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A monitoring method of surface vegetation distribution in the Yellow River Basin based on remote sensing image segmentation

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Abstract: In order to overcome the problems of low accuracy and the time-consuming nature of traditional vegetation distribution monitoring methods, a new monitoring method of surface vegetation distribution in the Yellow River Basin based on remote sensing image segmentation is proposed. First, describe the segmentation features of remote sensing images. Secondly, based on the results of feature description, H-minimum transform is used to calculate the segmentation parameters of remote sensing image and complete the segmentation of remote sensing image. Finally, the maximum value synthesis method is used to calculate the surface vegetation coverage. Combined with the normalised vegetation index, the dichotomy model is used to calculate the distribution parameters of surface vegetation, and the distribution monitoring of surface vegetation is completed. The experimental results show that this method can effectively improve the monitoring accuracy and reduce the monitoring time, and the monitoring accuracy reaches more than 93%.

Keywords: remote sensing image segmentation; the Yellow River Basin; surface vegetation; distribution monitoring.

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1 Introduction

Vegetation is an important part of terrestrial ecosystem, which not only affects the material and energy cycle of the ecological environment, but also plays an important role in the climate stability and carbon budget balance of the whole region (Li et al., 2019a). Monitoring the distribution of surface vegetation can reflect the changes of regional ecological environment. As an effective indicator of ecological change research, the distribution of surface vegetation can well reflect the distribution of surface vegetation (Yue et al., 2019; Li et al., 2019b).

As an important area of social and economic development and ecological security, river basins are important ecological barriers in China. Desert and sandstorm areas are distributed in the north of the Yellow River Basin, the west is located in the alpine zone, and the middle is the Loess Plateau with serious soil erosion and fragile ecological environment (Liu et al., 2021; Zhang et al., 2019). In recent years, with the rapid development of the national economy, human activities have become more frequent and the intensity has increased. Therefore, studying the monitoring method of the distribution of surface vegetation in the Yellow River Basin can understand the ecological environment of the Yellow River Basin. For the fragile ecological environment areas, measures such as planting trees for forestry and returning farmland to forests can be taken. Therefore, the monitoring of surface vegetation distribution plays an important role in improving the environmental quality of the watershed.

Chen and Liang (2019) propose a vegetation distribution monitoring method based on EVI2 and multi trend analysis. This method extracts the spatio-temporal dynamic change characteristics of vegetation under the length of green turning period, dry yellow period and growing season. It is found that the East-West distribution difference of vegetation is very obvious, and it is also affected by the altitude of plant growth. With the increase of altitude, the trend of vegetation coverage gradually decreases. However, this method can only analyse the impact of natural environment on vegetation distribution, resulting in insufficient accuracy of vegetation distribution monitoring. Bai and Hu (2020) propose a vegetation distribution monitoring method based on CART decision tree. This method collects remote sensing data of natural reserves and performs regional segmentation on the remote sensing data. Taking the minimum segmentation area as a unit, it extracts spectral features, geometric features and texture features of the study area. The CART decision tree is used to classify the vegetation types, so as to obtain the distribution results of different vegetation types and complete the vegetation distribution monitoring.

However, this method requires a large number of remote sensing data operations, resulting in the overall monitoring time-consuming. Luo et al. (2019) based on the ecological data of the studied area over the years, combined with the maximum value synthesis method, trend analysis method and correlation coefficient method, analyses the dynamic change characteristics of vegetation distribution, and deeply analyses the impact of climatic factors and human activities on vegetation distribution characteristics. However, the research data of this method are all historical data, so it is difficult to analyse the current and future vegetation distribution.

In order to solve the problems of low monitoring accuracy and long monitoring time of the above traditional methods, a monitoring method of surface vegetation distribution in the Yellow River Basin based on remote sensing image segmentation is proposed. The overall research technical route of this method is as follows:

1. Describe the segmentation features of remote sensing images of the Yellow River Basin, including homogeneous features, heterogeneous features, texture features and shape features.
2. Based on the segmentation feature description results of remote sensing images, multi spectral weighted mixed gradient is introduced to calculate the information entropy of remote sensing images, and morphological operations are carried out on remote sensing images.
3. According to the morphological operation results, H-minimum transform is used to calculate the segmentation parameters of remote sensing image, and complete the segmentation of remote sensing image, so as to improve the effectiveness of surface vegetation distribution monitoring. According to the segmentation results of remote sensing images, the maximum value synthesis method is used to calculate the surface vegetation coverage of the Yellow River Basin. Combined with the normalised vegetation index, the dichotomy model is used to calculate the distribution parameters of surface vegetation, and the distribution monitoring of surface vegetation is completed.
4. Experimental verification, taking the monitoring accuracy and efficiency of surface vegetation distribution as the experimental comparison index, this method is compared with the traditional method.

2 Monitoring of surface vegetation distribution in the Yellow River Basin

2.1 Segmentation feature description of remote sensing images in the Yellow River Basin

Because the remote sensing image is the spatial object of the Yellow River Basin, it is necessary to describe the segmentation characteristics of the remote sensing image. The features that affect the segmentation quality mainly include homogeneous features and heterogeneous features. The homogeneous features mainly reflect the spectral standard of remote sensing images, and the heterogeneous features are reflected in the spectral mean of adjacent super pixels (Sharipjonova et al., 2020). The calculation formulas of the two are:

$$f = \frac{\sum_{k=1}^{n} N_k v_k}{\sum_{k=1}^{n} v_k} \tag{1}$$

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(y_i - \overline{y}\right)\left(y_j - \overline{y}\right)}{\left(\sum_{i=1}^{n}\left(y_i - \overline{y}\right)^2\right)\left(\sum_{i \neq j}\sum w_{ij}\right)} \tag{2}$$

In the above formula, k represents super pixels, N_k represents the number of pixels, v_k represents the standard deviation of pixels, w_{ij} represents the adjacent discrimination weight of super pixels, and y_i and y_j represent the spectral mean value of two super pixels respectively (Zhang et al., 2020).

Based on the above two features, texture features and shape features are combined to better describe the segmentation features.

The grey level co-occurrence matrix is used to express the texture features:

$$S = \sqrt{\sum_{i,j=0}^{n-1}\left(P_{i,j} - M_{i,j}\right)^2} \tag{3}$$

In the formula, S represents the standard deviation, $P_{i,j}$ represents the position of the square matrix, m represents the number of remote sensing images, and $M_{i,j}$ represents the mean value of texture features of remote sensing images. The calculation formula of $M_{i,j}$ is:

$$M_{i,j} = \frac{1}{m}\sum_{i,j=1}^{n-1} P_{i,j} \tag{4}$$

The shape characteristics of remote sensing images are mainly studied from the aspect ratio and area. The aspect ratio can describe the distribution characteristics of vegetation in different areas of the Yellow River Basin, and the area can distinguish the distribution area characteristics of different types of vegetation, so as to improve the effectiveness of vegetation distribution monitoring.

The calculation formula of length width ratio is:

$$R = \frac{L}{W} \tag{5}$$

In the formula, L and W respectively circumscribe the length and width of the matrix (Xie et al., 2019).

The calculation formula of area is:

$$A = \sum_{i=1}^{m} a_i \tag{6}$$

In the formula, a_i represents the area of a vegetation.

Through the above process, the calculation of texture features, shape features, aspect ratio and area is completed, and the accurate extraction of remote sensing image segmentation features of the Yellow River Basin is completed, which provides support for the follow-up remote sensing image segmentation to complete the monitoring of surface vegetation distribution in the Yellow River Basin.

2.2 *Monitoring of surface vegetation distribution in the Yellow River Basin based on remote sensing image segmentation*

Based on the segmentation features of the remote sensing image described above, the remote sensing image is segmented to realise the accurate monitoring of the surface vegetation distribution in the Yellow River Basin.

In order to improve the segmentation accuracy of the remote sensing image of the Yellow River Basin, it is necessary to convert the colour multispectral remote sensing image into grey-scale image. In this process, in order to avoid the loss of remote sensing image information, multispectral weighted mixed gradient is introduced to calculate the information entropy of remote sensing image (Astamirova et al., 2021; Wahyuningrum, 2020; Pourghasemi et al., 2019). The calculation formula of multispectral weighted mixing gradient is:

$$G_{mix} = \sum_{i=1}^{n} \omega_i G_i \tag{7}$$

In the formula, ω_i represents the weight coefficient and G_i represents the morphological gradient of remote sensing image. The calculation formula of weight coefficient ω_i is:

$$Q_i = \frac{E_i}{\sum_{i=1}^{n} E_i} \tag{8}$$

In the formula, E_i represents the information entropy of remote sensing image, and its calculation formula is:

$$E_i = -\sum_{j=0}^{L-1} p(j) \log_2 p(j) \tag{9}$$

In the formula, L represents the grey level of the remote sensing image, and $p(j)$ represents the histogram.

Because the direct use of gradient information entropy for remote sensing images will cause image noise problems and make the image contour information cheap, it is necessary to filter the remote sensing images of the Yellow River Basin. According to the multispectral weighted mixed gradient G_{mix}, the remote sensing image is processed by morphological operation:

$$\begin{cases} G_{rec}^{1} = I_{marker} \\ G_{rec}^{s+1} = \left(I_{marker} \oplus S_e\right) \cap I_{mask} \\ s = 1, 2, 3, \ldots \end{cases} \tag{10}$$

In the formula, G_{rec} represents the gradient of the reconstructed remote sensing image, $\oplus$ represents the morphological expansion operation, S_e represents the structural element, I_{marker} represents the remote sensing image mark, and I_{mask} represents the mask image (Zhao et al., 2021).

Because the ground features contained in the remote sensing image are relatively complex, it is impossible to directly segment the remote sensing image by background segmentation, which will lead to false minimum in the remote sensing image and reduce the monitoring effect of vegetation distribution. In order to improve the universality of remote sensing image segmentation and avoid the influence of extreme values on the segmentation results, h-minima transform is used to calculate the segmentation parameters of remote sensing image. The H-minima transform method can suppress noise and obtain more accurate segmentation results.

The calculation formula of segmentation parameters is:

$$H = \frac{(Med_2 - Med_0)^2 + (Med_0 - Med_1)}{Med_2 - Med_1} \tag{11}$$

In the formula, Med_0 represents the median value of the gradient image during remote sensing image segmentation, and Med_1 and Med_2 represent the maximum and minimum values of the gradient respectively.

According to the segmentation parameters shown in formula (11), high-precision segmentation of remote sensing images of the Yellow River Basin can be achieved, so as to improve the effectiveness of surface vegetation distribution monitoring.

Based on the segmentation results of remote sensing images, the distribution of surface vegetation in the Yellow River Basin is monitored. Because the sensitive fluctuations of surface vegetation are in infrared band and near-infrared band, the distribution information of surface vegetation can be obtained through the spectral characteristics of relevant bands.

The maximum value synthesis method is used to calculate the surface vegetation coverage of the Yellow River Basin, and the formula is:

$$I_{NDV}^{i,\max} = \overset{m}{\max_{\rho=1}} I_{NDVI}^{\rho} \tag{12}$$

In the formula, $I_{NDV}^{i,\max}$ represents the maximum value of surface vegetation coverage, m represents the number of remote sensing images, and I_{NDVI}^{ρ} represents the normalised vegetation index.

Under the infrared band and near-infrared band, the calculation formula of normalised vegetation index (NDVI) is:

$$I_{NDVI} = \frac{NIR - R}{NIR + R} \tag{13}$$

In the formula, NIR and R represent the reflection values in the near-infrared band and the infrared band respectively.

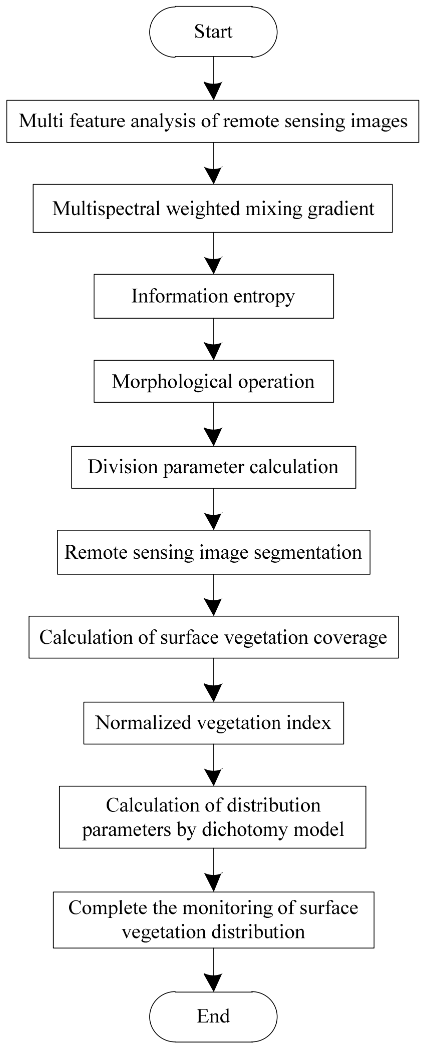
According to the normalised vegetation index, the distribution parameters of surface vegetation are calculated by using the dichotomy model:

$$C_{FV} = \frac{I_{NDVI} - I_{NDVI}^{soid}}{I_{NDVI}^{veg} - I_{NDVI}^{soid}} \tag{14}$$

In the formula, C_{FV} represents the distribution parameter of surface vegetation, I_{NDVI}^{soid} represents the pixel of surface bare soil coverage, and I_{NDVI}^{veg} represents the pixel of pure vegetation coverage.

In order to accurately monitor the distribution of surface vegetation in the Yellow River Basin, firstly, the segmentation characteristics of the remote sensing image of the Yellow River Basin are described. Secondly, the remote sensing image is morphologically processed and the segmentation parameters are calculated. Finally, the maximum value synthesis method is used to calculate the coverage of surface vegetation in the Yellow River Basin, and the dichotomy model is used to calculate the distribution parameters of surface vegetation, so as to complete the monitoring of surface vegetation distribution in the Yellow River Basin. The monitoring process of surface vegetation distribution in the Yellow River Basin is shown in Figure 1.

Figure 1 Monitoring process of surface vegetation distribution in the Yellow River Basin



3 Experimental verification

In order to verify the effectiveness of the proposed method for monitoring the distribution of surface vegetation in the Yellow River Basin Based on remote sensing image segmentation, comparative verification experiments were carried out.

3.1 Experimental data

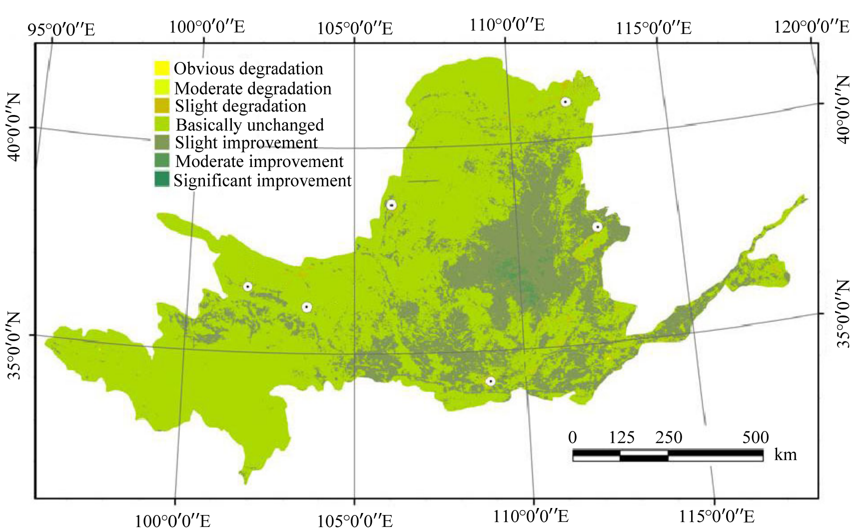
The experiment selected the multispectral remote sensing data of the Yellow River Basin as the experimental data. The Yellow River Basin is located in arid, semi-arid and semi humid areas, with a total area of 8 × 105 km^2, spanning four different geomorphic units from west to East. The Yellow River Basin has a large population and complex geographical conditions, which increases the difficulty of monitoring the distribution of surface vegetation. The distribution and changes of vegetation in the Yellow River Basin are shown in Table 1.

Table 1 Vegetation distribution change

Trend line slope	*Distribution change nature*	*The measure of area/km^2*	*Area percentage/%*
< –0.02	Obvious degradation	46.470	0.006
–0.02~–0.012	Moderate degradation	358.373	0.044
–0.012~–0.004	Slight degradation	7,635.311	0.932
–0.004~0.004	Basically unchanged	582,526.000	71.131
0.004~0.012	Slight improvement	223,570.300	27.300
0.012~0.02	Moderate improvement	4,796.683	0.586
> 0.02	Significant improvement	10.239	0.001

The vegetation distribution map of the Yellow River Basin is shown in Figure 2.

Figure 2 Vegetation distribution in the Yellow River Basin (see online version for colours)



3.2 Experimental scheme and index

Based on the above experimental data, the performance of the monitoring method is tested. Taking the monitoring accuracy and monitoring time as the experimental comparison indicators, the method in this paper is compared with the methods in Chen and Liang (2019) and Bai and Hu (2020).

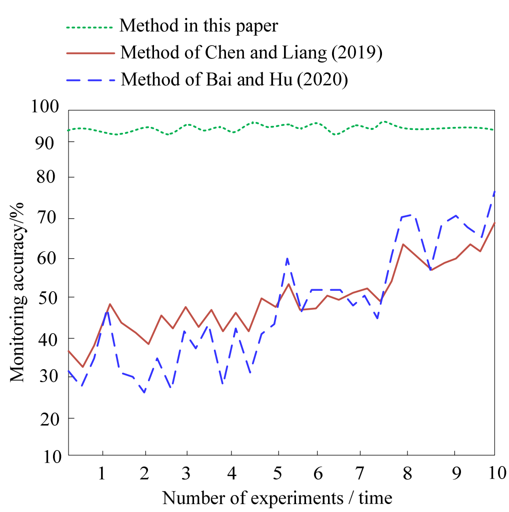
- Monitoring accuracy: monitoring accuracy refers to the degree of consistency between the monitoring results of surface vegetation distribution by different methods and the actual results. The higher the monitoring accuracy, the better.
- Monitoring time: monitoring time refers to the time consumed by different methods to complete a single monitoring of surface vegetation distribution under the same amount of data. The shorter the time, the higher the monitoring efficiency of the method.

3.3 Analysis of experimental results

3.3.1 Monitoring accuracy

The most important indicator of the surface vegetation distribution monitoring method is the monitoring accuracy, because the monitoring results are meaningful and can be used as technical support only if they are consistent with the actual vegetation distribution results. Therefore, the monitoring accuracy of this method is verified and compared with the two traditional methods. The monitoring accuracy results of surface vegetation distribution are shown in Figure 3.

Figure 3 Monitoring accuracy results of surface vegetation distribution (see online version for colours)

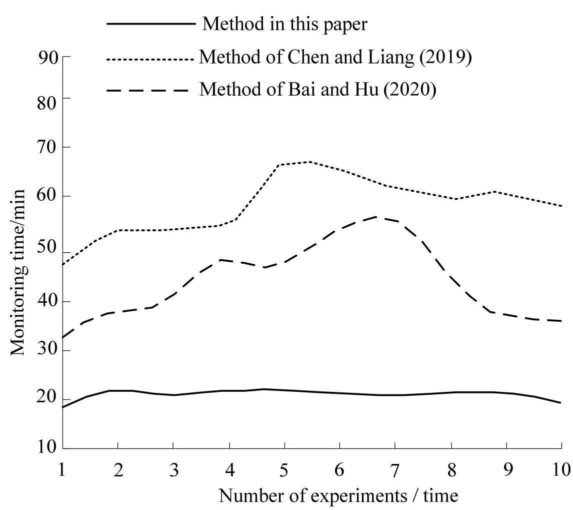


From the monitoring accuracy results of surface vegetation distribution shown in Figure 3, it can be seen that under multiple monitoring experiments, the monitoring accuracy curve of the method in this paper is above the two traditional monitoring methods, and is always stable at more than 93%. However, the monitoring accuracy of the surface vegetation distribution of the methods in Chen and Liang (2019) and Bai and Hu (2020) fluctuates strongly. Although it is in a rising trend, the highest monitoring accuracy of the two traditional methods does not exceed 80%. Therefore, this method can improve the monitoring accuracy of the surface vegetation distribution.

3.3.2 Monitoring time

Due to the large amount of surface vegetation distribution data, the monitoring time of the method is required to be high, so the monitoring time of the proposed method needs to be verified. In order to ensure the reliability of the experimental results, the method in this paper is compared with two traditional methods under the same data environment. The monitoring time-consuming results are shown in Figure 4.

Figure 4 Time-consuming results of surface vegetation distribution monitoring



According to the monitoring time-consuming results of surface vegetation distribution shown in Figure 4, there are obvious differences among the three methods. Among them, the monitoring time-consuming method of Chen and Liang (2019) is the longest, and the single monitoring time-consuming even reaches 67 min. Although the monitoring time-consuming method of Bai and Hu (2020) is lower than that of Chen and Liang (2019), the maximum time-consuming method of Bai and Hu (2020) also reaches more than 55 min. Among the three methods, the monitoring time of this method is the shortest, and the maximum is no more than 25 min. Compared with Chen and Liang (2019) and Bai and Hu (2020), the monitoring time of this method has been significantly reduced.

4 Conclusions

In order to clarify the distribution characteristics of surface vegetation in the Yellow River Basin, a monitoring method of surface vegetation distribution in the Yellow River Basin based on remote sensing image segmentation is proposed, and the performance of the method is verified from both theoretical and experimental aspects. This method has higher monitoring accuracy and shorter monitoring time when monitoring the distribution of surface vegetation in the Yellow River Basin. Specifically, compared with the monitoring method based on EVI2 and multi trend analysis, the monitoring accuracy of this method is significantly improved, and the maximum monitoring accuracy reaches more than 93%; compared with the monitoring method based on CART decision tree, the monitoring time of this method is significantly shortened, and the longest monitoring time is no more than 25 min. Therefore, it fully shows that the proposed monitoring method based on remote sensing image segmentation can better meet the requirements of monitoring the distribution of surface vegetation in the Yellow River Basin.

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