Analysis on Dynamic Changes of Roliai Laterite Nickel Mine from 2013 to 2020

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Abstract. In order to accurately obtain the mining activities of Roliai laterite nickel mine, based on the remote sensing technology and object-oriented image analysis, methods of multi-scale segmentation based on scale optimization and optimal classification threshold selection were used to extract nine mining activity elements from WorldView II images of 2013 and 2020 respectively. According to the extraction results, the dynamic changes of each element from 2013 to 2020 were analysed from the aspects of area and intensity. Our accuracy evaluation results showed that the overall accuracies of the two extraction results are higher than 90%, and the Kappa coefficients are higher than 0.81. From 2013 to 2020, the mining scale and mining intensity of Roliai laterite nickel mine showed a trend of rapid expansion on the whole, in which the mining area increased the most, reaching 1.02 km², and the average annual change intensity was intense, and the corresponding dump area also increased by about 0.35 km². In the past seven years, Roliai laterite nickel mine has developed from the stage of exploration and mining to forming a relatively complete industrial chain of mining, milling and metallurgy, entering a development stage of rapid expansion.

1 Introduction

Nickel is widely used in stainless steel industry, alloy steel, electroplating, electronic batteries and aerospace fields. At present, nickel resources are relatively poor in China, especially under the background of rapid development of stainless steel industry and new energy vehicles, the import volume of nickel ore sands and nickel concentrate is gradually increasing. At present, the Indonesia laterite nickel ore is one of the main sources of imported nickel resources for China. Therefore, multi-factor extraction and multi-period remote sensing dynamic change study of laterite-type nickel ore in the Philippines can master its mining dynamics, which is of great significance for predicting the resource development potential and future development trend of the mineral areas[1-2].

The Roliai laterite nickel mine is located in the ore concentration area of Southeast Sulawesi Province in the southeast of Sulawesi Island, Indonesia. As a mining that has developed in recent years, there is still a lack of reliable data information about the mining development status of Roliai laterite-type nickel mine. Therefore, it is necessary to quickly and intuitively acquire the dynamic change status of the mining development by using remote sensing technology.

In this paper, based on the extraction results of mining activity elements of Roliai laterite nickel mine, the transfer matrix of various types was calculated. Combined with Aldwaik theory of change intensity analysis, the changes of the nickel mine were analysed from the aspects of area and strength, in order to judge its dynamic changes. Our research can provide basic reference for understanding the development of laterite-type nickel ore in Indonesia and evaluating the dynamics of nickel resource export.

2 Data and methods

2.1 Data resources

The WorldView-2 satellite image data of Roliai laterite nickel mine in 2013 and 2020, obtained in this research (Fig.1), includes panchromatic image and multispectral image with spatial resolution of 0.5 m and 2 m, respectively. The multispectral image includes six visible bands and two near-infrared bands. The acquired images were preprocessed by atmospheric correction, geometric correction, image fusion, etc., and an eight-band image with 0.5m spatial resolution was obtained.
According to the object-oriented thought[3], multi-scale segmentation based on scale optimization[4-5] and optimal classification threshold selection method[6] were adopted to complete the extraction of elements from Roliai laterite nickel mine in the two phase images, including nine factor categories such as mining area, dump and smelter. See Fig.2 for the extraction results of elements in the two phase images. In the study area, 600 test samples were uniformly selected by visual interpretation for accuracy test, getting the accuracy of all kinds and the overall accuracy. The overall accuracies of Roliai laterite nickel mine of two phase remote sensing image are 91.41% and 90.9%, respectively, and the Kappa coefficients are 0.8145 and 0.8407, respectively. The results meet the analysis needs.

\[ S(t) = \frac{\left[ \sum_{i=1}^{J} \left( Y_{t+1} \times C_{ij} - Y_t \times C_{ij}\right) \right] \times 100\%}{Y_{t+1} - Y_t} \]  

Where \( J \) is the number of land use categories; \( C_{ij} \) is the area transformed from categories \( i \) to categories \( j \) in time \( t \); \( Y_{t+1} \) and \( Y_t \) are the start time and the end time of time segment \( t \) separately.

The category intensity analysis can show the intensity change of each land use category over a specific time interval, using annual increase intensity \( G_{ij} \) (Equation 2) and annual decrease intensity \( L_{ti} \) (Equation 3) to explain a certain type of land use change. \( G_{ij} \) is the increasing intensity of land use category \( j \) in time \( t \), and \( L_{ti} \) is the decreasing intensity of land use category \( i \) in time \( t \). Based on the observed change intensity \( S(t) \), if \( G_{ij} \) or \( L_{ti} \) is greater than \( S(t) \), the land use category is active. Otherwise, the changes lie dormant. The difference between \( G_{ij} \) and \( L_{ti} \) is the net intensity.
\[ G_{ij} = \left[ \frac{\left( \sum_{i=1}^{n} c_{ij} \right) - \left( \sum_{i=1}^{n} c_{ij+} \right)}{\sum_{i=1}^{n} c_{ij}} \right] \times 100\% \tag{2} \]

\[ L_{ij} = \left[ \frac{\left( \sum_{i=1}^{n} c_{ij} \right) - \left( \sum_{i=1}^{n} c_{ij-} \right)}{\sum_{i=1}^{n} c_{ij}} \right] \times 100\% \tag{3} \]

### 3 Results and analysis

#### 3.1 The change and transfer of various types of area

Based on the results of multi-factor extraction in the second phase, the changes of area and area quantity of each factor category and the transfer matrix were calculated (Table 1, Table 2). According to the table analysis, it can be seen that the areas of mining areas, dumps and smelters in the factors of mining activity areas showed a significant increasing trend. Among them, the area of mining area increased the most, from 1.03 km² in 2013 to 2.05 km² in 2020, an increase of about 1.02 km², most of which came from the transformation of vegetation (0.86 km²) and bare soil (0.37 km²). At the same time, the mining area also transformed into dump (0.11 km²) and bare soil (0.07 km²) to varying degrees, which also indicated that the area of the mining area was not simply increased or decreased, but transformed with other elements, and a part of the old mining area (tailings or waste mining area) transformed into dump or bare soil, or as a result of natural restoration and man-made restoration into vegetation areas. The area of the refuse dump increased from 0.15 km² in 2013 to 0.49 km² in 2020 with an increase of about 0.34 km², mainly due to the transformation of vegetation, bare soil and mining area (waste mining area or tail mining area). Compared with the images in 2013, Roliai nickel mine has built a new laterite nickel smelting plant in 2020, covering an area of about 0.18 km², which was mainly occupied vegetation area (0.11 km²) and bare soil (0.06 km²) indicating that Roliai laterite nickel mine has the smelting and processing capacity of laterite nickel mine at least in 2020 and begun to form a mining development system with the integration of mining, metallurgy and processing. The establishment of the smelter has further improved the progress and speed of mining development of Roliai laterite nickel mine.

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<tr>
<th>Table 1. Area statistics and transfer matrix of Roliai laterite nickel mine in 2013 and 2020. (km²)</th>
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<td><strong>2013</strong></td>
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<td><strong>area change</strong></td>
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#### 3.2 Intensity of change

According to the formula of annual observed change intensity, the annual observed change intensity of Roliai laterite nickel mine from 2013 to 2020 was calculated as S=5.82%, which was used as the reference value to judge the change rate of each category.
As can be seen from the figure 3, the average annual increase intensity of other factor categories except vegetation area is greater than the base value $S$, indicating that the overall changes in our study area were drastic. Among them, mining area, dump and building (smelter), three factor categories directly related to mining activities, the net increase and strengthening degree are positive, indicating that they all show a net increase and a fast growth trend reflecting that the overall mining of Roliai laterite nickel mine maintains a faster speed during 2013-2020.

4 Conclusion

Based on the object-oriented method, this paper extracted nine factor categories, such as mining area, dump, and smelter and so on, from the images of Roliai laterite nickel mine in 2013 and 2020 respectively. According to the extraction results, the changes of each category from 2013 to 2020 were analysed in terms of area and intensity. From 2013 to 2020, the mining scale and mining intensity of Roliai laterite nickel mine showed a trend of rapid expansion on the whole, in which the mining area increased the most, reaching to 1.02 km$^2$, and the average annual change intensity was intense, and the refuse dump area also increased by about 0.34 km$^2$ correspondingly. In 2013, Roliai laterite nickel mine was basically in the early stage of mining. By 2020, the completion of smelter indicated that Roliai laterite nickel mine has started to build a relatively complete industrial chain of integrating mining and metallurgy, and there were a number of trunk roads connecting the southern coastal ports for export transportation. Therefore, Roliai laterite nickel mine has begun to enter a rapid expansion stage of mining development.

In future work, it is planned to increase the frequency of observation, and expand the intensity of interval level changes based on more period data, so as to obtain more detailed changes.

References