DISCRIMINATING C3 AND C4 PLANTS FROM HYPERSPECTRAL DATA

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1. INTRODUCTION

Plant functional types (PFT) are groups of plant species that share similar functions at the organismic level, similar responses to environmental factors or similar effects on ecosystems. PFT is a crucial variable needed in studies of global climate, carbon cycle and ecosystem change. There is a need for accurate and up-to-date information on the spatial distribution of C3 and C4 vegetation.

There is a wealth of literature on how to use remotely sensed data to extract land cover information and certain biogeophysical variables. However, using remote sensing techniques to extract PFTs is a relatively recent field of research. To date, very few methods for mapping PFTs have been reported[1-2] (Strahler et al., 1999; Bonan et al., 2002; Foody and Dash, 2007; Sun et al.2008).

In this paper, we proposed a novel method to discriminate C3 and C4 plant functional types using the solar-induced chlorophyll fluorescence derived from hyperspectral remote sensing data. The potential was evaluated using airborne hyperspectral data acquired by OMIS II instrument. Compared to the traditional reflectance method, our method can greatly enhance the classification potential of C3 and C4 plant functional types for hyperspectral remote sensing data.

2. STUDY AREA AND DATA

The study area is in Linze Oasis in Gansu Province, China. The area is located in the middle of the Heihe River Basin, which is one of the largest inland river basins in the northwest arid land in China. The river originates on the northern side of the Qilian Mountain, flows through the north of the Hexi Corridor, and terminates in the Badan Jiran Desert on the Ala-shan Plateau. The weather in this region is controlled by the continental climate and the Tibet Plateau climate. Its sunlight is abundant and the annual hours of sunshine reaches 3088 h. The precipitation is, however, as low as 104.4 mm. A transition zone from Oasis to desert was selected as the research site, which lies between 100°8′9″ - 100°8′47″ E and 39°19′28″ - 39°21′30″ N.

On the study site, C3 species include Poplar, Hedy sarum scoparium, Tamarix chinensis Lour, soybean, and potato, while the C4 species include maize, Haloxylon ammodendron, and Calligonum mongolicum Turcz.

The airborne hyperspectral image data were acquired at a nominal spatial resolution of 3 m on June 15, 2008 by Operation Modular Imaging Spectrometer (OMIS II, made by Shanghai Institute of Technical Physics, Chinese

Academy of Science). In the flight time, the air temperature was 30.5°C high, and the incident photosynthetically active radiation (PAR) was 1908 μmol m^{-2} s^{-1}.

3. METHODS AND RESULTS

3.1 Separation of ChlF signal based on the FLD method

The amount of chlorophyll fluorescence emitted by a leaf under natural sunlight only accounts for up to 1% of the absorbed light in the visible part of the spectrum. It is difficult to quantify the emitted fluorescence because the signal is dominated by the reflected light. However, at certain wavelengths where the solar spectrum is attenuated (Fraunhofer lines), the fluorescence signal may be quantifiable. Many absorption bands appear in the solar irradiance spectra, including those at 486, 527, 589, 656, 688, and 760 nm. All these bands can be detected if signal to noise ratio (SNR) and spectral resolution of the spectral instrument is sufficiently high. The two oxygen absorption bands (688 nm and 760 nm) located closer to the chlorophyll fluorescence peaks can be selected to monitor the chlorophyll fluorescence emission under daylight excitation by the method of the Fraunhofer lines in-filling [3-5]. The chlorophyll fluorescence flux *f* can be calculated as[3-4]:

$$f = \frac{(a \times d - c \times b)}{(a - b)}, \qquad (1)$$

where *a* and *b* represent the detected irradiance from the reference panel in and out of the oxygen-absorption feature. Similarly, *c* and *d* represent the detected radiance from the target at the border and at the bottom of the band.

The relative chlorophyll fluorescence is calculated by the ratio of the fluorescence flux *f* to NDVI,

$$f_{ratio} = \frac{f}{NDVI} \qquad (2)$$

where f_{ratio} is the relative chlorophyll fluorescence.

3.2 Classification of C3 and C4 functional types using hyperspectral data

The capability of remote sensing data to discriminate between vegetation species can be assessed by a simple separability measure (Schotten et al., 1995). The separation rate for two classes is estimated using their mean values μ_i and standard deviations SD_i, where

$$S = \frac{|\mu_1 - \mu_2|}{SD_1 + SD_2} \qquad (2)$$

Table 1 shows the separation rate for C3 and C4 species. The separation rate of chlorophyll fluorescence intensity was better than NDVI and other spectral reflectances. The separation rate was greatly improved by the ratio of chlorophyll fluorescence intensity to NDVI. Therefore, the emitted chlorophyll signals demonstrated a prospective advantage compared to the traditional reflectance signals.

Table 1 The spectral separation rates for C3 and C4 species

Band	*NDVI*	f	f_{ratio}	*471*	*483*	*495*	*508*	*520*	*532*	*545*
Distance	0.04	0.90	1.31	0.20	0.20	0.20	0.20	0.21	0.23	0.24
Band	*557*	*570*	*582*	*595*	*607*	*620*	*632*	*644*	*656*	*668*
Distance	0.24	0.24	0.23	0.22	0.22	0.22	0.21	0.20	0.20	0.19
Band	680	692	704	715	727	738	750	761	772	783
Distance	0.19	0.19	0.20	0.23	0.52	0.62	0.63	0.62	0.61	0.61
Band	*795*	*805*	*816*	*826*	*837*	*848*	*858*	*868*	*878*	*888*
Distance	0.61	0.61	0.60	0.60	0.60	0.59	0.59	0.58	0.58	0.57
Band	*898*	*908*	*918*	*927*	*936*	*946*	*954*	*963*	*972*	*981*
Distance	0.57	0.56	0.56	0.55	0.54	0.54	0.54	0.53	0.53	0.52
Band	*989*	*999*	*1007*	*1015*	*1023*	*1031*	*1038*	*1046*	*1053*	*1060*
Distance	0.52	0.51	0.51	0.50	0.50	0.49	0.49	0.48	0.47	0.47
Band	*1068*	*1074*	*1081*	*1650*	*2215*	*4000*	*10250*			
Distance	0.46	0.46	0.45	0.20	0.17	0.08	0.09			

* The numbers in the band rows represent the spectral reflectance at the relative central wavelengths (unit: nm).

To build the classification rules, the chlorophyll fluorescence signals of C3 and C4 species at different NDVI levels were calculated. The results show that the fluorescence signals of C4 species were about 2.2 times greater than that of C3 species at the same NDVI level. And the average values of the relative chlorophyll fluorescence of C4 species was 18.2 w $m^{-2}\mu m^{-1}$, compared with a smaller value of 7.8 w m^{-2} μm^{-1} for C3 species.

A simple decision tree, based on NDVI and chlorophyll fluorescence signal, was built to classify C3 and C4 species (Fig. 1). In this study, the constant to discriminate the C3 and C4 species was set at the value of 13 w $m^{-2}\mu m^{-1}$, which was the median chlorophyll signal between C3 and C4 species. The resulting classification mapping was illustrated as Fig. 2.

A confusion matrix was extracted from the accuracy assessment of the C3 and C4 mapping. According to Table 3, the C3 and C4 species were well classified, with an overall classification accuracy of 92% and a kappa coefficient of 0.84.

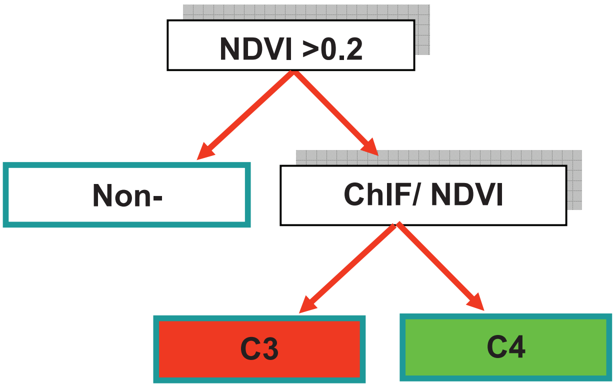

Fig. 1 The decision tree to classify C3 and C4 species

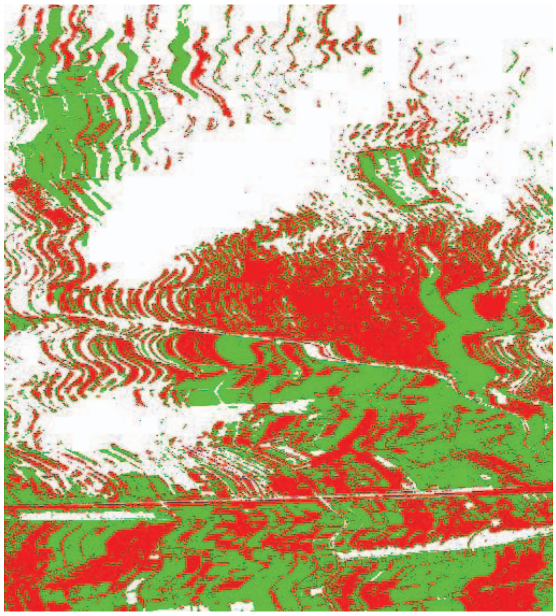

Fig. 2 The map of C3 and C4 species

4. DISCUSSIONS AND CONCLUSIONS

The present study proposed a novel method to discriminate C3 and C4 plant functional types using solar-induced chlorophyll fluorescence derived from hyperspectral remote sensing data. The results showed that the fluorescence signal of C4 species was about 2.2 times greater than that of C3 species at the same NDVI level. The accuracy assessment result showed that the C3 and C4 species were well classified with an overall classification accuracy of 92% and a kappa coefficient of 0.84. However, the performance of C3 and C4 species' chlorophyll fluorescence was quite different under different environment stresses, and could be influenced by the biophysical and biochemical status of the plants. Therefore, more researches are necessary to explore the potential of solar-induced chlorophyll fluorescence signals to discriminate the C3 and C4 species at different wavelengths under various environment conditions.

5. REFERENCES

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