and disadvantages of the surface soil development in the mining area, we can cover a
certain thickness of soil, sludge and fly ash on the surface of the abandoned land, which will greatly improve the soil environment and facilitate plant growth.

In Shendong mining area, the loess slope is relatively slow, thick, rich in plant species, and vegetation types in loess area are *Cleistogenes squarrosum*, *Lespedeza*, *Astragalus*, *Thyme*, *Alfalfa*, *Sweet clover*; vegetation to desert shrub of *Artemisia ordosica* and *Yang Chai* as the dominant species associated with rice, insect, P. tricuspidata sand 1 to 2 years of herbaceous plants. According to the climate and soil in Shendong mining area, rainfall and other natural conditions and adjacent ecological geographical area of the vegetation, such as Table 1 preferred plant species and vegetation restoration.

**Table 1.** Plant species of re-vegetation at Shendong Mining Region.

|                | Sand area                    | loess area                   |
|----------------|------------------------------|------------------------------|
| **Trees**      | *Populus*                    | *Populus*                    |
|                | *Pinus sylvestris var. mongolica* | *Robinia pseudoacacia*       |
|                | *Pinus tabulaeformis carr*   | *Sophora japonica*           |
| **Shrubs**     | *Salix mongolica*            | *Hippophae rhamnoides*       |
|                | *Amorpha fruticosa*          | *Caragana microphylla*        |
|                | *Artemisia ordosica*         | *Amorpha fruticosa*          |
|                | *Hedysarum mongolicum*       | *Melilotus officinalis*       |
|                | *Astragalus adsurgens*       | *Crown Vetch*                |
| **Herbaceous** | *Alfalfa*                    | *Alfalfa*                    |

**Figure 6.** Ecological restoration system of mining wastelands.

In the ecological reconstruction in mining area, the main choice of Herbage vegetation are *Alfalfa* and *Astragalus adsurgens*, *Coronilla varia*, which are pioneer plant species in Shendong mining area.
Its drought resistance is higher, the growth rate is faster, and has the ability of nitrogen fixation to improve soil; For shrub species, Salix, Caragana, Amorpha fruticosa, Sabina vulgaris are the first choice. These shrubs have good adaptability, resistance and high survival rate; the main tree species are considering Pinus tabulaeformis, Platycladus orientalis, Sophora japonica, Robinia pseudoacacia, Xinjiang Yang, which are excellent local native species. Shendong mining area is water shortage area, cultivating suitable alien species is difficult, so the excellent local plant species are preferred. Overall, the goal of land reclamation and eco reconstruction is to take practical measures to make the completion of the sustainable utilization of land damaged due to mining. The ecological reconstruction system of land reclamation in mining area is like Figure 6.

5. Land regeneration Modes in Shendong mining area

5.1. Ecological agriculture model
Based on China's large population, less cultivated land per capita, insufficient reserve resources and prominent contradiction between people and land, most of the land damage is agricultural land, or even the vast majority of cultivated land. Therefore, the purpose of land reclamation is to take the priority of agricultural land. The combination of climate, light, water and other natural conditions, use comprehensive analysis and design of ecological reclamation mode, agriculture reclamation mode of fruit industry and comprehensive breeding mode.

5.1.1. Ecological agricultural park reclamation model. The mode of Eco Agriculture Park focuses on creating plant landscapes from the perspective of ecology and gardens, highlighting the landscapes of local rural plants, and rationally laying out production projects and facilities, making them an ornamental sight, aiming at developing courtyard economy and eco-tourism and leisure agriculture. The agricultural products are mainly planted with corn, potato, sunflower and other high quality varieties, such as mixed grain, melon and fruit, vegetables and so on, forming a standardized planting base.

Making full use of modern agricultural technology, building “four areas a garden” of modern agricultural park, that is the production of pig breeding and vegetable planting area, planting grasses and sheep farming area, grain planting area, processing and distribution area and Cultural Industrial Park, and making the construction of ecological agriculture park as the core, comprehensive national park, modern planting breeding, processing, science and technology, tourism and development, to build a modern agricultural circulation northwest paradigm.

5.1.2. Forestry and fruit farming reclamation model. The forestry and fruit farming reclamation model is ecological reclamation on abandoned land and damage and collapse area in Shendong mining area. On the choice of forestry tree species, we should consider not only the high economic benefits, but also the multi-functional benefits, such as the well-developed roots, the strong adaptability to drought and the good effect of water and sand fixation. Suitable economic forest planting in Shendong mining area mainly include Ginkgo, Salix, Caragana, Yang and Xinjiang both ecological forest and economic forest of peach, apricot and jujube [38].
In wasteland and mining subsidence in loess hilly gully region area, desert area, building reclamation mode of forestry and fruit farming can not only improve the ecological landscape in desert areas, but formed in apricot, peach, jujube forest based industrial chain. This is conducive to the preservation of soil moisture and preventing soil erosion, desertification, also can produce considerable economic benefit and good ecological benefits.

5.1.3. Comprehensive breeding model. In Shendong mining area where water is sufficient for a generation, according to the design standard of ecological integrated farming, aquaculture and reclamation with plant watering function also can use the level terrace of cultivated land or shallow flat crop planting, dryland farming reclamation will be before a single operation mode for the transformation of three-dimensional ecological agriculture mode of water reclamation the integration of the land.

Taking a dig deep shallow, flat land reclamation, in the vicinity of the Yellow River and its tributaries Linhe area, it can build ecological agriculture comprehensive breeding project, aquaculture ponds, pig farms, sheep farms and backyard farms and high standard greenhouses, planting potatoes, small grains and other crops quality. In this ecosystem, feed fermented manure pond and pond fertile, plant straw and grass, to achieve multi-level recycling plant breeding system, ecological and reasonable structure, complete functions, a higher proportion of the whole energy input-output culture system, has the superiority of ecological agriculture.

5.2. Mine park model
Taking land reclamation ecological park as a means to optimize the mining area ecological sustainable development as the goal, using the unique natural landscape and remains mining landscape as the background, we can built to reflect the Shendong mineral resources exploration and mining development history and has regional characteristics, Erdos northern prairie style, at the same time with the wetlands, desertification research study on the value of historical and cultural education function, and it also can be used for people viewing and leisure tour in scientific research experiment of ecological reclamation development model [39-40].

Land reclamation of ecological park model in ecological fragile mining area in Shenfu mining, is based on mining land reclamation, environmental governance and protection, taking the mining landscape as the axis, with green (agriculture, forestry, animal husbandry) landscape as the main body, implemented by the local cultural landscape, relying on the scientific connotation of the landscape. The mining environmental governance culture, typical ecological landscape, historical and cultural, recreational and other landscape are the organic combination of the series. A show of Shendong mining area special mineral resources exploration and development history, more important is through the land reclamation of this model to promote the transformation of social economy development in Shendong mining area, in order to promote the social, economic, Shendong mining area ecological harmony sustainable development.

5.3. Building land model
In view of the contradiction between natural conditions in Shendong mining area restrictions and increasingly people tense trend, in light of a large area of ground subsidence, press accounts,
combined with the county industrial development planning and regional natural conditions, we can use filling reclamation mode in the steady subsidence area, to supplement the construction land. The use of coal gangue, fly ash and other solid waste production, living garbage filling reclamation as construction land reclamation is a more mature mode, which can dispose of a large number of coal gangue, fly ash and other solid waste production and living waste material, avoid the cause of soil, environment and water pollution. It can increase the construction land for industrial park planning and construction, mining, urban construction and new rural construction land.

Especially in the industrial Park, logistics park location relatively flat area such as Jinjie, Dian Ta, Yan Jia TA of the "Shenfu economic and Technological Development Zone", taking the subsidence filling reclamation process at the same time by solving packing, pumping dredging, in-situ soil, gangue backfill layer of dams, and combing the policy of land use overall planning requirements and the construction of new rural life and production infrastructure land, industrial park, wind power generation infrastructure land after land reclamation. At the same time, the park should make full use of coal gangue and fly ash as materials of building material recycling economy.

6. Discussion and conclusion
This paper uses Shendong mining area as the research object, making an understanding of the natural and social conditions in the project area through literature research, on-the-spot investigation and analysis of the damage situation of mining wasteland reclamation area. Large area mining in Shendong mining area resulted in evident ground fissures, increasing open-pit mining wasteland and soil and water pollution, and serious damage of ecological vegetation. Based on the current situation of land destruction in Shendong mining area, the ecological remediation technology is proposed to control the damaged land in the mining area. The main engineering measures included the restoration of landform reshaping, soil, vegetation and ecological reconstruction. To make full use of coal mining of coal gangue and fly ash as basic material of pit filling, cover the surface soil and subsurface soil; the physical properties improvement, pH improvement and improvement to improve the nutritional status can improve the soil texture and structure, enhance microbial activity, improve soil nutrient status; planting advantage cultivation in Shendong Mining Area such as alfalfa, Artemisia, Salix, poplar and other local superior crop varieties, can restore the soil, create artificial ecological community at the same time, improve the ecological environment of the abandoned opencast mining area.

Based on the ecological restoration of abandoned mine land in Shendong mining area, this paper explores the development mode of the future, including ecological agriculture mode, mine park mode and construction land use pattern. Ecological agriculture mode was dominated by agricultural land use, land reclamation ecological agriculture park by planting corn, potato, sunflower and other agricultural products, aiming at the development of courtyard economy and Ecological Sightseeing Leisure Agriculture; Forestry and fruit farming is growing with the reclamation of ecological forest and economic forest of peach, apricot and jujube tree, to improve the ecological environment of the reclamation area at the same time, to build the economy forestry industry chain; integrated culture to dig deep shallow water is relatively abundant in the region, the establishment of aquaculture, poultry raising, agricultural planting and other eco cycle industrial chain integration. Mine park mode making the sustainable development of Shendong mining area as the goal, the mining landscape as the axis, build ecological tourism industry both in Loess Plateau of Northern Shaanxi Province customs and
Erdos prairie style. The mode of building land is to supplement construction land resources, make rational use of land, and build land for land use planning based on filling reclamation. To sum up, from the mining land remediation, reclamation of land use development, economic development and protect the environment, it was to fully explore the sustainable development way for Shandong mining area of Shaanxi Province and the Inner Mongolia Autonomous Region.

Mining damage control, ecological restoration and renewal development mode is a multi-disciplinary comprehensive control project involving mining, geology, surveying, ecology, environment, land use and planning. This article gives the ecological restoration and regeneration of Shandong mining area reclamation mode from the macro aspects, but in some detail problems in ecological restoration, such as selecting appropriate exotic plant species, high technology and utilization of water resources in arid area, the mining land matrix modified heavy metals removal technology and so on, which will encounter in the implementation process. These are the difficulties in future research of ecological restoration and reconstruction of western areas.

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