Land Reclamation of Metal Mines in Hilly Areas ——A Case Study of hematite in Yao Jia Gou

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Abstract: In the case of shortage of land resources, in order to make reasonable use of land, increase the utilization of land resources, improve the contradiction human and land from different, promote the coordinated development of economy, society and ecology, it is a desirability to complete land reclamation and ecological restoration of diggings. In this paper, Taking Yao jiagou hematite for example, this paper has study land reclamation of metal mine in hilly areas, and made the land suitability evaluation for reclaimed land in based on the prediction of the planned-damaged land, then used DEA-SOLVER efficiency calculation model to propose the optimizing land reclamation plan, finally determined the direction of land reclamation of evaluation unit, laying a good foundation for land reclamation work, providing reliable basis for effective restoration of the damaged topography and vegetation in the production and construction process of metal ore.

1. Introduction

In more than 30 years since reform and opening up, China experienced a great development period with rapid economic growth and rapid development of science and technology, when social productivity has been greatly improved, people's living standards have been greatly improved. But environmental pollution, land degradation, biodiversity reduction and other issues have been very prominent, and these problems hinder the sustainable development of society. Mining is organized human activities to change land use mode and damage terrestrial ecosystems in largest scale[1]. Mine land reclamation and mine ecological environment restoration have always been the focus issues of at home and abroad, but also the problems all countries in the world attaches great importance to[2-5]. In foreign countries, the mining space is taken as dumping ground when mining, and the land reclamation of mining area is carried out by using backward pushing method and sequential stripping method and other technologies[6-7]. In terms of chemical technology, the United States, Germany and other countries with developed reclamation technology have study the "erosion vegetation" to solve the problem of soil erosion because of mining. In the aspect of domestic land reclamation theory and subject system, Hu Zhenqi[8] believes that the comprehensive application of the foundational theory of environmental science, land science and other subjects is the basic theory of land reclamation and ecological reconstruction. Land reclamation science concept is proposed in his paper that "Concept and method of Participatory Land Reclamation " published in 2003. In the "metal mining wasteland ecological restoration technology research" Han Yu[1],etc have summarized types and characteristics of metal mining wasteland , sketched out their impacts on the ecological environment, and concluded the classified remediation technology to the ecological environment of metal mine waste. Taking Yao Jia Gou hematite in Chengde county as an example, this paper has made the land suitability evaluation, and on the basis initially formulated the damaged land reclamation project in the area, then used DEA data envelopment analysis method to optimize the reclamation plan, at the same time in accordance with the land reclamation plan, proposed reclamation target, method, standard, prevention control measures and reclamation measures meeting the actual area, found the coordination mechanism between mineral mining and mine environmental protection, minimizing the damage to the environment because of mining,

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laying a good foundation for land reclamation work.

2. General situation of research area and prediction of planned-damaged land

2.1 General situation of research area

Chengde county is located in the northwest of Hebei Province, belonging to Chengde City, on the East of Pingquan County, to the south of Kuancheng and flourishing county, adjacent to the West of Shuangqiao District of Chengde city and Luanping County, bordering the northwest of Longhua County, to the northesst of Ningcheng County in Inner Mongolia and to the southwest of Beijing Miyun District. Within the territory of East and West 89km, north-south length of 95km, it has a 220km-distance from Tianjin city, 180km from the capital. Da Ying Zi Xiang is located in the southwest of Chengde county in Chengde city of Hebei Province, which has a reputation of "pear town.". The project is located in Yao Jia Gou team of Da Ying Zi village in Chengde County, which has a 60m distance from Da Caowa village to the south, 170m from the residential area of two road village to the southwest, and 100m from the residential area of nine groups of Dong Gou to the west. The geographical coordinates are: east longitude 117° 52 '12 "53' ~ 117 ° 57 ', north latitude 40 ° 42 '31" ~ 40 ° 43' 01 ".

2.2 Prediction of planned-damaged land

This paper forecasts the planned-damaged land from three aspects: mining site, abandoned dreg field and goaf. There is a total of 3 Mining and underground stope in east and west mining area , and stacking yard, office, duty room is located in Yaojia ditch Dayingzi village. 3 mining caves are located on both sides of the road in rural areas, and mining site is located in the area surrounding the underground mining. The destruction type of the land gave priority to occupation, and damaged land area is 0.1177hm^2. Among them, the forest area is 0.0328hm^2, shrub forest is 0.0378hm^2 and other woodland is 0.0471hm^2. The abandoned dreg yard is located in the ditch on the east side of the rural road in the east of mining area. The main types of land damage caused by waste dumping site are the occupation, and the damaged land area is 0.3703hm^2, and the damage degree is more serious. The east and the west mining area include three mined out areas, of which, the total mining area of the east mining area is 0.6404hm^2, and the mined out area of the west mining area is 0.1690hm^2. The damage area of mined out area was 0.8094hm^2, and the damage type is mainly collapse, and the damage degree is lighter.

3 Suitability evaluation of land reclamation in hematite mine area

3.1 Divide evaluation unit

The paper divided the land reclamation suitability evaluation unit in accordance with the land destruction prediction zoning, namely land reclamation suitability evaluation unit was divided for mining site, slag field and mining subsidence area 5 evaluation unit.

3.2 Select evaluation factors

The selection of evaluation factors should consider the following requirements: measurability of evaluation factor, relevance between the evaluation factor and land element quality, sustained stability of evaluation factors on response of land quality, non superposition among evaluation factors[9]. In this paper, the selection of evaluation factor factor is shown in table 1.

3.3 Ascertainment of weights

In the field, agriculture, forestry and animal husbandry feieds have different requirements on the surrounding environment and various evaluation factors. Therefore, the same evaluation factor has different importance degree in its suitability evaluation[10]. This paper used the analytic hierarchy process (AHP) to determine the weight of the suitability evaluation factors of land reclamation in mining area, which past the consistency test, as shown in table 1.

Table 1 Suitability evaluation factors and there weights

Evaluation factors	Fit to cultivation	Fit to forestry	Fit to garden	Fit to grass
Effective soil thickness	0.1149	0.2571	0.1839	0.1292
Topographic slope	0.1914	0.0898	0.1407	0.1026
Organic content of soil	0.0979	0.2014	0.0975	0.2042
Degree of damage	0.1177	0.1000	0.0493	0.0781
Rock-soil pollution	0.3261	0.1359	0.3514	0.2665
Agrotype	0.1519	0.2158	0.1772	0.2195

3.4 Classification of evaluation indexes

According to the high-low level of each evaluation factor, the corresponding grade score is assigned respectively. The evaluation factors were classified into four grades: I, II, III and IV, and the grade scores were 400, 300, 200 and 100 respectively. Combining the actual situation of mine, the factors of each suitable type are determined,shown as table 2, table 3, table 4.

Table 2 Exponent table of Factor suitable for cultivation

Evaluation factors	I	Factor exponent	II	Factor exponent	III	Factor exponent	IV	Factor exponent
Effective soil thickness	＞100cm	400	60～100cm	300	30～60cm	200	＜30cm	100
Topographic slope	＜5°	400	5°～10°	300	11～15°	200	16-25°	100
Organic content of soil	＞15%	400	10%～15%	300	6%～10%	200	＜6%	100
Degree of damage	Nothing	400	Mild	300	Medium	200	Serious	100
Rock-soil pollution	Nothing	400	Mild	300	Medium	200	Serious	100
Agrotype	Loam	400	Clay sand Loam	300	Heavy clay Sand	200	Sandy soil Chad	100

Table 3 Exponent table of Factor suitable for forestry

Evaluation factors	I	Factor exponent	II	Factor exponent	III	Factor exponent
Effective soil thickness	＞60cm	300	30～60cm	200	＜30cm	100
Topographic slope	＜15°	300	15～35°	200	＞35°	100
Organic content of soil	＞10%	300	6～10%	200	＜6%	100
Degree of damage	Nothing	300	Mild	200	Medium or serious	100

Rock-soil pollution	Nothing	300	Mild	200	Medium or serious	100
Agrotype	Loam	300	Sand	200	Sandy soil	100

Table 4 Exponent table of Factor suitable for grass

Evaluation factors	I	Factor exponent	II	Factor exponent	III	Factor exponent
Effective soil thickness	＞30cm	300	10～30cm	200	＜10cm	100
Topographic slope	＜35°	300	35～50°	200	＞50°	100
Organic content of soil	＞10%	300	6～10%	200	＜6%	100
Degree of damage	Nothing	300	Mild	200	Medium or serious	100
Rock-soil pollution	Nothing	300	Mild	200	Medium or serious	100
Agrotype	Loam	300	Sand	200	Sandy soil	100

3.5 Classification of evaluation grade

In this paper, the sum of the highest and lowest land index was calculated. and , when the mean of all evaluation index factors was I, the grade was divided into 4 level(3 for forest, grassland), and the highest score of the index sum was 400 points (300 points for forest and grassland). When all the evaluation factor index value was at the end of class, or grade was divided into 1, the index and the lowest score was 100 points. The highest index sum subtracted the lowest, and then divided by the level number, the average scores gained by which were gradient values for grades, such as farmland gradient value = (400-300) /4=75, forest and grassland sub gradient value = (300-100) /3=66; The index and range of land are divided according to the gradient scores, as shown in table 5.

Table 5 Land evaluation grade index and scope table

Suitability for land	Grade			
	Ⅰ（Suitable）	Ⅱ（More suitable）	Ⅲ（Suitable barely）	Ⅳ（Unsuitable）
Fit to cultivation	326～400	251～325	176～250	100～175
Fit to forest, grassland	235～300	168～234	100～167	——

3.6 Suitability evaluation and preliminary reclamation scheme

The comprehensive index method was used to evaluate the suitability of land reclamation in mining area, and the suitability and its degree of each evaluation unit were made. The comprehensive index of land quality is multiplied by the grade scores with corresponding weights values of evaluation factors, namely the evaluation factors index can be calculated, and then added the sum of each evaluation index of evaluation unit together, and the calculation model is:

$$S_i = \sum_{j=1}^{n} X_{ij} Y_{ij}$$ （Formula 1）

In formula 1, Si is the land comprehensive quality index of the i-st evaluation unit; Xij is the j-st evaluation factor weight corresponding to the i-st evaluation unit; Yij is the grade scores of the j-st evaluation factor corresponding to the i-st evaluation unit[11] .

Combining the natural conditions and social factors of Yao Jia Gou hematite region, according to the characteristics of land after the destruction of each evaluation unit and the evaluation factors index and weight in mining area, the weighted land comprehensive quality of each evaluation unit was calculated, and then contrasting the suitability classification standard, the land suitability evaluation results of each evaluation unit was gained, shown in table 6.

Table 6 Suitability evaluation results of each evaluation unit

Evaluation unit		Evaluation of suitable for agriculture		Evaluation of suitable for forest		Evaluation of suitable for grass	
Destruction type	Evaluation unit	Comprehensive index	Corresponding grade	Comprehensive index	Corresponding grade	Comprehensive index	Corresponding grade
Occupation	West mining area	263.5	II	187.4	II	223	II
Occupation	East mining area	263.5	II	187.4	II	223	II
Collapse	West mined-out area	265	II	200	II	225	II
Collapse	East mined-out area	265	II	200	II	225	II
Occupation	Waste dump	169	Ⅳ	196.4	II	188.7	II

According to the evaluation results in Table 6: based on the principle of reclamation for arable land as a priority, according to the land suitability assessment results and combining social and natural conditions, the scheme of the land reclamation in mining area was formulated initially , as table 7.

Table 7 Preliminary scheme of land reclamation in mining area

Destruction unit	Destruction type	Land types and areas(hm2) after destruction			Total	Reclamation direction	Reclamation areas
		Arable land	Woodland	Grassland			
West mining area	Occupation	-	0.0471	-	0.0471	Arable land	0.0471
East mining area	Occupation	-	0.0706	-	0.0706	Arable land	0.0706
West mined-out area	Collapse	-	0.1690	-	0.1690	Woodland	0.1690
East mined-out area	Collapse	-	0.6404	-	0.6404	Woodland	0.6404
Waste dump	Occupation	-	0.3703	-	0.3703	Woodland	0.3703

4. Optimization and adjustment of reclamation scheme based on DEA (Data Envelopment Analysis)

Data Envelopment Analysis (referred to as DEA) is created by Charlles and Cooper to, and a new field of scientific research, management science and mathematical economics, mainly for evaluating the relative efficiency between input- output of many decision units in same type[12]. DEA has a variety of computational models, such as the first one named CCR model. After years of development, DEA computing model has been further improved and supplemented, such as CCGSS model, CCW model, CCWH model and so on. The most commonly used is the super efficiency model (DEA-SOLVER).

In order to better reflect the input-output efficiency, this study selected the construction costs, other expenses, basic reserve funds (unforeseen costs) and the difference reserve as an input factors; then selected land after reclamation expected economic value, social value and ecological value as the output factors. The input and output values of each reclamation unit were calculated, which were imported in the DEA model.Using C2R calculation model of DEA solver software, the input-output efficiency value of land reclamation project of Yao Jia Gou hematite. The final reclamation project was formed through adjustment, as Table 8.

Table 8 Final scheme of reclamation

Destruction unit	Destruction type	Land types and areas(hm2) after destruction			Total	Reclamation direction	Reclamation areas
		Arable land	Woodland	Grassland			
West mining area	Occupation	-	0.0471	-	0.0471	Woodland	0.0471
East mining area	Occupation	-	0.0706	-	0.0706	Woodland	0.0706
West mined-out area	Collapse	-	0.1690	-	0.1690	Woodland	0.1690
East mined-out area	Collapse	-	0.6404	-	0.6404	Woodland	0.6404
Waste dump	Occupation	-	0.3703	-	0.3703	Woodland	0.3703

5. Conclusion

Based on the planned-damaged land prediction, the paper has used AHP to determine the weight of each evaluation factor to reclamation in different directions, and used the index sum for reclaimed land to make the suitability evaluation and initial reclamation project: East and west mining sites were suitable for cultivation, the east and west mined-out areas and dump wastes were suitable for forest. It has used DEA-SOLVER to calculate the efficiency values of reclamation input and output: efficiency value of east and west mining sites suitable for cultivation was lower than the mined-out areas and dump wastes, and has further optimized the initial reclamation scheme, then has adjusted east and west mining sites for forest. Finally the paper regarded as that we should take proper biological measures to deal with the probable heavy metals pollution, and sow Thlaspi weeds in the early land reclamation, and the selected seabuckthorn and Robinia pseudoacacia as plant species of land reclamation.

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