Typical Feature Extraction in Alpine Lake Area of Northern Tibet Based on Gaofen-1 Satellite

Dong Lina¹, Shang Kun¹, He Yun¹ and Zheng Xiongwei²*

¹ Land Satellite Remote Sensing Application Center, MNR, Beijing, 100000, China
² China geological Survey
*Corresponding author’s e-mail: zhengxiongwei@mail.cgs.gov.cn

Abstract. Satellite remote sensing is one of the indispensable means of natural resources monitoring and management. With the great improvement of the spatial resolution, spectral resolution, temporal resolution and data coverage capability of Chinese satellites, domestic satellites have been deeply and extensively applied in the natural resource management and geological survey. In recent years, the impact of global change on the ecological environment and biodiversity in the alpine region of northern Tibet has aroused great concern, among which the response to land degradation, desertification and plateau wetland protection are the important contents. In this paper, Gaofen-1 (hereinafter referred to as “GF-1”) satellite data are used to conduct the research and experiment of wetland and saline-alkali land feature extraction, which provides guiding suggestions and scientific references for the wider and deeper application of domestic satellites in feature extraction.

1. Introduction
Since the successful launch of the first operational satellite of the former Ministry of Land and Resources of the People's Republic of China, Resource No. 1 02C Satellite, on December 22, 2011, 14 natural resources remote sensing satellites have operated stably on orbit successively. The load variety of China’s natural resources remote sensing satellites has been expanded from original single-multispectral loads to multiple types of loads covering multispectral, hyperspectral and radar, greatly improving the spatial resolution, spectral resolution, time resolution and data covering capability, which has basically replaced foreign satellite remote sensing data of the same resolution and played a significant role in natural resources management and geological survey.

The GF-1 satellite was successfully launched on April 26, 2013, equipped with two 2m resolution panchromatic and 8m resolution multispectral cameras and four 16m resolution multispectral cameras, realizing the synthesis of high resolution and wide swath imaging on a single satellite at the same time with the scene width of more than 60 km at 2 m high resolution, and realizes a wide imaging of more than 800 km at 16m resolution.

Taking GF-1 satellite data as an example, this paper endeavors to dig the potential of satellite data interpretation, application capabilities and explores the research on element-oriented remote sensing information extraction. In this paper, the alpine lake area in northern Tibet is selected as the experimental area. Aiming at two typical elements of wetland and saline-alkali land which have a great impact on the ecological environment of the study area, the application and comparison experiments based on GF-1 satellite data are carried out, and the optimization strategy is put forward with certain results achieved.
2. Wetland extraction based on the fusion images of GF-1 satellite data

The wetland natural ecosystems, along with forests and oceans, are among the world’s three major ecosystems and are known as the "kidneys of the earth". The natural environment in the alpine area of northern Tibet is very harsh and the ecosystem is fragile as well. With the global change, the dynamic monitoring and analysis of large-scale wetland resources by using satellite remote sensing technology has significant advantages and great significance for ecological environmental protection. The identification and information extraction of wetland are the most basic and important way of using remote sensing technology in wetland resource monitoring. The supervised classification method is usually used to conduct the wetland extraction, so this study compares four supervised classification algorithms, including the maximum likelihood method, minimum distance method, neural network method and Mahalanobis distance method.

(1) Maximum likelihood method

Assuming that the statistics of each class in each waveband are normally distributed and given the likelihood of an image element belonging to a certain training sample, the image element is eventually grouped into the category with the highest likelihood. Its expression is shown as:

\[
g_i(x) = \ln p(\omega_i) - \frac{1}{2} \ln |\Sigma_i| - \frac{1}{2} (x - m_i)^T \Sigma_i^{-1} (x - m_i)
\]

Where \(i\) represents a certain classification; \(x\) is the n-dimensional feature space data (n is the waveband number), \(p(\omega_i)\) is the prior probability of \(\omega_i\); \(|\Sigma_i|\) is the determinant of the covariance matrix of \(\omega\) categorical data; \(\Sigma_i^{-1}\) represents the matrix reciprocal; and \(m_i\) represents the mean vector.

(2) Minimum distance method

It is a statistical identification method for pattern classification according to the distance between the pattern and representative samples of each category, where the identified pattern has the smallest distance from the sample of the pattern category to which it belongs. Assuming that the eigenvectors of \(c\) categories are represented by \(R_1, ..., R_c\), \(x\) is the eigenvector of the identified pattern, \(|x-R_i|\) indicates the distance between \(x\) and \(R_i\) (\(i=1,2,...,c\), and if \(|x-R_i|\) is the smallest, then \(x\) is classified as the \(i\) category.

(3) Neural network method

It refers to the method that uses computers to simulate the structure of the human brain and many small processing units to simulate the neurons of creatures, and algorithms to implement the identification, memory, and thinking processes of the human brain for image classification.

(4) Mahalanobis distance method

Assuming that the categories of all surface features are subject to Gaussian distribution, the J-M distance can be expressed as:

\[
JM_{ij} = \sqrt{k \left(1 - e^a\right)}
\]

\[
a = \frac{1}{8} \left(\mu_i - \mu_j\right)^T \left(\frac{C_i + C_j}{2}\right)^{-1} \left(\mu_i - \mu_j\right) + \frac{1}{2} \ln \left(\frac{1}{2} \frac{|C_i + C_j|}{\sqrt{|C_i| \cdot |C_j|}}\right)
\]

Where \(\mu_i\) and \(\mu_j\) indicate the mean vectors of the surface feature of Category \(i\) and \(j\) respectively; \(C_i\) and \(C_j\) indicate the covariance matrices of Category \(i\) and \(j\) respectively; \(\ln\) denotes the natural logarithm; \(|C_i|\) denotes the value of the determinant of matrix \(C_i\). In practice, assuming \(k=2\), the J-M distance ranges 0-2. For supervised classification, the small J-M distance between categories in the training samples reflects the poor separability of the categories in the samples, which will lead to that classification accuracy is not high.

Based on the actual distribution of regional wetlands, four types of samples were selected, including grassland, wetland, water body, and saline-alkali land.
Table 1. Degree of Separation of Wetlands from Other Samples Categories

| Category          | Quantity of Samples | Jeffries-Matusita Distance | Transformed-Divergence |
|-------------------|---------------------|----------------------------|------------------------|
| Grassland         | 3078                | 2.000000000                | 2.000000000            |
| Water body        | 227                 | 1.94018954                | 1.99787784            |
| Saline-alkali land| 1933                | 1.99922316                | 1.99999936            |

Figure 1. Wetland Information Extraction Results

The results that can be seen from Figure 1 are shown as follows:

Using the maximum likelihood method, the area of the extracted wetlands is smaller compared with the distribution of actual wetland, and too much information is extracted from the water bodies in the wetlands as well as the saline-alkali land in the upper left corner, leading to the reduction of the wetland area. Therefore, the extraction effect is just general.

Using the minimum distance method, the area of the extracted wetlands is larger compared with the distribution of actual wetland, and a small part of saline-alkali land and grassland is mistakenly classified as wetlands; the water bodies inside the wetlands are extracted more completely, with clear contour, and the water bodies at the boundary between wetlands and grassland is less extracted, so the overall extraction effect is ideal.

Using the neural network method, the extraction accuracy for wetlands is very close to that of the
minimum distance method, and the slight difference lies in the classification of grassland and saline-alkali land. It can be seen from the result drawing that, the neural network classification method tends to classify the perimeter of wetlands as grassland, while the minimum distance method tends to classify it as saline-alkali land. It can be seen from the image by visual observation that the wetlands are mostly surrounded by saline-alkali land, so the extraction of wetland information is comparable between the two methods, but the minimum distance method is more accurate, seen from the overall classification effect.

Using the Mahalanobis distance method, the area of the extracted wetlands is larger compared with the distribution of actual wetland, and the extracted location of wetland information by visual observation is basically accurate, only with slightly larger contour; the extraction effect for saline-alkali land is better; and the water bodies within the wetlands are extracted more completely, with missed extraction of external water bodies, so the overall effect is satisfactory.

It can be seen by making comparison and analysis on the above four methods that the extraction effect is relatively good when the Mahalanobis distance method is used for wetland information extraction using GF1 fusion images.

3. Land salinization extraction based on the fusion images of GF-1 satellite data

The land salinization is a phenomenon or process in which salts from the soil substratum or groundwater rise to the surface with capillary water, and then the water evaporates, so that the salts accumulate in the surface soil. The salinized soils or saline-alkali soils are widely distributed in China, covering a total area of about 100 million hectares. The soluble salts in the saline-alkali land mainly include sulfates, chlorides, carbonates and bicarbonates of sodium, potassium, calcium and magnesium, etc. Tibet has a good natural environment and a good foundation for developing green agriculture. However, soil salinization restricts the development and utilization of soil resources in Tibet. In this study, GF-1 satellite fusion image was used to carry out a research experiment on land salinization information extraction and classification.

Since the extent of land salinization is mainly determined by vegetation coverage and soil salinity, through calculating the normalized difference vegetation index (NDVI) and salinity index (SI) in this study and based on these two, a salinization monitoring model is constructed to extract the grading information of saline-alkali land.

(1) NDVI: Against the very small red-light reflection of dense vegetation and its unboundedly increasing RVI value, Deernig (1978) firstly put forward obtaining the normalized difference vegetation index (NDVI) by processing the simple ratio vegetation index (RVI) with nonlinear normalization, so that the specific value is limited in the range of [-1, 1].

\[
NDVI = \frac{b_{NIR} - b_R}{b_{NIR} + b_R} \quad (4)
\]

(2) SI: Select the blue and red wavebands that are sensitive to soil salinity.

\[
SI = \sqrt{b_B \times b_R} \quad (5)
\]

(3) SDI: By consulting the literature, the construction of "NDVI (vegetation index)-SI (salinity index)" is applied to extract saline-alkali land information. In the NDVI-SI feature space, there is a nonlinear relationship between NDVI and SI, and according to the research conclusions of Verstraete and Pinty, a straight line perpendicular to curve AB can nonetheless classify saline-alkali land into different grades. In the scatter diagram, the farther the point from point D, the more serious the land salinization will be, and the distance between the two points of C and D is SDI.

\[
SDI = \sqrt{(NDVI - 1)^2 + (SI)^2} \quad (6)
\]
In this study, the samples were classified into four categories using the natural breaks classification method (Jenks), including non-salinized land, slightly salinized land, moderately salinized land and heavily salinized land. The threshold is set as shown in the table below.

| Non-salinized land | Slightly salinized land | Moderately salinized land | Heavily salinized land |
|--------------------|------------------------|---------------------------|------------------------|
| 0~38               | 38~92                  | 92~186                    | 186~255                |

The calculation results of NDVI, SI and SDI index are shown in the figure below.

Figure 3. NDVI, SI and SDI calculation results

The fusion image and classification results of saline-alkali land are shown in the figures below.

Figure 4. GF-1 Satellite Fusion Image with Classification Results of Saline-Alkali Land

Combined with the analysis on the GF-1 satellite fusion images, the blue part in the classification diagram corresponds to the saline-alkali land with grayish-white tones in the image, the green part corresponds to the saline-alkali land with white color in the image, and the red part corresponds to the white saline-alkali land with higher brightness in the image. It can be seen from the overall extraction drawing of saline-alkali land that, the extracted information of saline-alkali land is more complete. From the detailed drawing, it can be seen that the classification of saline-alkali land is relatively accurate; therefore, it is ideal to extract the land salinization information from domestic satellite fusion images by using the soil salinization remote sensing model based on NDVI-SI feature space.

4. Conclusion

The GF-1 image was used to extract the wetland and saline-alkali land information, and different
methods and optimal effects were analyzed in the paper. However, with the difference of image phase and quality, there are also some differences in the extraction effects, especially for the extraction of fine texture elements, more experiments are further needed. With the great improvement of domestic satellite spatial resolution, spectral resolution, temporal resolution and data coverage, remote sensing satellite image acquisition cycle is short, data update speed is fast, and the amount of data is huge. Therefore, it is imperative to carry out automatic information extraction, which is also an important direction to carry out accurate information extraction of wetland and saline-alkali land by using high-resolution remote sensing information at present and in the future.

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