Research Article
Study on Heavy Metal Pollutants Monitoring Methods in Wheat Producing Areas Based on Hyperspectral Remote Sensing

[1]Ma Jing, [2]Shang Hai-Yang and [3]Xu Peilong
[1]College of Resources and Environmental Sciences, Gansu Agricultural University,
[2]Lanzhou University of Finance and Economics, Lanzhou 730070,
[3]Analysis and Test Center, Qingdao University, Qingdao 266071, China

Abstract: Aims: To establish heavy metal pollutants monitoring methods in wheat producing areas. Methods: Through hyperspectral remote sensing technology, wavelet energy coefficient was used to estimate the heavy metal pollution threads in wheat producing areas. Results: The study results showed that the spectral fractal dimension db series db5 wavelet decomposition of the third layer is the most stable and reliable signal. Conclusion: This method is rapid, widely applicable and could provide a convenient and accurate way in monitoring cadmium contamination of wheat.

Keywords: Hyperspectral remote sensing, wavelet fractal analysis, wheat cadmium pollution

INTRODUCTION

For a long period, people pursuit high investment and high yield excessively in agriculture production. This caused serious pollution problems together with grain harvest. Smelting wastewater, sewage irrigation, pesticides and chemical fertilizers, excessive applying fertilizer and agricultural garbage etc. have lead to serious regional agricultural environmental deterioration in China, especially heavy metal pollution problems (Zhang, 2015). According to statistics, in 1980 Chinese industrial "three wastes" polluted farmland area has reached to 2667 thousand hm^2 and the number reached to 6667 hm^2 in 1988 and 10 million hm^2 in 1992 (Jiao *et al*., 2014). By now, the heavy metal polluted soil have reached to nearly 20 million hm^2, this is nearly 1/5 of the cultivated land area in China (Chen *et al*., 2012). And the direct loss caused by heavy metal every year exceed 30 billion RMB. In some areas seriously polluted by heavy metal, cancer incidence and mortality are significantly higher than those of areas without pollution. Study results have showed that, cultivated land heavy metal pollution are caused mainly by wastes application, farmland sewage irrigation, organic fertilizer, pesticide and herbicide application, precipitation and atmospheric deposition and other reasons (Wang *et al*., 2014). And the agricultural products and areas with heavy metal contents exceed the standards have reached to more than 80% of the total quantities. The main heavy metals caused soil pollution are Hg, Cd, Pb, Cr, As, Zn, Cu, Co, Ni etc., especially Cd, Pb, Hg, As and their compounds. By now, studies on heavy metal pollution are mainly on pollution repair and treatment methods and mechanisms and risk evaluations on the pollution et al.

Recent advances in remote sensing and geographic information has led the way for the development of hyperspectral sensors. Hyperspectral remote sensing, also known as imaging spectroscopy, is a relatively new technology that is currently being investigated by researchers and scientists with regard to the detection and identification of minerals, terrestial vegetation and man-made materials and backgrounds.

Imaging spectroscopy has been used in the laboratory by physicists and chemists for over 100 years for identification of materials and their composition. Spectroscopy can be used to detect individual absorption features due to specific chemical bonds in a solid, liquid, or gas. Recently, with advancing technology (Ceballos *et al*., 2015), imaging spectroscopy has begun to focus on the Earth. The concept of hyperspectral remote sensing began in the mid-80's and to this point has been used most widely by geologists for the mapping of minerals. Actual detection of materials is dependent on the spectral coverage, spectral resolution and signal-to-noise of the spectrometer, the abundance of the material and the strength of absorption features for that material in the wavelength region measured.

Hyperspectral remote sensing combines imaging and spectroscopy in a single system which often includes large data sets and require new processing methods (Reader and Miller, 2014). Hyperspectral data

sets are generally composed of about 100 to 200 spectral bands of relatively narrow bandwidths (5-10 nm), whereas, multispectral data sets are usually composed of about 5 to 10 bands of relatively large bandwidths (70-400 nm).

Wavelet is a wave-like oscillation with an amplitude that begins at zero, increases and then decreases back to zero (Mench *et al.*, 1997). It can typically be visualized as a "brief oscillation" like one might see recorded by a seismograph or heart monitor. Generally, wavelets are purposefully crafted to have specific properties that make them useful for signal processing (Wang *et al.*, 2014). Wavelets can be combined, using a "reverse, shift, multiply and integrate" technique called convolution, with portions of a known signal to extract information from the unknown signal. As a mathematical tool, wavelets can be used to extract information from many different kinds of data, including-but certainly not limited to-audio signals and images. Sets of wavelets are generally needed to analyze data fully. A set of "complementary" wavelets will decompose data without gaps or overlap so that the decomposition process is mathematically reversible. Thus, sets of complementary wavelets are useful in wavelet based compression/decompression algorithms where it is desirable to recover the original information with minimal loss.

Wheat is in the end of the food chain, if wheat is polluted by the cadmium that will be human health hazards. Therefore, quickly and accurately identify wheat cadmium pollution stress conditions is crucial for the protection of food security (Lee and Carder, 2005). The traditional field sampling and laboratory chemical analysis method, although high accuracy, but the work tedious, high-cost, long cycle. With the development of hyper spectral remote sensing technology, it can make get wheat cadmium pollution stress information fast, efficient, real-time, large-scale, non-destructive become a possibility.

This study attempts to take advantage of wavelet singularity analysis. Diagnostic wheat cadmium pollution stress conditions, using wavelet energy coefficient estimate on the cadmium content in order to establish wheat cadmium pollution stress a highly sensitive diagnostic method.

MATERIALS AND METHODS

Data collection: Choose three studies test area plots of different pollution levels three wheat samples, the use of U.S. ASD produced FieldSpec FR Pro portable spectroradiometer wheat canopy spectral data using a standard whiteboard before each measurement calibration field of view angle of 10°. Each plot to take 20 sampling points, each point measured 10 times and averaged as spectral measurements.
Technical parameters of FieldSpec Pro:

Spectral Range
350-2500 nm
Sampling Interval
1.4 nm, 350-1000 nm
2 nm, 1000-2500 nm
Spectral Resolution (FWHM)
3 nm @ 700 nm
10 nm @ 1400
12 nm @ 2100 nm
Detectors
One 512 element VNIR silicon photodiode array (350-1000 nm)
Two separate, TE cooled, graded index SWIR InGaAs photodiodes (1000-2500 nm)
Input
1.4 m fiber optic lightb guide
Fore Optics Field of View
8°, 18°, 25°
Additional Fore Optics

Hyperion data preprocessing: Surface radiation arriving sensor is a complex process influenced by many factors, including the biophysical properties of the ground, the surface roughness geometry, observation and light exposure, atmospheric conditions and other factors, so the data cannot be directly reflected Hyperion feature reflectance information and the process of acquiring the image due to some mechanical reasons may also cause some degree of distortion of the data.

Band selection: In the 242 bands, removing 49 uncalibrated band and two overlapping bands, there are 191 bands actually had radiometric calibration. Removing uncalibrated band ever, need to strongly consider removing water vapor absorption band. Image noise is affected by the water vapor band, cannot show the information of surface. Delete severely affected by the water vapor bands 35.

Repair broken lines: Hyperion sensor is a push-broom scanning system. Differences in sensitivity between the push-broom scanning systems tend to produce a large number of detector noise ribbon needs to be calibrated. After checking 158 bands of Hyperion images, record the existence of bad lines and bands corresponding column number, checking a total of 13 bands 39 bad line. Use ENVI4.7 Software to remove bad software, then repaired by the average of its neighboring row.

Stripe removal: Hyperion sensor is a push-broom imaging spectrometer calibration tens of thousands of area array CCD detector elements on the device is very difficult to make a bad line Hyperion images in addition, there are many different levels of striped band distribution, especially in the short-wave infrared range more obvious. Standard techniques such as FFT strip

removal filtering, wavelet transform and so cannot produce satisfactory results.

Smile effect: Smile effect, also known as frown curve, it is the push-broom scanning sensor spectral distortions typical distortion means in the vertical direction of flight (Zhang, 2015), as per wavelength position offset from the center to both sides because the last step in the implementation of the MNF pretreatment transformation, therefore, at this time temporarily removing Smile effect and the use of space MNF adjustment method in the pretreatment column means the final step (Column Mean Adjusted in MNF Space) eliminate Smile effects.

Atmospheric correction: Even remote sensing system to work properly, the data acquired with the radiation still errors. Two of the most important environmental decay is atmospheric attenuation and terrain attenuation caused by scattering and absorption of atmospheric. Hyperion image data used in this study is the plain area, terrain attenuation is negligible. In this study, the data is extracted from Hyperion implicit information cadmium pollution stress the need to consider small differences in reflectivity, hence the need for atmospheric correction.

The Minimum Noise Fraction transform (MNF): The minimum noise fraction transform MNF (Minimum Noise Fraction) first determine the intrinsic dimensionality of image data (i.e., number of bands), isolated noise in the data, in essence, is the principal component transform stacked twice: the first conversion (based on the estimated noise covariance matrix) for the separation and re-adjust the noise in the data; the second main component is the noise whitening data transformation.

RESULTS AND DISCUSSION

Hyperion data preprocessing results: Contrast is located at longitude 103° 0'32.13", latitude 36°0'30.15" original spectral curve coordinate point, atmospheric corrected spectral curve and minimum noise removal spectral curve, in Fig. 1 and 2 have shown a characteristic vegetation spectral curve, but obviously a lot smoother than in Fig. 3 of the spectral curve.

Cadmium contamination of wheat recognition model based on Hyperion spectrum: Wheat cadmium pollution stress level evaluation model based on Hyperion image, the first of Hyperion image preprocessing and then select the area of the two typical images of wavelet transform and fractal analysis and the establishment of large-scale wheat cadmium pollution stress level evaluation model.
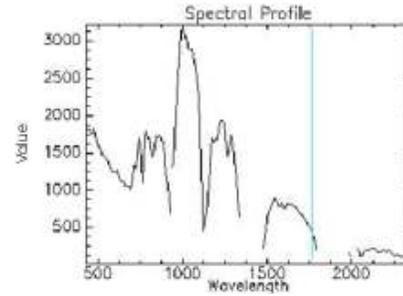

Fig. 1: Hyperion original feature spectral curve example of FIG
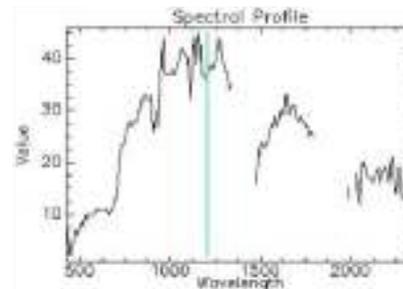

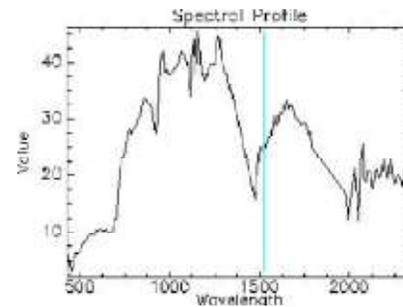Fig. 2: After the example of FIG atmospheric correction spectral curve

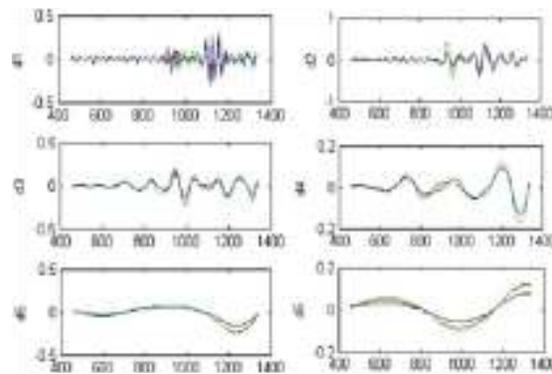Fig. 3: After the example of FIG MNF transform spectral curve

Fig. 4: After db5 wavelet decomposition layers of high frequency detail signal waveforms

Analysis of Hyperion spectral data: Pollution levels in three different regions were extracted five Hyperion

spectral curve, every five averaging, using mat-lab programming for the three spectral curves were decomposed experimental results show that, Dubieties series db4, db5, db6 wavelet wheat under Cd Stress spectroscopy to detect abnormal signal better results, when decomposition level reached the 6th floor of the details of the signal waveform to flatten, it is only broken down to the 6th floor. Detail coefficients first 1-6 layers are denoted by d1, d2, d3, d4, d5, d6. Fractal dimension each wavelet decomposition level varies with the degree of pollution and presents regularly changing circumstances as shown in Fig. 4.

Wavelet function using three small areas of the image interpolated wavelet transform and strike a fractal dimension. After a comparative analysis found that the fractal dimension and the third layer of wheat cadmium concentration db5 wavelet decomposition of the signal indication has the most stable relationship.

CONCLUSION

By the choice of cadmium contamination as the research object, using only the wavelet transform and fractal analysis to extract cadmium pollution stress weak information. The results showed that, db series wavelet has good predictive results, including fractal dimension db5 wavelet Layer 3 details the most stable and reliable signal, can be more accurately indicate a wide range of wheat cadmium pollution degree coercion, to other crops or grasses high heavy metal stress spectral diagnostics and retrieval with reference.

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