Monitoring of Landscape Change for Waste Land Rehabilitation in Haizhou Opencast Coal Mine

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Abstract: - Land rehabilitation is being carried out throughout the whole country. But in many areas, the main purpose of land rehabilitation is to increase the overall cultivated land area which neglects the eco-construction. Important tasks of modern landscape ecology are to monitor and assess natural resources, to examine the impacts and effects of human intervention and, last but not least, to observe the state of the environment over long periods of time. The objective of this research was to create a method for land rehabilitation project using landscape ecology by combining Geographical Information Systems (GIS) and Landscape Ecology Analysis (LEA). GIS technologies were developed for the digital preparation and analysis of historical maps, and subsequent digital land use mapping. The landscape spatial pattern and influence on landscape were expressed by dominance index, contagion index, cohesion index, etc. Applying those landscape ecology indexes landscape spatial pattern influence caused by the land development and rehabilitation planning of Haizhou coal mine waste area was studied by comparing landscape characteristics between those before and after planning implementation. The analysis of the structural landscape changes proved to be an important aspect.

Key-Words: -Monitoring, Landscape Ecology, Land rehabilitation, opencast coal mine

1 Introduction

Land is a finite, non-reproducible consumption resource held as a source of livelihood and a financial security transferred as wealth across generations [1]. In China there is a high constant demand (growing in some areas) for land to construct settlements and new roadways. Today, landscape development in China is primarily a result of anthropogenic processes, affecting almost the entire landscape. In China, there are 12,000 active mine sites, more than 300 mining cities exist while their environmental problems and industry adjustment pose a serious environmental, social and economic challenge for Chinese local governments and authorities. China meets many problems on mine waste pollution. The land rehabilitation for mine waste area is an important task in the recent years[2-3].

The demand for earth materials is very large, not only in regions where mining damage has occurred. Because of mine backfilling and filling of derelict land, the costs of the use and delivery of sand and other natural materials are reduced. Under such conditions the continuation of the construction of huge waste deposits which defile the natural environment should not be tolerated. Mining typically has serious, negative effects on the ecology, at all levels of organization, from microbial to landscape. All these cases promote environmental protection because the volume of waste storage is reduced and areas affected by the extraction of the natural raw materials are replaced by coal mining waste.

Landscape ecology is the science and art of studying and improving the relationship between spatial pattern and ecological processes on a multitude of scales and organizational levels [5-6]. Many studies have shown that composition and spatial arrangement of landscapes within land rehabilitation for mine waste area (e.g.[7]). Based on the theory of landscape ecology planning and design, the method in land rehabilitation project using landscape ecology planning and design was put forward. Based on the analysis about the ecological engineering of farmland protection, the engineering of biological habitats protection, the engineering of natural landscape conservation, the engineering of pollution, the key controlled factors in each engineering, which were very helpful to effectively sustain ecological safety of farmland were discussed. Landscape metrics such as proportion, edge density and contagion were calculated based on the classified imagery. In addition, as many studies have documented, the conservation policies should necessarily be complemented with a proactive approach, which can accommodate the needs of contemporary development while ensuring the protection of natural and cultural resources.

Changing landscapes, especially changes to the way in which land is used, result in alterations to the landscape structure—and hence also to the abiotic and biotic functions and potentials of a landscape. Changes in land use often take place as small scale individual measures, insignificant in themselves. However, over the long-term, the accumulation of such minor changes can lead to significant shifts in regional structures and environmental conditions. For analyzing the effects of land use, it is fundamental to realize that ecological processes occur within a temporal setting and change over time [6-7]. Here, we applied those landscape ecology indexes landscape spatial pattern influence caused by the land development and rehabilitation planning of Haizhou coal mine waste area was studied by comparing landscape characteristics between those before and after planning implementation. The effects of landscape fragmentation on biodiversity, landscape diversity and the imbalance of pastures on land rehabilitation project, road engineering, irrigation project, shelter forest project are also discussed.

2 Land rehabilitation and landscape ecology in coal mine waste land

The main types of solid wastes produced from mining activities include waste rock and tailings resulting from ore exploitation and ore processing respectively. These are commonly disposed at the surface and/or backfilled into open pits and underground mines and/or beneficially used in the mine area for construction and restoration workings. The mine waste has different physical and chemical properties, resulting in different potential environmental impacts. The volume of waste produced depends on the type of deposit and the technological alternatives used for mining and for ore processing. The chemical composition of the waste varies considerably according to the substance mined and the nature of the geological formation containing the deposit[12,16,18].

Mining activities are known to ravage large areas leaving them uncultivable resulting in permanent, non-restorable land surface. The disturbances are most evident and protracted in arid areas subjected to moisture deficiency, salt accumulation and erosional hazards. Thus the successful establishment of vegetation on these sites is difficult. The findings of many research projects were reported. Ye et al. evaluated the major constraints to the revegetation of lead/zinc tailings use bioassay techniques in China[11]. Many pilot studies and field trials of revegetation or rehabilitation are carried out on settlement ponds or tailing dumps to determine the effectiveness of replacing topsoil, the desirability of using a brushwood mulch and on evaluation of the rate of establishment of various species from seeds, and landscape development all over the world. The success of these studies provides valuable data, knowledge and technologies [13-18].

Extractive industries exploit and process huge amounts of natural resources resulting in the generation of millions of tones of wastes. Improper management may result in significant contamination of land, air, surface and ground waters posing a high risk to human health as well as to agricultural production. Today, extractive industry has to efficiently respond to the increased public environmental pressure and comply with the stringent environmental legislation.

By contrast, some tree species grow strongly on mine spoils and their plantations require less site preparation and maintenance. Trees may also serve to prepare the soil for agriculture. Both reclamation approaches remain active areas for discussion and research. Reclamation practices in the coalfield have progressed considerably in the last decades. Landform design has evolved from the oldest restored landscapes based on platforms, banks and ditches to catchments structured by gentle slopes and watercourses [8-9]. Soil management practices tend to favour the use of topsoil instead of overburden materials to cover the new forms.

Ecology, in the 100 years since its inception, has increasingly provided the scientific foundation for understanding natural processes, managing environmental resources and achieving sustainable development. The objective of applying landscape ecology in land rehabilitation is to coordinate the relationship among the ecological environment, biological diversity and sustainable. Landscape ecology has indeed contributed successfully to methods of landscape assessment and evaluation and towards systems thinking in landscape planning.

3 Study area

Fuxin with about 1.9 million inhabitants is a prefecture-level city in the Liaoning province of northeastern China (see Fig.1), where is in the north temperature zone and is characterized by mountainous topography. The coal mine dump in FuXin extends over 170 km from West to East and over 84 km from North to South, covering an area of 13 km^2. (Fig.1) The dump is located in the north temperature zone and characterized by the mountainous topography [16,20-22].

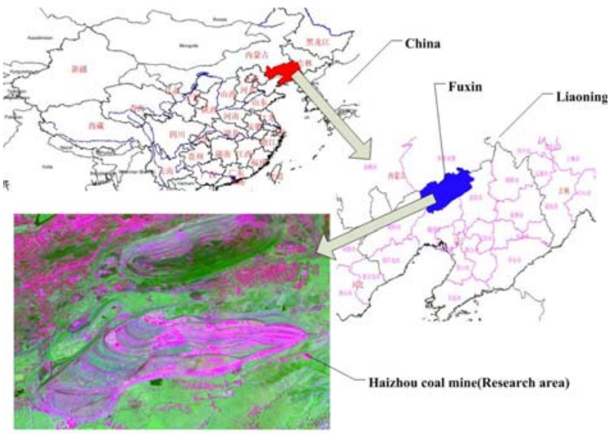

Fig.1 Map showing the location of the research area

The research area is Haizhou opencast coal mine with longitude between 121° 36′ E and 121° 42′ E, and latitude between 41° 56′ N and 42° 00′ N. This site has been studied for approximately 5 years by researchers at China Agricultural University. According to the meteorological data supplied by Fuxin Environmental Protection Department, the annual rainfall is 420~540mm but the annual average evaporation reaches 1,644.9 mm. Furthermore, the precipitation shows asymmetrical distribution in spatial and temporal extension, descending from south to north and focus on June to September. The annual mean wind speed is 2.84 m/s while the predominant wind direction is SSW. And the annual frost-free period covers 150 days[1,15-17]. Fig.2 shows the RS image of the study area which had been preprocessed.

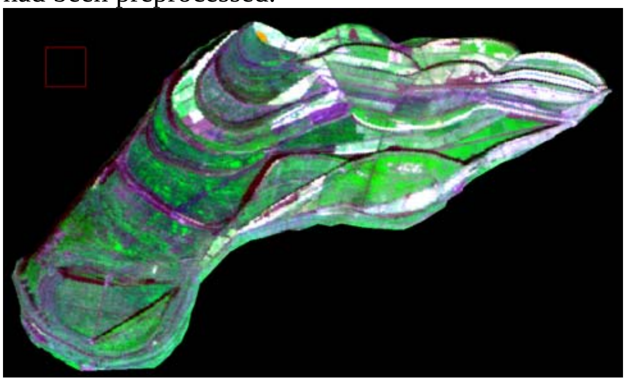

Fig.2 RS image of the study areas-Fuxin

From 1982, the revegetation of the Fuxin coal mine has been actualized by FuXin Land Rehabilitation and rehabilitation Centre, China Agricultural University and Beijing Forestry University. The Haizhou coal mine waste area is at an elevation of 250-350 meters. It distributes in gradient from northeast to southwest (see Fig. 3).

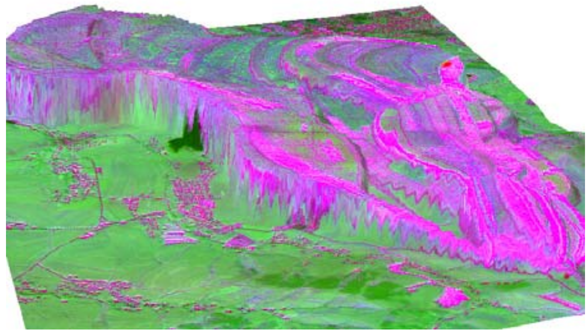

Fig. 3 The landscape of Haizhou coal mine waste area (2005)

4 Ecological planning and designing in coal mine waste landscapes

Ecological landscape design integrates input from landscape ecology and design, both of which are seen as providing parallel and complementary, albeit different methodological approaches. Ecological landscape design is based on a holistic understanding of landscape, which encourages a dynamic and responsive approach. It is holistic because it simultaneously considers past and present as well as local and regional landscape patterns and processes. The methodology of Ecological Landscape Association has been developed to achieve these objectives. The simplicity and spontaneity of the methodological framework encourages the intuitive and creative problem-solving potential of the landscape designer while prioritising the maintenance of landscape integrity and long-term environmental sustainability.

Ecological landscape design is based on a holistic understanding of landscape, which encourages a dynamic and responsive approach. It is holistic because it simultaneously considers past and present as well as local and regional landscape patterns and processes. It is responsive because it develops from a realisation of the constraints and opportunities of context whether natural, cultural or a combination of both. Haizhou coal mine waste area mainly includes the following project: the construction of terraced platform, the platform covered with new soil, road reconstruction and rehabilitation. According to the above project, the land planning and design composed of land leveling project, planning of parcel of rice field, planning design of road landscape, irrigation project, planning design of Ecosystem Boundaries.

When the mining activities have been completed, a proper environmental situation must be restored within the area. For this purpose, medium resolution data can supply a very powerful instrument. After quarry cultivation is then possible, with the integration of GIS and satellite data:

- To monitor the recovery action taking place within the mined area.
- To quantify the effectiveness of the recovering action.
- To verify the differences between the area external to the mined area and the recovered area.
- To operate objective comparisons with pre-existing situation.

Earth observation satellite data can provide unique time series information showing spatial and physical changes, thus monitoring of large and remote mine areas can be performed in a cost effective way. The information collected can then be combined with other environmental data and integrated into GIS, allowing the performance of a number of actions including the assessment and monitoring of the environmental impact of mining and mineral processing activities as well as the development of waste rehabilitation strategies. EO data and GIS can thus greatly contribute to the management process of extractive industry activities enhancing the quality of decisions made for environmental protection.

GIS are tools for collecting, storing, retrieving at will, transforming, and displaying spatial data for a particular set of purposes [23]. Given the spatial nature of many environmental impacts, GIS can have a wide application in all EIA stages, acting as an integrative framework for the entire process, from the generation, storage, and display of the thematic information relative to the vulnerability/sensitivity of the affected resources, to impact prediction and finally their evaluation for decision support. Given the local and regional nature of many environmental impacts, we combine the spatial analysis capabilities of GIS and the analytical properties of succession models into an efficient decision tool[24-27]. The introduction of computerized methods of analyzing spatial information has made it possible to evaluate map data while accounting for the spatial distribution of components. We were interested in combining the spatial analysis capabilities of GIS and the analytical properties of forecast models into an efficient decision tool.

A GIS based architecture was developed to handle the i) reference maps, ii) satellite data, iii) information layers extracted by satellite data handling and processing and iv) information collected regarding the characteristics of each study area. Main outputs of the system for the assessment of environmental impact are considered to be the land use/land cover map, cross maps and tables showing the change in the area of different land use/land cover classes during a time period (i.e. before the start of operation and current conditions, before and after reclamation of a mine component). The GIS is integrated with the decision-making models for the rehabilitation and revegetation of wastes[28-30].

4.1 Land leveling project

The research area distributes in gradient with an elevation from 250 to 350 meters, the height of which arranges from 5 to 10meters. In order to meet the ecological reconstruction, it should be build terraced fields, in which the surface can be earth up. According to the characteristics of the waste area, the area that will be planed as tilled land should be filled with gangue first. It should pay attention to the lower level gangue upper-compacting loose, and covered with a layer of 30 ~ 50cm of soil. The area that will be used for habitant or integrated service area, at the bottom of ground it should also be filled with gangue. The area that close to road should be tilled land. The place that human can’t management conveniently, should be plant trees or grass.

Irrigation Land Leveling consists of reshaping the surface of the land to be irrigated to planned grades. The purpose of land leveling is to permit the uniform and efficient application of irrigation water to provide adequate surface drainage without causing erosion or waterlogging. Irrigation land leveling can remove high and low spots in a field to reestablish a desired slope to allow for a steady water advance down toe furrows, flatten steep slopes, or change the slope of the head ditch/pipe or tailwater ditch slope.

In the project area a total land area of 998.1707 hectares, The land mainly used for housing construction, road, bare waste rock, and the slope to dump waste and other types of land-use. The housing covers 4.1399 hectares, accounting for 0.41 percent of the total area; road traffic land covers 20.5742 hectares, accounting for 2.06 percent of the total area; bare waste covers 2.6801 hectares, accounting for The total area of 0.27 percent; slope land covers 192.0939 hectares, accounting for 19.25 percent of the total area; and the dump waste covers 778.6826 hectares, accounting for 78.01 percent of the total area (See Fig.4).

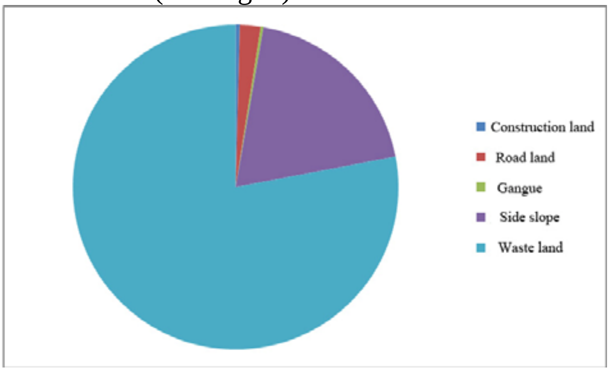

Fig.4 Project Area Land Use Structure

4.2 Planning design of road landscape

The conception of road landscape ecology is fresh in China, which mainly contains three aspects of contents: ecological effect of road,aesthetics quality assessment and landscape planning or design. Its adjacent canal system forms an integral part of the streetscape and acts as a visual amenity, provides wildlife circulation and corridor, as well as being a conduit for improved water quality.

The road construction should be considering the shape of the parcel of rice field. It can be constructed as a net work, so that the road can go anywhere of the field to enhance landscape connectivity and connectivity. It also was facilitate on agricultural, on the other hand The net work road arrangement will provide the corridors for animal living. So it can be can be used for circulation corridor for the protection of animal life. According to the above, the road can be composed of four types: trunk road, branch road, field road and production road. Trunk road and branch road in the project area is the main transport routes, the width of which usually was 6-8meters and 3-6 meters. And the original road which used for transporting mining can be act as the foundation stone. Field road and production road directly linked to the general field with width in 3 ~ 4m, the general way for the production of about 2m. Field road should be able to access agricultural machinery; production road is the way to the fields of roads, production and field management in accordance with the actual needs of the general layout along each field with shape in square. The two roads should be mutually perpendicular lines.

4.3 Farmland shelterbelt project

Farmland shelterbelt network aims at increase of forest coverage, improvement of oasis ecological environment and farming condition, prevention of desert extension over the oasis, reduction of wind and sand disasters, maintaining oasis stability, safeguarding stable and high yield of crops and meeting local demand for timber and firewood. After the farmland shelterbelt network is established, the ecosystem deterioration trend can be reversed, and local farmer's living standard can be improved. The technology extension also promotes local social and economic sustainable development.

It is windy all through the year and with little shade in the research area. Farmland and forest belt can reduce wind speed, raising the temperature, reduce evaporation of soil, increase the relative humidity of the surface, water conservation, block sand, reduce aeolian erosion and reduce dry and hot wind.. At the same time, the construction of farmland and forest belt could be used to improve working conditions for farmers to improve agricultural production, living and ecological environment and promoting rural economic development and increase their income.

There are many plants in the research area such as Robinia pseudoacacia L., Embla, Amorpha fruticosa and Hippophae rhamnoides. In the farmland and forest belt the arbor, shrub and grass are combined together to improve the revegetion. The main direction of the forest in the project area from the main victims of the direction of the wind and terrain conditions, the general direction of the forest perpendicular to the main victims of the wind South by Southwest (SSW) direction and Field along the long side of the direction of arrangement. Research is expected to total area planted shelterbelts 6957, Such as the use of poplar trees. Tiankan the edge of terraced fields in the bushes planted soil and water conservation plans to cluster 7367. Farmland protection forest is not only to improve the local micro-climate, soil and water conservation and an important means of sand-fixing, but also increase land-use space and biodiversity.

4.4 The planning of piece of paddy field

As the study area is a trapezoidal structure, the shape of the tilled land should be in rectangular or in square, in some place it also can be constructed as right-angle trapezoid or parallelogram. And the shape should avoid irregular triangles and polygons. Field size should be less than 10 hm^2. The direction of field can also help control soil erosion. As the wind of the study area is more serious and Field should be the main victims of the direction of the wind direction, or close to 90 ° vertical angle layout. In the plot on the type of plants should be based on the natural prototype and the human economy, the design of a superposition of its ideal system should adapt to the environment, for social production of more material wealth. For example, we can find some of the pioneer plants (preferably be able to bring some economic benefits, in the near future such as legumes) of natural prototype in the mining area to increase biomass and the resumption of productive land, the development of feed industry for Farming (cattle, sheep, pigs, etc.) to provide the source of feed.

3 Results

During the implementation period of the project, the research group of China AgriculturalUniversity have collected data on 5345 coal mine sites in China, 12 big coal mine sites, 663 local plant species, climate for period 1975-2002, 81 soil types and DEM.

In this study, A space map (see Fig.5) was carried out based on existing land-use maps, maps of valuable historical and cultural landscapes, and the Vietnamese standards for planning and designing coal mine waste area. For existing land-use systems this is a significant input because it expresses the human impact, and influences the feasibility of developing coal mine waste area. Weighting is one of the most important steps in suitability analysis, as it precisely affects the output, and is complicated by interacting of factors with each other. The MATLAB 2008a software was used to solve the matrix which results from AHP and pair wise comparison; and the spatial function of the Arc GIS 9.2 platform was used to overlay the factors to make a composite map which acts as a suitable planning map.

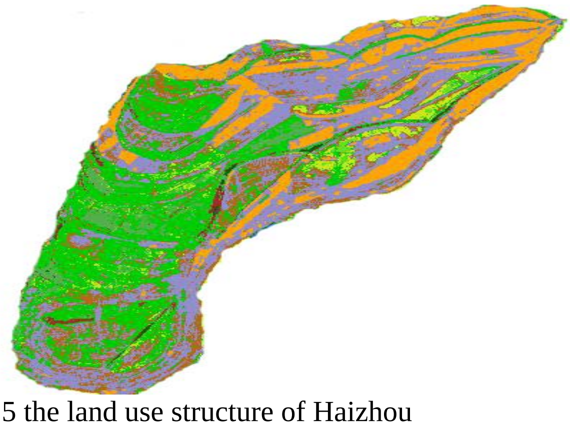

Fig.5 the land use structure of Haizhou

Several layers extracted by remotely sensed data are needed. All the layers, both raster and vector, are generated in UTM/WGS84 reference system, with the UTM zone depending on the geographic location of the area. The following layers have been considered:

- Land cover map
- Road and river map
- Vegetation coverage
- Vegetation coverage percentage
- Landscape diversity index
- Landscape dominance index

Area ratio of forest, farmland, grassland

From the first map it is possible to derive almost all the layers, except the road and river map, by means of raster geographic processing. The classes of this map are:

- Farmland
- Forest
- Grassland
- Bare soil
- Urban
- Water
- Mining activity

These classes can be considered very generic, even if they allow to cover the whole territory. The choice of these classes has been driven from one side from existing modelling, and from the other by the presence of historical medium resolution images (Landsat, 30 meters) for which it was not possible to detail the interpretation legend.

Digital elevation models (DEM). Are a digital representation of the height of an area. Their format can be a raster matrix or a group of points or lines. In the case of raster matrix, the digital elevation model has a fixed step, that is the size of the pixel of the grid. Each pixel stores an elevation value. Elevation in each location is computed from interpolation of the points on the grid (details in Fig. 6).

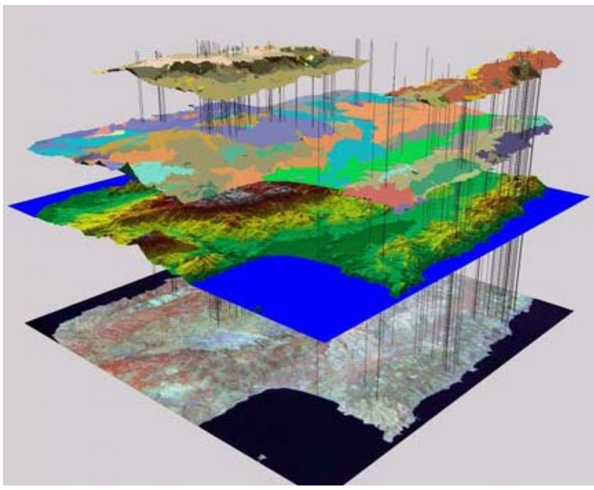

Fig.6 Soil, vegetation, landform Thematic Map

The main project divided into five types: (1) tilled land project, (2) the forest belt project (3) water conservancy projects, including irrigation pipeline, Hydrant, pumping stations, water reservoirs, drainage works and so on; (4) road project, including the main road, slip road and field; (5) transmission and distribution projects.

There are six types of land use after land rehabilitation in Haizhou Coal mine waste area with the total area 998.17 ha. They are tilled land with 427.02 ha, woodland with 384.87 ha, forest belt with 135.23 ha, road land with 27.58 ha, ditch land with 8.87 ha and other construction land with 1.60 ha (Details in Table 1).

Table 1 Land use structure of after land rehabilitation (Unit: ha)

	tilled land	woodland	forest belt	road	ditch	construction land	Total
Area	427.02	384.87	135.23	27.58	8.87	14.59	998.17
proportion	42.78	38.56	13.55	2.76	0.89	1.46	100

The statistical analysis of the changes in land use reveals only small percentage differences between the time states for several land use classes. If we consider land scape structure, e.g., the plot size for grassland or agriculture, then we can see a development from many small areas to a few large areas. Furthermore, overlays of maps from different time levels gives exact spatial information regarding the persistence of biotopes and ecosystems over long periods of time. This can be useful for nature conservation and in the allocation of limited financial resources for landscape conservation and development. From Fig.3 and Table 1, we can see that the land use had been changed. After land rehabilitation, the mainly type of land use are tilled land, which according for 42.78 percent instead of the waste land and side slope before. The forest has reached 384.87 ha, according for 38.56 percent (Details in Table 2). So we can see that the waste land disappear, instead, tilled land and forest instead of it.

Table 2 Change of land use structure between before and after the land rehabilitation

Type	Area(Unit: ha)			Proportion(%)		
	Before	After	Changed	Before	After	Changed
Road area	20.57	27.57	+7.01	2.06	2.76	+0.70
Highwall area	192.09	0	-192.09	19.25	0	-19.25
Dump area	778.68	0	-778.68	78.01	0	-78.01
Gangue area	2.68	0	-2.6801	0.27	0	-0.27
Construction land	4.13	14.59	+10.45	0.41	1.46	+1.05
Tilled land	0	427.02	+427.02	0	42.78	+42.78
Woodland	0	384.87	+384.87	0	38.56	+38.56
Forest belt	0	135.23	+135.23	0	13.55	+13.55
Ditch	0	8.86	+8.86	0	0.89	+0.89
Total	998.17	998.17	0	100	100	0

Note: 'changed'='After'-'Before', '+' means after the rehabilitation the area becomes larger, '-' has the opposite means with '+'.

3.1 Present land cover distribution

With the process of the land rehabilitation, the vegetation (trees, frutex, grass), climate (temperature, rainfall,) and soil data of the corresponding position were collected. Geographic data in the research area were collected by GPS in July, 2006.

On the spot spectrum measurement: the spectrum of main plant/vegetation species in the area were measured and analyzed. Many corresponding works on the digital map are in processing, 3000 point of the area was measured by GPS. In order to reduce the impact of the background of the soil and noise, here we selected amended soil conditioning index of vegetation. Related studies have shown that the method not only can enhance their signals revegetation, but also can greatly reduce the impact of soil, while this map can reflect the change in the distribution of vegetation types as a whole. Here FCD (Forest Canopy Density) models was used to extract land cover information, here vegetation index V = ((B3 +1) * (256-B2) * (B3-B2)) 1 / 3, using the ArcGIS Spatial Analysis function come As a result. As shown in Fig.7 on the grounds SPOT data extracted from the sea state Dump the spatial distribution of vegetation index.

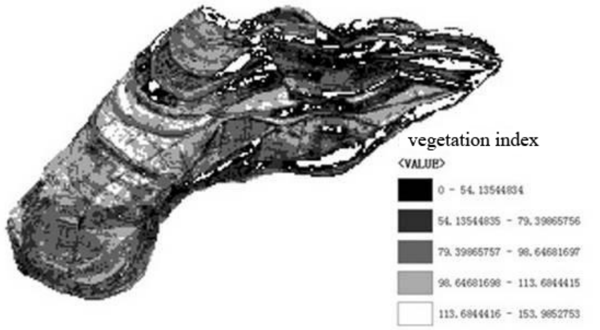

Fig. 7 the land coverage of Haizhou coal mine waste area.

4 Discussion and conclusions

Mining activities have been in existence for thousands of years. Mining activities are known to ravage large areas leaving them uncultivable resulting in permanent, non-restorable land surface. The disturbances are most evident and protracted in arid areas subjected to moisture deficiency, salt accumulation and erosional hazards.

For the environmental characterisation of mine wastes, both physical-geotechnical and geochemical parameters are determined. Physical-geotechnical properties of mine wastes such as grain size distribution, in situ density and hydraulic conductivity are also known to affect the geochemical behaviour of wastes and may impact design, stability and drainage of the waste facilities. Because of the importance of physical-geotechnical factors in most earth works, standard procedures have been developed.

The integration of medium resolution satellite data with high resolution satellite data is a powerful mix for a deep analysis of the territory covered by mined area. Medium resolution data, for which repetitive worldwide coverages are available, and having with a pixel size in the range 10-30 meters, provide information concerning medium scale mapping and the evaluation of historical changes. On the other side, high resolution data enable a more detailed description of the mining sites and its surrounding, enabling modeling procedures with a more detailed reference scale. Of course, in the analysis, specific attention must be paid also to the cost of the data, that quickly grows when geometrical resolution increases.

The land rehabilitation affects landscape by changing the type of land use and making the new patches, corridors and shape of matrix. After the land rehabilitation, waste land disappeared instead of the tilled land and forest.

Information about indicators such as landscape fragmentation should be disseminated to a wide audience, so that the general public, and especially the responsible actors, be made aware of the problem. A changing landscape can affect not only flora and fauna, but also the quality of life and health of our society, involving different aspects such as noise pollution, air pollution and recreation potentials.

The study provides a detailed analysis of the research area before and after land rehabilitation projects. The results show that the effect of the projects varies considerably according to the driving forces. The project aims to transfer know-how on Satellite Inspection Systems, to provide continuous monitoring and a quantitative and objective view of the environmental impact of land rerehabilitation operations in local, regional and national level and also on Geographic Information Systems (GIS) to integrate all the above information and perform different kind of territorial environmental analysis. Moreover, the project aims to transfer know-how on the characterisation of contaminated land and on the rehabilitation/revegetation technologies for polluted land and waste disposal areas.

Furthermore, Modern information technologies such as the internet and, in particular, interactive Web mapping tools, offer effective possibilities for public information. Modern visualization technologies, such as 3D Visualization, can create virtual impressions of landscapes and their changes, so that such information can be vividly illustrated and prepared for a wide spectrum of use.

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