Intelligently Extracting and Analysing High-Resolution Remote Sensing Images for Demolition and Reclamation Land Assessment in Population Relocation for Poverty Alleviation

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Abstract. In recent years, China has witnessed a rapid development in the field of high-resolution satellite data acquisition. These remote sensing images obtained from satellites have been extensively applied in the social and economic sectors. Population relocation for poverty alleviation is a key task during the implementation of the 13th Five-Year Plan, involving 1,400 counties in 22 provinces in China. This study focuses on the utilisation of high-resolution remote sensing data and data of the national relocation information system to intelligently analyse changes in demolished and reclaimed lands in the selected area. The area is a county in Shandong Province, and according to the data from the national relocation information system, it constitutes 12 centralised resettlement sites hosting 2,510 families comprising 7,708 people, all classified as poverty-stricken households by the state. This method is suitable for the relocation of the entire village areas rather than the scattered relocation of individual households. It also provides an effective support for the local government to save and intensively use land resources, thereby avoiding waste of land resources and construction funds.
1. Introduction

Prioritising helping those living in areas where lands are inadequate for subsistence to escape poverty, population relocation programmes for poverty alleviation are available under the direction of the National Development and Reform Commission (NDRC) since the end of 2015. This involves moving from areas with impoverished population and resettlement in moving-in areas. Resettlement methods are either centralised or decentralised. A centralised resettlement point refers to a point equipped with public service facilities and hosting more than six families categorised as poor households. This study focuses on the centralised resettlement point. Demolition and reclamation of moving-out areas and the construction of facilities and industrial development in moving-in areas are anticipated to become critical issues during the later stages of the 13th Five-Year Plan. Therefore, developing a fast and accurate approach for identifying the geographic positions of moving-in and moving-out areas is necessary. Although the mapping of moving-in and moving-out areas based on remote sensing approaches remains rudimentary, a few studies employing remote sensing imagery data for urban development land extraction are available.

Generally, urban development land is land within the range of urban development as defined in the overall land use plan, including residential, communal non-residential, industrial, mining, warehousing, commercial or other special purposes lands contained in the implementation of an urbanisation plan. Improving the convenience of urban land use information extraction, remote sensing is a widely used technology for the analysis of large-scale land use changes. The image features of the moving-out area are like those of an urban construction land before demolition and reclamation. This enables remote sensing to extract data for the moving-out area to verify demolition and reclamation progress.

2. Existing extraction methods of urban built-up areas

Some studies achieved favourable results in mapping urban built-up areas using remote sensors. Yang and Zhou semi-automatically extracted residential areas from Landsat Thematic Mapper (TM) imagery data using interspectral threshold values, but this lacks objectivity because the applicable threshold values are determined through multiple tests. Cha et al. improved this approach and extracted urban land use information from TM imagery data with the modified Normalised Difference Build-Up Index (NDBI). Following the launch of the Landsat-8 in 2015, Zhou et al. used Landsat-8 OLI imagery data to summarise spectral curve features of different ground objects, modified the NDBI approach and proposed an effective NDBI algorithm for the mapping of urban development lands. The principle of the NDBI method is applied to the WFV data of the GF-1 satellite image to extract data for the migration area. In recent years, studies on extraction methods for urban built-up areas from GF-1 and GF-2 remote sensing imagery data are increasing.

3. Experimental methods

3.1. The Water Eraser–Normalised Difference Build-Up Index (WE-NDBI) method

This method, used in our previous research, is suitable for GF-1 WFV image extraction for urban built-up areas. Through experimental comparison, the method was proven to yield good accuracy. The spectral curves of seven types of ground objects, namely, blue-roofed built-up areas, red-roofed
built-up areas, grey-roofed built-up areas, bare lands, water bodies, farmlands and woodlands, were obtained through supervised classification (Figure 1).

Figure 1. Spectral curves of seven ground objects, namely, blue-roofed built-up areas, red-roofed built-up areas, grey-roofed built-up areas, bare lands, water bodies, farmlands and woodlands.

Figure 1 shows that the DN values of the red-roofed built-up areas, blue-roofed built-up areas, grey-roofed built-up areas and water bodies in Band 4 are lower than those in Band 3. Therefore, NDBI_{Band4-Band3} data were extracted to create a new binary image, with grey levels involving positive values representing red-roofed built-up areas, blue-roofed built-up areas, grey-roofed built-up areas and water bodies derived from Equation (1).

\[
NDBI_{GF1} = \frac{\text{Band 4} - \text{Band 3}}{\text{Band 4} + \text{Band 3}} \quad (1)
\]

The NDBI_{GF1} in the equation denotes a normalised image. For mapping moving-in and moving-out areas for population relocation programmes associated with poverty alleviation, water bodies on the normalised images are considered as noise requiring elimination. Image analysis through NDBI_{GF1} reveals typically higher values for water bodies compared with the blue, red and grey-roofed built-up areas. If \( W \) is the minimum value for a water body, a new index excluding water bodies termed Water Eraser–Normalised Difference Built-Up Index (WE-NDBI) is advanced as expressed in Equation (2).

Since \( W \) is an empirical value, it changes with the data acquisition time, data pre-processing and other factors.

\[
f(NDBI) = \begin{cases} 
NDBI & (NDBI \leq W) \\
0 & (NDBI > W) 
\end{cases} \quad (2)
\]

3.2. Change detection in built-up areas

After the WE-NDBI method was used to extract the built-up area data, binary processing was conducted on the extracted results. The pixel value DN for areas with buildings is 1, whereas that without buildings is 0. To compare the changes for buildings before and after relocation, the DN value
of a new year’s data is subtracted from the DN value of the older year. The result is 0 for an unchanged area, 1 for a new area and −1 for a demolished area. (Table 1)

Table 1. Change detection index of built-up area.

| Result          | 0      | 1     | −1     |
|-----------------|--------|-------|--------|
| unchanged       |        |       |        |
| New built-up areas |      |       |        |
| Demolished areas |       |       |        |

4. Experimental data and preparation

Remote sensing data are classified according to spatial resolution into low, moderate, high and ultrahigh resolution data. In previous studies, moderate resolution data sources are primarily used for the mapping of urban built-up areas. This is because low resolution image data are advantageous in large-scale studies (e.g. large vegetation cover). High spatial resolution data is applicable to in-depth studies of a specific region (e.g. disaster assessment), as it records more details of ground objects, but at a greater cost. Ultrahigh spatial resolution data is the most expensive data source, revealing features of ground objects at the clearest level. Therefore, moderate resolution image data are the cheapest and most reasonable choice for the mapping of urban built-up areas.

In this experiment, Feixian County in Shandong Province was selected as the experimental area. Feixian County, under the jurisdiction of Linyi City, is in the south-central part of Shandong Province. It covers an area of 1,660.11km² with a population of 850,000. According to the statistics of the National Inspection Information System for Poverty Alleviation and Relocation, 12 centralized resettlement sites exist in the county, hosting 2,768 poor households comprising 1,069 families.

The experiments in this study utilise GF-1 WFV data. Considering that the poverty alleviation and relocation project started at the end of 2015 and ends in 2020, the relocation task for this year is basically completed around the country. Therefore, the downloaded GF-1 WFV data are images taken on 13 May 2016 and 23 May 2019. Their sensor ID is WFV1, and the product class is LEVEL1A, indicating that the product has undergone radiometric calibration. The experimental data exhibits four wavelength ranges presented in Table 2. The data were processed by orthometric and geometric corrections.

Table 2. Technical indicators for payloads of the GF-1 satellite.

| Band               | Wavelength (μm) | Spatial resolution (m) | Swath width (km) | Side swing | Revisit frequency (d) |
|--------------------|-----------------|------------------------|------------------|------------|-----------------------|
| Panchromatic and   |                 |                        |                  | ±35°       | 4                     |
| Multispectral      |                 |                        |                  |            |                       |
| cameras            |                 |                        |                  |            |                       |
| 1                  | 0.45 ~ 0.90     | 2                      |                 |            |                       |
| 2                  | 0.45 ~ 0.52     | 8                      | 60               |            |                       |
| 3                  | 0.52 ~ 0.59     |                        |                  | ±35°       | 4                     |
| 4                  | 0.63 ~ 0.69     | 16                     | --               |            | 2                     |
| 5                  | 0.77 ~ 0.89     |                        |                  |            |                       |
| Multispectral      | 0.45 ~ 0.52     | 16                     | --               |            | 2                     |
The WE-NDBI method was used to process GF-1 WFV data, producing extracted building area results for 2016 and 2019 in Feixian County. The poor households that relocated to the centralised resettlement area belonged to the same village or were from villages scattered around the centralised resettlement area. Therefore, considering the coordinates of the 12 resettlement points as the centre, the built-up area data is within the 3km buffer zone, enabling change detection in the built-up area and evaluation of the demolition of the 12 resettlement points.

5. Experimental method and result verification

5.1. Change detection in the built-up area

Using the processed data for both images, the WE-NDBI method was utilised for extracting built-up area data, followed by binary processing of the results. To obtain the new area (moving-in area) and the old area (moving-out area), change detection is performed on the extraction results by subtracting the two binary images to produce Figure 2. The areas with DN values of −1 (red areas) are possible old areas, that is, moving-out areas for poverty alleviation and relocation. The areas with DN values of 1 are new areas (yellow areas), indicated as capable of easily supporting centralised resettlement sites for poverty alleviation and relocation. Finally, the areas with DN values of 0 are unchanged areas (black areas).

![Figure 2. Change detection results of built-up areas highlighting demolition, unchanged and newly built areas.](image)

5.2. Verification of the location of centralised settlement points

According to the coordinates of the resettlement points reported by the local government, a distribution map of centralised resettlement points is generated (Figure 3).
Figure 3. Distribution map of centralised resettlement points of the study area.

The general residential area covers about 50,000 m², and so, a buffer zone was created with the coordinates of the settlement point as the centre and a 200 m radius. The buffer zone was overlain on Figure 2, providing data for built-up areas of the 12 centralised settlement points presented in Table 3.

Table 3. Extraction results of the centralised resettlement points

| Centralised resettlement points | Extraction results of built-up area | Centralised resettlement points | Extraction results of built-up area | Centralised resettlement points | Extraction results of built-up area |
|--------------------------------|-------------------------------------|---------------------------------|-------------------------------------|---------------------------------|-------------------------------------|
| No.1                           | No.5                                | No.9                            | No.5                                |
| No.2                           | No.6                                | No.10                           | No.6                                |
| No.3                           | No.7                                | No.11                           | No.7                                |
| No.4                           | No.8                                | No.12                           | No.8                                |

According to comparison of the scale of the resettlement sites and the extraction results in Table 3, those that are correct are preliminarily determined as Nos.1, 4-9 and 11-12. In July 2019, field survey was conducted on the 12 resettlement sites, with site No.2 located at the foot of the mountain, representing a resettlement site constructed from the original site. Therefore, the image comparison between the two phases produced no change. The small scale of resettlement site No.11 and its large built-up area extracted from the image are due to the reason that it is built in a newly developed residential area, and the area is a high-grade residential area built by a developer. The extraction
results for other resettlement sites are consistent with the field survey. Therefore, a high accuracy rate is inferred for the centralised settlement point extracted by this method. Figure 4 presents field survey photos of resettlement sites Nos.2 and 11.

![Field survey photos of resettlement sites: (a) No.2 and (b) No.11.](image)

**Figure 4.** Field survey photos of resettlement sites: (a) No.2 and (b) No.11.

5.3. **Monitoring results of demolition and reclamation**

5.3.1. **Image extraction results for demolished areas**

An area of about 2km around the centralised resettlement site is considered the moving-out area. The location of the settlement point coordinates was considered as the centre and 2km as the radius for extracting the buffer zone, and this was overlain with the change detection results of the built-up area extracted previously. The overlapping area is considered as a possible demolition area as indicated by the red areas in Figure 5.

![Image extraction results for demolition areas.](image)

**Figure 5.** Image extraction results for demolition areas.

5.3.2. **Image extraction results for reclamation areas**

The area reclaimed as vegetation in 2019 overlaps with the possible demolished area obtained in the previous step, with the overlapping area considered as a demolished and reclaimed area. Firstly, the vegetation index of the 2019 image is calculated, and the results were binarised. The area with a DN value of 1 is the reclaimed area, whereas the area with a DN value of 0 is considered as other areas. Then, the area with a DN value of 1 is overlain on the possible demolished area obtained in the
previous step, with the overlapping area as the demolished and reclaimed area. Figure 6 presents the area in black as that of demolition and reclamation.

![Figure 6. Image extraction results for the reclamation area.](image)

The total reclaimed area is estimated at 942802 m², although the accuracy of the estimate is presently unverifiable. In practical application, through a comparison of multi-stage calculations, a qualitative evaluation of the progress in demolition and reclamation of the area is possible.

6. Summary

Based on our previous research and the WE-NDBI method, Feixian County in Linyi City, Shandong Province, was selected as the experimental area to extract moving-out and moving-in areas for the poverty alleviation and relocation project. The main results are summarised as follows:

First, the migration area was extracted accurately. Compared with coordinates of the central resettlement sites reported by the local government, the current investigation accurately extracted data for 10 of the 12 resettlement sites.

Secondly, through extraction and calculation of demolished and reclaimed areas in the relocated area, a demolition and reclamation area was obtained. In the application process, the state can qualitatively analyse progress in the local government’s demolished and reclaimed area from extraction and calculation results of multi-phase images. The experiments in this study demonstrate the feasibility of using remote sensing images to monitor and evaluate demolition and reclamation of a relocation project.

However, some content for this method require improvement, and these can be further explored in the future. The first is exploring extraction of experimental data from the GF-2 satellite. Since the GF-2 satellite images exhibit higher resolution, these may yield more accurate extraction results. The second is that, although the moving-out area is assumed within 2km during extraction, the actual situation is not limited to 2km. The third is that the method used in the experiment was unable to extract reconstruction data of the original site. The fourth is that the experiment in this study evaluated demolition and reclamation in the moving-out area only qualitatively instead of quantitatively.

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