Maps for the reclamation of industrial and mining wasteland in Daye County, Hubei province, China

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(Received 10 September 2012; resubmitted 26 May 2013; accepted 26 August 2013)

Reclamation of industrial and mining wasteland can help to address the current urgent challenge of land resource needs in China. In order to ensure well-developed reclamation planning, a large number of field surveys of industrial and mining wasteland were undertaken in Daye County, which is located in the south-east of Hubei province. Through a series of indexes, the reclamation potential of the industrial and mining wasteland was determined. Based on the surveys and evaluation, a specific reclamation plan was then produced, and it is shown on four major maps, which are the industrial and mining wasteland status map, the reclamation planning map, the reclamation potential distribution map, and the major reclamation project distribution map. The scale of the first two maps is 1:250,000, and the scale of the latter two maps is 1:300,000. The main purpose of this project is to provide a detailed planning scheme for local government, which will assist with important decision making in land-use policy, and to provide a unique perspective and experience for scholars all over the world.

Keywords: reclamation; industrial and mining wasteland; planning; potential; maps; China

1. Introduction

In China, over the last 10 years, arable land has continued to decrease while construction land has increased drastically (Deng, Wang, Hong, & Qi, 2009; Liu, Wang, & Long, 2008, 2010). Meanwhile, China is facing severe environmental deterioration and damage due to continued industrial development (Xu, 1999). In order to satisfy the requirements of socio-economic development for land resources, and to protect arable land, the State Department of China has issued three policies relating to economic and intensive land use for the period of 2004 to 2012. Reclamation of industrial and mining wasteland is a primary tool for intensive land use and environmental restoration (Guo, Wu, & Zhu, 1990). Although some scholars have done a lot of work on the reclamation of mining wasteland, most of these studies have been qualitative and did not describe a specific and feasible project (Li & Jiang, 2004; Li, Zhao, & Chen, 2004; Song & Zhou, 2001). As of March 2013...
2012, China launched the first round of reclamation for industrial and mining wasteland in 10 different provinces. To ensure this activity is implemented effectively, strategic planning of the reclamation of industrial and mining wasteland has been implemented.

Reclamation planning has the same goals as land-use planning, both of which aim to increase land-use efficiency, keep a quantitative balance of arable land, and improve land quality, as well as protect the environment. However, reclamation plans and land-use planning concentrate on different aspects and different scales. While land-use planning maps mainly indicate the conversion to construction land from other land-use types (Huang et al., 2012), reclamation planning maps primarily indicate the boundaries of wasteland, assess the reclamation potential, and guide the project site selection.

In this study, we present some new reclamation maps of Daye County in Hubei province, China. Prior to mapping, we did a lot of work, including field surveys, statistical analyses of the plot numbers, cartographic generalization of the working map, and classification and analysis of every unit based on their attributes. These maps are a new creative achievement that will assist with the reclamation of industrial and mining wasteland in China. They will also help to give a better understanding of the geography of Daye County and will provide a new perspective for reclamation planning in other locations. Geographically, the study area, Daye County, is located in the south-east of Hubei province (114°31′~115°20′E; 29°40′~30°15′N). It has an area of 1566.3 km², with 6943.58 hectares of industrial and mining wasteland. The area has a typical subtropical monsoon climate, with an average annual temperature of 16.9°C and an average annual precipitation of 1385.8 mm. Daye is one of the six copper mine production bases and one of the 10 iron production bases of China. It has 82 kinds of mineral deposits, and mineral production reached 12.87 million tons in 2011. Nearly 15,000 employees are engaged in mining work in Daye County. In 2010, the GDP of Daye County was 25.108 billion dollars, with the mining industry comprising 60% of that.

2. Methods

2.1 Reclamation potential survey

We adopted a questionnaire and sample survey for each town which was taken as the basic administrative units to investigate the cause of the wasteland, the conditions of reclamation, the reclamation rate, the investment in treatment projects, and the reclamation effects. The specific methods were as follows:

(1) As a working map, industrial and mining map-plots were extracted in 1:10,000 DOM form from the rural database of the Second National Land Survey of China. With the help of the mine distribution and the boundary line maps, the wasteland regions were first identified through image interpretation. These regions were then confirmed by field investigation.

(2) For the map patches with clear ownership boundaries, we considered them as independent plots. Where the actual region was beyond the ownership boundary, the actual region boundary prevailed.

(3) The area of minimum plot that could finally be drawn on a map was 4.0 mm², which is 400 m² in practice. The attributes of the map-plots include serial number, location, ownership institution, name of mine, code of land type, area, etc. Serial numbers were marked from left to right and from top to bottom, based on the collective landowners. Text was added in the form of ab/c, where a stands for the ID of the map-plot, b indicates the ownership properties, and c is the code of the wasteland type.
The spatial data were imported into a new database, which was in accordance with the Standard for Land Use Database, and the Prime Cultivated Land Database Standard. Classification codes and the fields of the database were set up according to the classification and coding table of the special investigation, and the structure of the outdoor survey table, respectively. A classification scheme of land types, legend, and color chart was created by reference to the Second National Land Survey Technical Regulations. Industrial and mining wasteland was shown in light brown. The colors of the other land types were the same as the colors used in the Second National Land Survey.

2.2 Evaluation and ranking of the reclamation potential

To evaluate the potential for new arable land from the reclamation of wasteland, a hierarchical analysis system using two steps was adopted for this study. At step 1, the recovery probability of each parcel was computed according to the pollution degree and its land suitability. For the wasteland that was ‘highly polluted,’ we designated it as planned urban-rural construction land. For the ‘not highly polluted’ and ‘not suitable for arable land’ category, we designated it as new forest land. The other remaining wastelands were designated as new planned cultivated lands that could be recovered, and the total area for each town \( A_i \) was aggregated. At step 2, we used a comprehensive analysis comprising another two indexes (the socio-economic constraint coefficient and the unknown influence variable) to estimate the ease or complexity of reclamation for the new planned cultivated lands generated in step 1, i.e. the probability of the land being recovered to agricultural land, based on the potential survey and the experts’ experiences. The potential index, the areas, and the rank size of new cultivated land for each town were then computed.

2.2.1 Recovery probability evaluation

The recovery probability was evaluated through the land suitability and the pollution degree. For the suitability of each parcel, we undertook a qualitative analysis according to the adjacent land suitability derived from the map of Regulations for Classification on Agricultural Land (Ministry of Land and Resources, 2003), the field survey, and the suggestions of local farmers. Firstly, the different evaluation scores were attached to the different parcels according to the suitability level (see Table 1). Secondly, a correction value was generated to correct the initial evaluation score, based on the suggestion of experts from the local land resource management office and local farmers. Finally, the sum of the scores for each parcel was considered as the evaluation score \( E_i \) for the land suitability of each town.

To identify the degree of pollution, a total of 77 soil samples were gathered in a field survey (see Figures 1 and 2). The soil samples were then analyzed in a laboratory to determine the degree

| Classes of suitability from the Regulations for Classification on Agricultural Land map | Quality score |
|--------------------------------|---------------|
| Highly suitable (I)          | 8~10          |
| Moderately suitable (II)     | 7~8           |
| Marginally suitable (III)    | 4~6           |
| Not suitable (IV)            | 0~4           |
of soil pollution. The soil pH, organic material content, and heavy metal content were determined. Following the pollution assessment, empirical estimated scores for the contamination treatment probability ($P_i$) for each town were determined from the samples and the experts’ experience. Table 2 shows the value ranges for each pollution category. Finally, the recovery probability index ($n_i$) can be defined as:

$$n_i = \left( \frac{E_i}{\sum_{i=1}^{n} E_i} + \frac{P_i}{\sum_{i=1}^{n} P_i} \right)$$

### 2.2.2 Computing the socio-economic constraint coefficient

In China, due to the constraints of limited funds, the lack of specialized persons for reclamation, and so on, the actual intra-county and inter-county reclaimed land areas are different each year. Local government cannot provide sufficient resources to change the theoretical reclaimed potential to the actual potential for each town. In this paper, the average share of the reclaimed area for each town in the total experimental reclaimed area of the whole city in the last 10 years was

**Table 2. The value ranges for each pollution category.**

| Soil pollution degree   | Contamination treatment probability score |
|-------------------------|-------------------------------------------|
| Highly polluted (I)     | 0                                         |
| Moderately polluted (II)| 1~4                                       |
| Slightly polluted (III) | 4~10                                      |
| Not polluted (IV)       | 10                                        |
computed and normalized and was taken as a constraint coefficient of the theoretical potential converted to actual potential. The constraint coefficient is expressed as:

\[ \alpha_i = \frac{q_i}{\sum_{i=1}^{n} q_i} \]

where \( \alpha_i \) is the constraint coefficient, and \( q_i \) is the reclamation area of town \( i \).

2.2.3 Determining the influence of the unknown variables

Although the rate of implementation of new cultivated land from land reclamation is very high for each province in China, it is difficult to return wasteland which is polluted or unused to its previous condition (Hu, Zheng, Xu, & Zheng, 2012). In addition to social and economic constraints, there will be other unknown causes which are occurring randomly that prevent wasteland and polluted land being recovered to a normal state. In this paper, we compute the transformation index, which accounts for the influence of unknown factors, based on the historical data of Daye County. With the aid of the aforementioned questionnaires that were collected from every local land
management administration, we also acquired the historical growth rate of new cultivated land from reclamation in each town. Subsequently, the rate of increase of new cultivated land was calculated and normalized. The transformation index is defined as:

$$\beta_i = \frac{g_i}{\sum_{i=1}^{n} g_i}$$

where $\beta_i$ is the transformation index, and $g_i$ is the rate of increase of new cultivated land from reclamation in town $i$.

2.2.4 Calculating the potential index and the new cultivated land area from reclamation

The potential index and the new arable land area from reclamation of each town can be described as:

$$\mu_i = \alpha_i \times \beta_i \times n_i$$

$$S_i = A_i \times \mu_i$$

where $\mu_i$ is the potential index, $A_i$ is the total area of wasteland that is planned to be reclaimed as cultivated land for town $i$, and $S_i$ is the potential area of new cultivated land from reclamation.

2.3 Project sites division

Four project areas were created, obeying the following rules: (1) the areas were based on the evaluation of the reclamation potential; (2) the areas must submit to the land-use planning of Daye County; (3) the reclamation should not destroy the ecosystem and environment; (4) boundary lines should be perfectly kept; and (5) the new project sites must be located in a permitted zone of land-use planning. The working map and the potential distribution map were imported into ArcGIS 9.3 software. Then, given the spatial distribution and the scale of the potential, we used an overlay analysis method by taking the towns as the basic units to divide the whole experimental area into four parts. According to the importance of the location, and the suggestions from experts, several sites were adjusted by a small margin.

With regard to those towns that could not be self-balanced, we just made them balanced at a county level, which means that when the reclamation area was bigger than the new built-up area within one town, another town could obtain the same amount of new building area as an extra part. At the same time, the reclamation area was clustered into the surrounding area based on the types of the surrounding land use.

Based on the above thinking, five major thematic maps were compiled (see Figure 3).

3. Description of the four major map designs

For a full understanding of the distribution and the other characteristics of the industrial and mining wastelands, as well as to give specific guidance to local government, supported by a geographic information system, four major maps were designed under the ArcGIS 9.3 software environment.

The current distribution and damage situation of the polluted lands and wasteland are shown on the industrial and mining wasteland status map. As can be seen from the map, the light brown areas with a blue dotted line boundary are the damaged and wasteland areas. Each plot has a unique code in the form of ‘Fxxx’, where ‘xxx’ is the number of the plot, and ‘F’ represents reclamation.
The reclamation potential map primarily indicates the potential reclamation quantity (the total area of potential) and the proportion of different kind of potential. We used different sizes of pies and different heights of pillars to represent the total potential area and the proportion of different kind of potential for different towns, respectively. There was no reclamation potential in the towns occupied by light blue color while a great deal of potential was generated in the towns covered by orange color.

Figure 3. Framework of the four major map designs.
The reclamation planning map provides a comprehensive perspective for land-use change by industrial and mining wasteland reclamation in the future. Unlike the display of the industrial and mining wasteland status, there are two types of dotted line with different colors, to show the reclamation zones (with black dotted line boundary), new built-up areas in constructive expansion permitted zone (with red dotted line boundary) and constructive expansion conditionally permitted zones (right-inclined lilac stripes). The increases in new built-up areas and the decreases in reclamation areas reflect the dynamic balance in the quantity of land resources. This is one of the most important tools for land management in China. We have numbered the new built-up parcels in the form of ‘Jxxx’, where ‘xxx’ is the number of the parcel and ‘J’ represents construction. Because all the kinds of thematic planning and all the land-use actions must be consistent with the general plan of land use in China, the new built-up areas are programmed within the constructive expansion permitted and conditionally permitted zones, which are strictly designated on the overall land-use planning map. Other features are shown in the same way as the overall land-use planning map.

The major reclaimed project distribution map shows the regions that government will invest most of the money and labor in, to allow the polluted land and wasteland to recover in the future. We used different value tints to represent the distribution of the four major reclaimed project: the area with the darkest purple color (the 1st project zone); the area with ‘Aster Purple’ color (the 2nd project zone); the area with ‘Medium Lilac’ color (the 3rd project zone); and the area with the lightest purple color (the 4th project zone). In addition, the main transportation networks and most of the built-up areas are also shown through the use of different colors and patterns. It should be noted that the project distribution region just indicates the rough extent of the major projects to be implemented in the future.

4. Conclusion
While we must face the reality that the construction land of every city cannot be expended indefinitely, but we do need more land for social and economic development. The reclamation of polluted land and wasteland is one of the most effective approaches to resolve this problem. However, at present, this has not yet been taken seriously into account in China. In this project, we undertook a lot of detailed field surveys and gave the local government a specific process to investigate and evaluate the reclamation potential. Finally, the detailed reclamation planning is shown on four major maps. Ultimately, we expect that our research will provide a useful perspective for policymakers in today’s land shortage climate. Meanwhile, we think that our study will also be a valuable resource for those wanting to understand the geography of Daye County.

Software
The field survey data storage and processing were completed in Microsoft Office Excel 2007. The database building and spatial analysis were undertaken in ArcGIS 9.3. Adobe Illustrator CS6 and ArcGIS 9.3 were used to make the maps.

Acknowledgements
This research was supported by Geographical Conditions Monitoring in China (NO: 2012BAH28B02) and the China Postdoctoral Sustentation Fund (2012M511679). The authors would like to thank Xu Tingting, Zhang Cheng, Tang Zijing, Wang Na, Sun Janwei, Qian Jing, and Liu Chang for their assistance with the
field survey data collection. The authors also acknowledge the review and improvement of the manuscript by Prof. Yaolin Liu.

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