RETRIEVE SOIL MOISTURE FROM VEGETATION-SOIL MIXED PIXELS BASED ON SCALE TRANSFORMATION RULE

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1. INTRODUCTION

Soil water plays a very important role in the exchange of the material and energy between the land surfaces and atmosphere. And soil moisture is a key parameter which characterizes soil water. The soil moisture characterizes the moisture degree of soil at certain depth. It is an important input parameter of hydrological and micrometeorological models. And it is also a key parameter for drought monitoring.

The previous studies of soil moisture retrieval mostly focused on the bare soil. But the mixed pixels universally exist in land surface. The soil moisture retrieved from vegetation-soil mixed pixels is very important for drought monitoring and ecological study. Microwave, thermal infrared and vegetable index methods can be used to monitor soil moisture, but these three methods have inevitable defects, when retrieving soil moisture from vegetation-soil mixed pixels. Along with the development of hyperspectral remote sensing, the mixed pixels can be unmixed. The area ratios and components information can be retrieved. In this paper, based on scale transformation approach, we established a new method retrieving soil moisture from vegetation-soil mixed pixels using hyperspectral data.

2. METHODOLOGY

2.1. Pixel Unmixing and Scale Transformation Rule

Suppose that the vegetation and soil are linear mixed in a pixel. The sum of area ratios equal 1. The reflectance of mixed pixel can be described as:

$$\rho = \rho_v a_v + \rho_s (1 - a_v) \quad (1)$$

where ρ_v, ρ_s are the reflectance of vegetation and soil respectively. a_v is the area ratio of vegetation. The area ratio of vegetation can be retrieved by unmixing method. But the accuracy and stability are not satisfied with the request. In this paper, the average area ratio of vegetation in low resolution pixel is obtained based on scale transformation rule.

For a n order pixel (the larger the order, the coarser the resolution, defined in Xu X., et al., 2009, and it is supposed that only pure pixels exist in 0-order image), the average of n-order x values, which is the spatial scale transformation formula, is as following [2] :

$$\overline{x_n} = \frac{\overline{\rho''}}{\rho''_v} = \overline{a_v(n)}\overline{\left[L_s\left(1-e^{-b\cdot LAI_0}\right)+\left(1-L_s\right)\left(1-e^{-b'\cdot LAI_0}\right)\right]} \tag{2}$$

$a_v(n)$ is the area ratio of vegetation in n order pixel. The following expression can be obtained according to a numerical simulation [3]:

$$\overline{a_v(n)} = e^{-pn}(1-c)+c \tag{3}$$

where p and c are parameters related to the distribution and the structure of heterogeneity [3]. Three different scales data was used, according to equation (2) and (3), a_v in low resolution pixels can be obtained.

2.2. Retrieve Soil Moisture Based on Hyperspectral Data

2.2.1. Retrieval Formula

According to Beer law, the relation between soil reflectance and soil moisture can be written as:

$$\rho_s(\lambda) = a(\lambda)e^{b(\lambda)w} \tag{4}$$

where $\rho_s(\lambda)$ is the reflectance of soil s in the spectral band λ. w is the soil moisture. $a(\lambda)$, $b(\lambda)$ are empirical parameters in the spectral band λ.

2.2.2. Band Choice

Hyperspectral data provides the whole radiometric information. However, a limited set of wavebands is likely to express the highest sensitivity to given characteristics. We selected the best suited wavelength domains to retrieve soil moisture. Firstly, the wavebands (1350-1450nm, 1800nm-1900nm and 2400-2500nm) which are strongly absorbed by the atmosphere are discarded. Secondly, in order to reduce the influence of vegetation, focusing on the wavebands in which the reflectance of soil is high and the reflectance of vegetation is low. Thirdly, in order to retrieve soil moisture better, the band chosen should be sensitive to soil moisture. This was achieved by calculating the correlation coefficient between soil reflectance and soil moisture. The best performance was observed at 2036nm, which was 0.8706. And 2036nm also met the above conditions.

3. NUMERICAL SIMULATION

In order to quantify the relationship between the area ratio of vegetation and the retrieval accuracy, a sensitivity analyses was performed using simulations with the leaf radiative transfer model PROSPECT [4] and the canopy reflectance model GeoSAIL [5]. Along with the increasing of the area ratio of vegetation, the retrieval error is exponentially increasing. When the area ratio of vegetation is more than 27%, the retrieval error reaches 5%. When the area ration of vegetation reaches 50%, the retrieval error is more than 10%. So when the area ration of vegetation is more than 50%, it is hard to retrieve soil moisture from mixed pixels.

There always exist 10%~ 15% errors during the measurements. So the impact of measurement error was also analyzed. When 5%-15% random errors are considered, the retrieval error is from 3.6586% to 6.7287%.

4. EXPERIMENTS

The study area is located at Yingke Oasis, Zhangye City, Gansu Province, China, (38.75°N~39.12°N ， 100.33°E ~100.52°E), where an extensive and well organized ground experiment "WATER" [6] has collected abundant ground measured and remotely sensed data. A Hyperion/EO-1 data acquired on Jul. 15, 2008 was pre-processed and upscaled to 180m and 1080m resolution data. Using the above method, the soil moisture of the 1080m pixels were calculated using equation (4). 60 soil moisture data sets obtained using TDR, equipped with GPS, were taken as ground truth. The soil moisture data sets measured by TDR were first averaged to the same scale of the retrieved results and then compared with them. The average error between simulated values and measured values is 4.4539%, and the relative error is 16.39%.

5. REFERENCES

[1] Xu X., Fan W., Tao X., et al., "The Spatial Scaling Effect of continuous canopy Leaves Area Index Retrieved by Remote Sensing," Sci China Ser D-Earth Sci, 2009,52, 393-401

[2] Fan W., Xu X., Liu X.,et al., "The accurate LAI retrieval method based on PROBA/ CHRIS data," Hydrology and Earth System Sciences. 2009 (accepted).

[3] Tao X, Yan B, Wang K, Wu D, Fan W, Xu X, Liang S. "Scale transformation of leaf area index product retrieved from multi-resolution remotely sensed data;analysis and case studies,". Int J Remote Sensing, 2009, 20(20): 5383~5395.

[4] Jacquemoud S, Baret F., "PROSPECT: A model of leaf optical properties spectra," Rem. Sens. Environ., 34 pp. 75-91,1990.

[5]Bach H, Verhoef W, Schneider K., "Coupling remote sensing observation models and a growth model for improved retrieval of (geo) biophysical information from optical remote sensing data," Reomote sens. For Agric., Ecosystems and Hydrology, SPIE 4171, pp. 1-11, 2000.

[6] Li X., Ma M., Wang J., et al., "Simultaneous remote sensing and ground-based experiment in the Heihe River basin: scientific objectives and experiment design," Advances in earth science, 2008, 23(9): 897-914.