A Study on Spectral Signature Analysis of Wetland Vegetation Based on Ground Imaging Spectrum Data

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Abstract. The objective of this study was to verify the application of imaging spectrometer in wetland vegetation remote sensing monitoring, based on analysis of wetland vegetation spectral features. Spectral information of Carex vegetation spectral data under different water environment was collected by SOC710VP and ASD FieldSpec 3; Meanwhile, the chlorophyll contents of wheat leaves were tested in the lab. A total 9 typical vegetation indices were calculated by using two instruments' data which were spectral values from 400nm to 1000 nm. Then features between the same vegetation indices and soil water contents for two applications were analyzed and compared. The results showed that there were same spectrum curve trends of Carex vegetation (soil moisture content of 51%, 32%, 14% and three regional comparative analysis) reflectance between SOC710VP and ASD FieldSpec 3, including the two reflectance peak of 550nm and 730 nm, two reflectance valley of 690 nm and 970nm, and continuous near infrared reflectance platform. However, The two also have a very clear distinction: (1) The reflection spectra of SOC710VP leaves of Carex Carex leaf spectra in the three soil moisture environment values are greater than ASD FieldSpec 3 collected value; (2) The SOC710VP reflectivity curve does not have the smooth curve of the original spectrum measured by the ASD FieldSpec 3, the amplitude of fluctuation is bigger, and it is more obvious in the near infrared band. It is concluded that SOC710VP spectral data are reliable, with the image features, spectral curve features reliable. It has great potential in the research of hyperspectral remote sensing technology in the development of wetland near earth, remote sensing monitoring of wetland resources.

1. Introduction
In a relatively complex wetland ecological system, the hyperspectral remote sensing plays an important role in the quantitative detection of wetland resources by remote sensing, research on spatial distribution characteristics of wetland types, remote sensing inversion of the wetland vegetation ecosystem and the like by the virtue of its huge advantages, such as thousands of available wave bands, extremely high definition and special sensitivity to spectral features [1]. The wetland vegetation is an important component of the wetland ecosystem. In recent years, domestic scholars have also implemented extensive and deep study to the application of the hyperspectral remote sensing extraction technology with remote sensing into the collection of wetland vegetation information [2]. Lin Chuan and Gong Zhaoning have studied the identification method of the typical wetland vegetation ecological types based on spectral signature variants [3]. Li Fengxiu and others have conducted actual tests and measurements of the reflection rate and chlorophyl density at the Calamagrostis angustifolia shrub layer under different coverage and water depth level to create related vegetation indexes based on the data collection from both visible light - near-infrared band and find
out the vegetation indexes and the wave bands with the highest relevance to chlorophyll [4]. Zou Weina analyzes the effects of coverage and canopy water depth to the spectral characteristics of the submerged plant cabomba caroliniana. The research results indicate the basic characteristics of the reflection rate of cabomba caroliniana cluster under different coverage are mostly apparent in the green and near-infrared band[5]. Schmidt and others use GER 3700 wild portable field spectrometer to measure the reflection spectrum of 27 species of wetland vegetation in the coastal saline alkali wetland of southern Holland, apply the statistical tests, continuous removal and distance analysis to finally select out 6 optimal bands for classification[6]. Zomer and others use GER 2600 wild portable spectrometer to measure the spectrum of both the canopy and the leaves of 7 species of wetland vegetation in the Pacheco Creek Salt Marsh in US California. Afterwards, they apply the acquired ground object spectrum curve to create a spectrum bank, providing the scientific bedrock for the classification of wetland vegetation based on hyperspectral remote sensing image. Among such studies most of them are the study and application of the hyperspectral data acquired through aerial imaging and the non-imaging hyperspectral data acquired on the ground without figures. However, the analysis and monitoring techniques about the imaging spectral characteristics of wetland vegetation based on the ground hyperspectral imaging are still quite scarce. The field spectrometer can study a single crop, but cannot do the imaging, and the canopy spectrum collected from the vegetation is mixed large cluster of spectral information. This has restricted the precision of various inversion models to be established. Therefore, this study uses both the imaging spectrum and the non-imaging field spectrometer and selects the water environment which is the most sensitive in the wetland ecosystem, collects the spectral information from the single plant of sedge, which is a wetland vegetation, and compares and analyzes the differences of the hyperspectral band obtained from both equipment and uses the field spectrometer as the standard to verify the reliability of the data acquired from the imaging spectrum; then selects the typical wetland vegetation index to study the spectral differences of the sedge vegetation in the environments with different moisture gradients and provides support to the further study of the wave bands selection for the wetland hyperspectral information acquisition using ground object imaging spectrum.

2. Material and Method

2.1. Test location
The test location of this research selects the Jinjiang river segment in the middle section of Yangtze river located in the Hunan East Dongting Lake in Yueyang city, northeastern Hunan province. The place is one of the wetland natural protection zone designated by the Chinese government and also gets listed in the "Ramsar Convention". The central coordinates of the place are 28°59′52″N and 112°59′52″E. The area belongs to the subtropical humid climate zone with very typical wetland types and wetland vegetation, ample sunshine, abundant precipitation, rich submerged plants, floating plants and emerging plants. The typical wetland vegetation sedge is widely distributed in the eastern Dongting lake wetland protection zone and is a typical plant species of this wetland.
2.2. Data collection instrument

Table 2-1 Comparison of Data Collection Instrument

| Comparison of instruments | Imaging spectrum (SOC710VP) | Field spectrometer (ASD Fieldspec 3) |
|---------------------------|-----------------------------|-------------------------------------|
| Spectral range:           | 400-1000 nm                 | 350-2500 nm                         |
| Spectral resolution       | 4.6875 nm                   | 3nm@700nm; 10nm@1400nm,2100nm       |
| Wave band characteristics | 128 bands                   | Data interval: 1nm                  |
| Sampling features         | 30 lines/sec Pixel per line: 696; 23.2 sec/cube (696 by 520 cube) | 1.4nm@350-1050nm; 2nm@1000-2500nm |
| Lens/focus                | Adjustable (based on the camera used) | Cameras with the view angles of 1°, 5°, 8° |

2.3 Test plan and measurement method

2.3.1. Experimental program. Use the soil moisture detector to get the concentrated distributed moisture gradient environment. Take sedge as the example and select three regions with sedge distribution with soil moisture of 51%, 32% and 14% respectively for concentrated measurement. Compare and analyze the test results of single wetland vegetation type scale obtained by the SOC710VP imaging spectrum and field spectrometer ASDFieldSpec 3. The test content is the relevance analysis of the sedge vegetation indexes under different soil moisture level to determine the soil moisture distribution patterns suitable for the ground object classification.

(a) Sedge spectral data acquired by SOC710VP imaging spectrum  
(b) the sedge spectral data acquired by ASDFieldSpec 3  
(c) Soil moisture measurement  

Figure 2-1 Field Data Collection
2.3.2. Measurement methods. Use the soil moisture meter to measure the sample points of sedge distribution areas under different moisture gradient environments, then collect SOC imaging hyperspectral data, convert the original data into reflection rate, before the conversion implement the dark current removal, wavelength calibration, radiation calibration and other operations at first, afterwards remove the electrical noises which is affected by the environmental factors including the ambient temperature. Therefore, ahead of the start of each test, conduct the Dark measurement and keep the record. Then conduct the wavelength calibration and radiation calibration. The method of reflection rate conversion: To use the actual tested whiteboard reference board, select the target sedge, use the empirical linear algorithm to solve the calibration coefficients, then extract the reflection rate. Sedge reflection rate = (sedge DN value/reference board DN value) × reference board reflection rate. The reflection rate of the reference board is the indoor calibrated value. Finally, the image DN value can be converted into the reflection rate through the processing module of the hyperspectral software.

3. Result and Analysis

3.1 Imaging spectrum data analysis
We can obtain the effective imaging hyperspectral data and non-imaging field spectrometer data in three sedge distribution area with the moisture levels of 51%, 32% and 14% respectively through the aforementioned measurement method with 25 data groups for each sedge area which means 75 samples in total. Administer the post-treatment of the measured data to acquire the pretreated results of the sedge imaging spectrum data and conduct noise reduction to the original imaging spectrum data. The sedge spectral characteristic curves in the visible light and infrared and near infrared bands are all clearly seen.

(a) Post-treatment of collected imaging spectrum data  
(b) Conversion process of whiteboard reference board reflectivity
(c) The True color RGB combination and False color RGB combination of Carex imaging spectral data

True color RGB combination
- R: Band 53 (637.7945)
- G: Band 36 (549.4165)
- B: Band 19 (462.4512)

False color RGB combination
- R: Band 95 (862.1963)
- G: Band 55 (648.2848)
- B: Band 36 (549.4165)

Figure 2-2 Pre-treatment Results of Sedge Imaging Spectrum Data
Based on the data reduction and statistics, we can obtain the spectral signature curve of the three sedge distribution areas with different moisture gradients with the moisture of 51%, 32% and 14% respectively. The non-imaging spectrum data collected by the ASD FieldSpec 3 from the same area are shown in the following diagram:

![Sedge Spectral Curves](image)

**Figure 2-3** Reflection Rate Curve Collected by SOC710VP and ASD FieldSpec 3 under Different Moisture Levels

The spectrum of the sedge in different distribution gradients measured by using the ground imaging spectrum SOC710 and non-imaging ASD FieldSpec 3 respectively shows the strongest reflection in the band between 550nm and 730nm. After 750nm there is a near infrared high reflection platform. The wavelength around 690nm and 970nm witnesses the apparent absorption trough. The sedge spectral characteristic curve measured by two instruments has basically maintained the same development trend, but the two instruments also bear some quite obvious differences:

1. The reflection rates acquired by two instruments in the same sedge area under the same moisture level are different in value. The spectral data of sedge leaves collected by SOC710VP in all three areas are all bigger than the sedge leaves spectral reflection rate collected by ASD FieldSpec 3.

2. The original SOC710VP reflection rate curve is not as smooth as the original spectral curve measured by ASD FieldSpec 3. The former has more turbulence, in particular at the near-infrared band. After the noise is diminished, the curve trough of the reflection rate collected by the SOC710VP witnesses more drastic change of magnitude at 970nm. (As shown in Figure 2-3)

The analysis of the reflection rate curve collected by SOC710VP under three different moisture indicates the whole trend completely complies with the sedge vegetation spectral characteristic curve, the difference lies at the characteristic bands (red edge, green edge, near infrared platform) of the sedge spectrum curve under 51% soil moisture all show that the water content directly affects the vegetation spectral reflection characteristics and the interference magnitude is bigger, the change is more stark, which is helpful for the subsequent spectral terminal element clustered analysis.

The results indicate that through the application of spectral data of a single sedge leaf collected by the SOC710VP imaging spectrum under different moisture level and the analysis of the leaf reflection rates under 3 moisture gradients, we can determine that the reflection rate characteristic curve of the SOC710VP spectrometer is similar to the results from the field spectrometer ASD. Both resemble the same pattern which is manifested by the reflection peak at 550nm and 730nm and the absorption trough at 690nm and 970nm as well as the continuous near infrared reflection platform. This result is
identical with the precedent conclusions obtained from satellite hyperspectral imaging facilities such as Hyperion, CHRIS, CASI and the like.

3.2 The sedge imaging spectrum vegetation index characteristic analysis under different water content environments

In order to proceed to compare and analyze the moisture's influence to the vegetation spectrum of the single sedge species collected from the imaging spectrum and the non-imaging spectrum, we apply the method of analyzing the vegetation indexes to give an analysis to sedge vegetation information characteristic. This research selects 9 vegetation indexes frequently used by the precedent cases and compare them with the sedge index in the wetland under different moisture condition, and relies on the data collected from both the SOC710VP and the ASD FieldSpec 3 for further analysis of the data from the vegetation imaging spectrum SOC71. Select the following vegetation indexes: Vegetation indexes with visible light: VARIgreen, VARI700, CARI; Visible light/near infrared vegetation index: NDVI, EVI, SR, DVI; Red edge ratio index: VOG3, Carter2.

Table 3-1 The Results of Spectral Vegetation Index of Carex Pure Pixel in Different Water Environment

| Vegetation index | Soil moisture content of 51% | Soil moisture content of 32% | Soil moisture content of 14% |
|------------------|-----------------------------|-----------------------------|-----------------------------|
|                  | ASD | SOC | ASD | SOC | ASD | SOC |
| NDVI             | 0.718 | 0.879 | 0.625 | 0.789 | 0.518 | 0.621 |
| EVI              | 0.542 | 0.675 | 0.508 | 0.606 | 0.507 | 0.555 |
| SR               | 8.143 | 9.845 | 7.104 | 7.841 | 7.007 | 7.889 |
| DVI              | 0.291 | 0.478 | 0.281 | 0.329 | 0.235 | 0.247 |
| CARI             | 0.041 | 0.051 | 0.033 | 0.039 | 0.051 | 0.054 |
| VARIgreen        | 0.552 | 0.553 | 0.425 | 0.497 | 0.514 | 0.573 |
| VARI700          | 1.216 | 1.611 | 1.366 | 1.247 | 1.839 | 1.936 |
| VOG3             | 1.121 | 1.414 | 1.787 | 1.271 | 1.507 | 1.455 |
| Carter2          | 0.187 | 0.195 | 0.141 | 0.165 | 0.161 | 0.187 |

From the Tab 3-1 we can see that the sedge spectrum data measured by SOC710VP and ASD FieldSpec 3 under different water content environment is the representative vegetation index value of that area, among which the data obtained from the imaging spectrum represents the visible light to which the green vegetation is most sensitive/the near infrared light index characteristic NDVI, EVI, SR and DVI value under three moisture environments all manifest very direct relationship. As the decreasing of the soil moisture these indexes also assume a debilitating trend and is slightly higher than the data acquired by the ASD non-imaging spectrum. This is highly identical to the spectral characteristic curve analyzed previously, which proves the data is reliable. From Table 2-1, the results in the visible light band and the red edge ratio area also show very good relevance. In summary with the selection of 9 vegetation indexes from the precedent investigations, especially the selection of 3 visible light vegetation indexes, 4 visible/near infrared vegetation index, 2 red edge ratio indexes, thereby the total quantity of vegetation indexes is 9. The imaging spectrum SOC710VP and non-imaging spectrum obtain the index characteristic of sedge vegetation index under different moisture gradient. The calculation results indicates the changing trends of the selected vegetation indexes are identical which means the imaging spectrum SOC and the field spectrometer ASD possess basically the same and consistent data acquisition.

4. Conclusion

By using the SOC710VP imaging spectrum and the ASD FieldSpec 3 field spectrometer, we collect the spectral reflection data information of the typical wetland vegetation sedge within the wetland, and compare the imaging spectral signature of the sedge pure pixel region and the vegetation index characteristics under different water contents, to understand and command the spectral features of the imaging spectrum on the single sedge area.
The study proves that the advantage of imaging spectrum is the ability to select the study scope on the spectral imaging figure, and the data are consistent with the data acquired directly obtained from the biological structure of leaves. From the vegetation indexes obtained from both instruments, the value acquired by the imaging spectrum SOC710VP is more accurate than the data acquired by field spectrometer ASD. From a side view, it means the imaging spectrum is able to determine the selection area which is acquired simultaneously with the biological parameters at the same position, this can enhance the extraction precision of vegetation biological related data. In summary, the data from the imaging spectrum has the advantages of figure-spectrum integrity and spectral characteristic curve reliability. The imaging spectrum has great potential in the hyperspectral remote sensing study of the wetland and expands the technical means of wetland resources remote sensing and monitoring.

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