Hyperspectral characteristics of vegetation height in Urumqi Nanshan meadow steppe in different months

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Abstract. In this study, the hyperspectral measurements of natural meadow grassland plants in Nanshan, Urumqi, and Xinjiang were carried out by using a portable ground object spectrometer. The results showed that the natural vegetation height of Nanshan natural meadow grassland increased in May and June, decreased in July and recovered in August and September. According to the hyperspectral data analysis, the correlation between vegetation height and vegetation height is mainly concentrated in the blue and green bands, and has a strong negative correlation. The correlation between blue light and green light is slightly higher than that between red light and natural height of vegetation. At the same time, we established a relational model based on the correlation between vegetation growth and spectral reflectance.

1. Introduction
Hyperspectral remote sensing is a new technology developed during the past decades. Its main advantages are high resolution, high band continuity, and large amount of spectral information and so on. Especially, high resolution can reflect the spectral characteristics of vegetation spectral curve in detail, which makes the recognition ability improved and the methods are flexible [1]. Because of these advantages, the emergence of hyperspectral remote sensing technology has broadened the new field of remote sensing information quantitative acquisition, crop identification, disaster assessment, area estimation, yield prediction in areas such as areas, grasslands have certain achievements, and gradually become the most advanced technology in agricultural remote sensing applications [2].

Grassland is the main terrestrial ecosystem in China, and Xinjiang is one of the main pastoral areas in China. Grassland area is widely distributed [3]. Ranking third in the country [4]. Among them, the natural grassland area is 5.7*10^7hm^2. The grassland area can be 4.8*10^7hm^2. It is a valuable, economic and renewable natural resource [5]. However, grassland degradation and desertification are caused by long-term human activities and harsh natural conditions, and lack of scientific management [6]. To some extent, these problems reflect the inadequacy of human understanding of the service function, status and potential economic value of grassland ecosystem [7]. Therefore, it is of great ecological and social significance to study grassland resources, especially natural grassland vegetation coverage [8].

Remote sensing monitoring has become the mainstream for its unique advantages of convenience, time-saving and labor-saving. Therefore, it is of great practical value to observe and analyze the grassland characteristics by hyperspectral method, and to understand the dynamic changes of grassland comprehensively. Due to the special topography and landform of Xinjiang, along the northern Altai Mountains, the distribution of grassland shows obvious zonal characteristics from the central Tianshan Mountains to the southern Kunlun Mountains [9]. Vegetation species, coverage,
height, biomass, albedo are the main physical parameters to describe grassland organisms [10]. At present, the application of 3S technology in grassland height estimation at home and abroad is mainly reflected in using vegetation index extracted from TM, MODIS and NOAA/AVHRR multi-spectral images to inverse vegetation coverage, so as to further evaluate the ecological environment [11, 12, and 13]. Therefore, Establishing spectral monitoring model and satellite remote sensing model of forage yield in different types of natural grassland will lay a foundation for establishing national grassland remote sensing monitoring [14]. The use of hyperspectral remote sensing for grassland vegetation classification monitoring and remote sensing inversion can provide theoretical basis and support, but also has important significance [15].

In this study, the correlation between canopy hyperspectral data and grassland height data of natural grassland on the northern slope of Tianshan Mountain in Xinjiang was analyzed, and the relationship model between hyperspectral data and vegetation height was established. In order to provide scientific basis for remote sensing monitoring and evaluation of grassland quality in the northern slope of Tianshan Mountains.

2. The general situation of the experiment

2.1. Study area

In this study, Sussio and carex were selected as the dominant species in the meadow steppe located in the 43°54′N, 87°20′E regions of Nanshan in Urumqi, Xinjiang. SVC HR-768 was used to measure the spectral data of natural grassland types and plants at different growth stages, such as germination, seedling and maturity.

2.2. Investigation and data processing of grassland samples

The spectrum of grassland plant communities on the northern slope of Tianshan Mountains in Xinjiang was collected and analyzed by SVC HR-768 portable spectrometer and its software. The survey was conducted from May to September. In order to reflect the overall characteristics and characteristics of this grassland, from the bottom of the slope to the top of the slope, 5 samples of 1m*1m were randomly selected. The spectral data of whiteboard and grassland samples were determined respectively. The spectral measurements of each sample were recorded and repeated several times to reduce the influence of random noise. After removing the anomaly line, the mean value was taken as the reflection spectrum of the grassland sample.

Because the hyperspectral data are disturbed by the outside world, the spectral signal obtained by the spectrometer contains both effective information and noise, so it is necessary to de-noise processing before analyzing the spectral characteristics in order to reflect clearly the change characteristics of grassland vegetation spectrum. Generally, the denoising method is to change the nonlinear relation into linear relation, and transform the original reflectivity into reciprocal, square root, logarithm, first derivative and so on [16]. Signal smoothing is also the most commonly used method to eliminate noise, its basic assumption is that the spectrum contains noise is zero, are random noise, if the average value of multiple measurements can reduce noise and improve signal-to-noise ratio. The commonly used signal smoothing methods include moving average smoothing and Savitzky-Golay convolution smoothing [17, 18]. In this paper, SVC HR-768 spectrograph software was used to denoise the original grassland spectral data. Nine-point moving average method was used to smooth the spectral curve, so that the data had better continuity.

The main principle of the derivative spectrum is that the soil spectral characteristics become linear and the derivative values of 700 ~ 750 nm are close to zero, while the vegetation reaches a small peak in this range because of the photosynthetic pigments. This feature can easily distinguish and eliminate the soil background signal, quickly determine the inflection point of the spectral curve and the wavelength position of the maximum and minimum reflectivity. In order to extract spectral absorption peak parameters of recognizable objects. It is an effective method for eliminating background noise and extracting spectral features in arid and semi-arid areas [19]. The first derivative spectral expression is:

\[
\dot{\rho}(\lambda_i) = \frac{\rho(\lambda_{i+1}) - \rho(\lambda_{i-1})}{2\Delta \lambda} \quad (1)
\]
The second derivative spectral expression is:

\[ \rho''(\lambda_i) = \frac{\rho(\lambda_{i+2}) - 2\rho(\lambda_i) + \rho(\lambda_{i-2})}{4(\Delta\lambda)^2} \] (2)

In the form, \( \lambda_i \) is the wavelength value of band \( i \), \( (\lambda_i) \) is the reflectivity of wavelength \( \lambda_i \), \( \rho(\lambda_{i+1}) \) is the reflectivity of wavelength \( \lambda_{i+1} \), \( \rho(\lambda_{i-1}) \) is the reflectivity of wavelength \( \lambda_{i-1} \), \( \Delta\lambda \) is the interval from \( \lambda_{i-1} \) to \( \lambda_i \), \( \rho(\lambda_{i+2}) \) is the reflectivity of wavelength \( \lambda_{i+2} \), \( \rho(\lambda_{i-2}) \) is the reflectivity of wavelength \( \lambda_{i-2} \), \( \rho'(\lambda_i) \) is the first derivative spectral value of band \( i \). \( \rho''(\lambda_i) \) is the second derivative spectral value of band \( i \).

In the Near Infrared Spectrum Instrument (NIS) analysis, Fourier transform (FT) can be used to smooth the spectrum, data compression and information extraction. McClure [20] builds a model by multivariate linear stepwise regression using Fourier transform coefficients. Devaux [21] uses FT to compress NIR reflectance spectrum data for flour classification and then principal component analysis (PCA) processing. The calculation time is greatly reduced without sacrificing accuracy. Wu [22] takes the Fourier transform coefficient as the characteristic variable of pattern recognition, and the result is equivalent to that of PCA. Pasti [23] uses the combination of Fourier transform and genetic algorithm to extract correlation features from NIR spectral data for multivariate correction.

3. Results and analysis

3.1 Spectral characteristics and height characteristics of grassland

Vegetation types, atmospheric conditions, soil texture, moisture content and other factors will affect the spectral reflectance of grassland, so the spectral characteristics of grassland is a comprehensive reflection of vegetation and its environment [24]. In different months, we investigated the grassland resources of meadow steppe with the grassland type of Sussio (I) + Carex (II) + Weeds (III), and the average height was as follows: Table 1. It can be seen that May and June were on the rise and peaked in June, declined and stabilized in July, and rose slightly in September. Since the calculated average height reflects the natural height of the entire meadow grassland, the vegetation height should be increased but decreased in July and August, because July and August are the months of water shortage and some vegetation is dry, so the overall height has decreased. The natural height of vegetation increased again in September because the withered plant stalks grew new ones in July and August when the rain was plentiful, with little effect on the growth period. So the vegetation height increased in September, but the overall change was very small.

| Table 1. Meadow steppe communities in different average height |
|-----------------|-----------------|-----------------|
| Class | Community height | The average height (cm) |
| May | I | 7.1 |
| | II | 6.7 |
| | III | 7.4 |
| | I | 10.2 |
| June | II | 7.8 |
| | III | 6.5 |
| | I | 5.2 |
| July | II | 3.5 |
| | III | 6.4 |
| | I | 6.0 |
| August | II | 4.9 |
| | III | 4.2 |
| | I | 4.0 |
| September | II | 5.7 |
| | III | 6.1 |
3.2 Spectral characteristics of meadow steppe

Spectral features are extracted from different months, and the average spectral reflectance of each month is calculated and plotted as shown in Figure 1: Chlorophyll absorbs blue and red light intensively and forms absorption valleys in the blue and red light regions with wavelengths of 480 nm and 680 nm, which are called "blue valley" and "red valley" respectively, and the reflectivity is 0.05 ~0.15 and 0.05 ~0.25. The green light absorption is weaker and the reflectivity is 0.075 to 0.2. But there is a reflection peak (Green peak) between "Blue Valley" and "Red Valley". The summit is located near 550nm. Near-infrared reflectance shows a strong reflection, from 700 nm to 760 nm spectral reflectance increases sharply with the increase of wavelength, in the 680 ~760 nm spectral range sharply increased, forming a reflection steep slope, known as the "red edge". The position, height and slope of "Red Edge" vary with the vegetation and the growth of the same vegetation. There are obvious differences between the spectral reflectance curves of different plant communities.

![Figure 1. Spectral curves in different months](image1)

Visible In the visible light band, the vegetation growth trend in May and June was higher than that in May. The chlorophyll content in the vegetation was relatively high. The blue valley, Red Valley and green peak were obvious. The reflectance in June was higher than that in May. The main reason is that although May is the turning green season, the growth is better in June, and the chlorophyll content in the vegetation has increased. In August, the natural height of vegetation was generally low, but the accumulation of chlorophyll in the vegetation was the highest, and the overall reflectance was high. The growth of vegetation recovered in September, but the chlorophyll content decreased in the late growth stage, so the overall reflectance was lower than that in July and August. In addition, from July to September, the flowering, fruiting and withering stages were respectively entered, and the effect of chlorophyll and leaf surface index on vegetation made the blue valley less obvious in these three months.

![Figure 2. First derivative spectra in different months](image2)

Combining with Figure 2, the red edge slope D\lambda red of the same type of grassland in different months is shown as follows: September > August > July > June > May. The same type of grassland has the same red edge range in different months, and it is between 680 and 760 nm. There is no offset, and the red edge position \lambda red is also the same. The larger the slope of red slope is,
the more obvious the spectral reflectance growth trend is in the red edge. It can be seen that the reflectivity in August and September is higher than that in May and June at 680 ~ 760 nm; the slope in July and August is similar to that in spectral curves; the slope in May is the smallest.

3.3 Correlation analysis of spectral reflectance and vegetation height in different bands

Because plants have a spectral absorption region at visible wavelengths. Then the correlation between the average spectral reflectance of red, green and blue and the vegetation height in corresponding months was analyzed.

Table 2. Statistical table of reflectance and vegetation height in blue, green and red bands

| Month     | Blue light reflectivity (%) | Green light reflectivity (%) | Red light reflectivity (%) | Height (cm) |
|-----------|-----------------------------|------------------------------|----------------------------|-------------|
| May       | 4.59                        | 6.28                         | 13.42                      | 6.67        |
|           | 3.94                        | 5.35                         | 10.71                      | 7.41        |
|           | 4.07                        | 5.72                         | 12.00                      | 7.05        |
|           | 5.57                        | 7.37                         | 12.58                      | 10.22       |
| June      | 5.79                        | 7.76                         | 13.88                      | 7.80        |
|           | 6.01                        | 8.15                         | 15.17                      | 6.46        |
|           | 9.97                        | 12.92                        | 20.74                      | 5.18        |
| July      | 10.00                       | 13.06                        | 22.22                      | 3.45        |
|           | 8.96                        | 11.72                        | 19.12                      | 6.40        |
|           | 6.27                        | 8.35                         | 13.98                      | 5.96        |
| August    | 7.24                        | 9.45                         | 15.35                      | 4.92        |
|           | 6.60                        | 8.65                         | 14.16                      | 4.24        |
|           | 7.41                        | 8.97                         | 13.53                      | 3.96        |
| September | 6.14                        | 7.70                         | 11.70                      | 5.74        |
|           | 5.60                        | 7.70                         | 11.44                      | 6.05        |

Table 3. Correlation between reflectance of blue, green, red light and vegetation height

| Sample reflectivity | Blue sample reflectivity Pearson correlation | Blue height sample | Green sample reflectivity Pearson correlation | Green height sample | Red sample reflectivity Pearson correlation | Red height sample |
|---------------------|---------------------------------------------|-------------------|---------------------------------------------|---------------------|---------------------------------------------|------------------|
|                     | 1                                           | -0.887*           | 1                                           | -0.860*            | 1                                           | -0.472*          |
| Sample size         | 15                                          | 15                | 15                                          | 15                 | 15                                          | 15               |

| Sample height       | Pearson correlation | Saliency (bilateral) | Sample size |
|---------------------|---------------------|----------------------|-------------|
|                     | -0.887*             | 0.021                | 15          |
|                     | 1                   | 0.860*               | 15          |
|                     | 1                   | 0.872*               | 15          |
|                     | 0.021               | 0.030                | 15          |
|                     | 0.076               |                      | 15          |

*: Significant correlation is found on 0.05 level (bilateral).

As can be seen from Table 3: The correlation coefficients between the reflectivity of blue and green light bands and the natural height of vegetation were -0.887 and -0.86 respectively. The higher the natural height of vegetation is, the lower the reflectance of blue light and green light is. At the same time, the correlation coefficient of vegetation reflectance in red light and natural height of vegetation is -0.472. That is to say, the analysis of the correlation between the reflectance of red light band and the natural height of vegetation is not strong and has no certain analytical value, while the reflectance of blue light and green light may have a certain correlation with the natural height of vegetation. The blue and green bands are between 450 and 580 nm, so the relationship between the natural height of vegetation and the reflectance of 450–580 nm band is established.
3.4 Establishment of hyperspectral remote sensing estimation model for natural grassland coverage

According to the distribution of scatter plots, S-curve model and exponential model were used to fit the curves. Figure 3 (left) is the fitting curve of blue-light reflectance and vegetation height. Figure 3 (right) is the fitting curve of green-light reflectance and vegetation height. Refer to table 4 for relevant parameters. The fitting effect can be reflected by comparing the R value. The larger the R value is, the better the fitting effect is. The fitting effect of the blue band is better than that of the green band. By comparing the significance value Sig, the fitting of exponential function is less than S-curve, and the R value of blue and green light is greater than S-curve model, so the fitting effect of exponential function model is the best. The formula for predicting vegetation natural height is exponential model.

4. Conclusion

Based on the correlation analysis between the original spectrum and the first order differential spectrum of natural grassland and the grassland height, the estimation model based on the first order differential spectrum sensitive band can better estimate the grassland height. At the same time, due to the low vegetation height spectrum affected by underlying surface soil, the red edge characteristics weakened [25]. Some results show that the first-order differential processing of vegetation spectral data can extract vegetation information more effectively [26, 27 and 28]. The conclusions of this study are as follows:

1) The natural vegetation height of the meadow steppe on the northern slope of Tianshan Mountains increased in May and June, decreased in July, grew steadily in August compared with July, and recovered in September. The main reason for the difference is that the growth cycle of different vegetation is different because of the change of vegetation composition.

2) The reflectance of meadow grassland in different months is different in visible light band, but the reflectance is basically consistent with the natural height of vegetation, which is strongly negative correlation, that is, the higher the natural height of vegetation, the lower the reflectance. But in May, the altitude was higher than that in June, but the reflectivity was lower than that in June. It is speculated that spectral reflectance is not only negatively correlated with height, but also related to leaf area of vegetation and internal structure of plant itself.
(3) The correlation between vegetation height and vegetation is mainly concentrated in blue and green bands, and has a strong negative correlation. The correlation between blue light and green light was slightly higher than that between red light and vegetation. Therefore, it is feasible to establish vegetation growth models based on the reflectance of blue light and green light. However, due to the lack of data and data, the model has some limitations.

Because hyperspectral remote sensing data can describe the spectral characteristics of ground objects in detail, the accuracy of detecting vegetation fine spectral information can be improved [29]. Hyperspectral reflectance is very sensitive to vegetation types, growth stages and different environmental conditions. In order to reduce the error and extend the research conclusions to practical applications, more experiments need to be carried out in more areas to study the hyperspectral characteristics and estimation models of various types of grasslands.

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