DETECTING SOIL HEAVY METAL ELEMENTS CONTENT BASED ON REFLECTANCE SPECTRA

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1. INTRODUCTION

The content of soil heavy metal elements is strongly affected by human actives. When the content of heavy metal elements is higher than the threshold, side effect will act on crop and human [12, 15]. Laboratory studies have already shown successful application of soil reflectance in the visible-near-infrared (VNIR) region for the prediction of soil characteristics like organic matter and clay content [1-3, 6, 8, and 13]. It is very difficult to extract heavy metal content of soil from reflectance spectra directly because the content is very little and the soil reflectance is slightly affected by them. However, the content of heavy metal can indirectly detect from soil reflectance through the content of organic matter, iron and manganese oxides, and clay [4, 5, 11, and 14]. This paper analyzes the possibility of reflectance spectra obtained under laboratory conditions for the assessment of plumbum (Pb), cadmium (Cd) and hydrargyrum (Hg) content in soil quickly.

2. MATERIALS AND METHODS

2.1. Data Source

The heavy metal content of some experiment area was over proof [16]. Fifty one topsoil samples were collected from the topsoil of experiment area. After pretreated, each sample was split into two subsamples. One was analyzed for total Cd, Hg, and Pb content, and the other was used for spectral measurements (from 400nm to 2480nm, at 2 nm increments).

2.2. Model Construction

Parabola correction and Hamming window was adopted to pre-precess the measured reflectance curve. Besides original spectra (R), several spectral indices were also calculated: first derivative reflectance spectra (FDR) [7, 10], inverse-log spectra (Log (1/R)) and band depth (BD) [9]. The measured reflectance spectra were resampled to VNIR bands of multi-spectral sensors (TM and ASTER) according to their reflectance response functions. The shapes of simulated spectra were consistent with the measured one except for the absorption band of oxide (Fe) and water or hydroxyl. Partial least square regression (PLSR) was used to develop calibrations between spectral indices data, simulated spectra data (TM and ASTER), and content of soil elements. To verify the prediction capability of model, a one-out cross-validation procedure was adopted. Coefficient of determination (R) and root-mean-square error (RMSE) were used as criteria for best model.

3. RESULTS

The results showed that 1) Log (1/R) is the best index for estimate soil heavy metal content, especially for Cd (R=0.8221) and Pb (R=0.8612); 2) The coefficient of the models showed that heavy metal has a better effect on visible and near infrared (VIS-NIR) band than on shortwave infrared band (SWIR); 3) There are three wavelength regions relevant closely to soil

heavy metal content. They are 500nm-1000nm which is absorption band of ferric oxide and the prominent area of organic matter to soil reflectance, 1750nm-1900nm which contains the character of 1870nm brought by vibration of carbonate ions, and band near 2200nm which is the absorption band of hydroxyl of dioctahedral clay mineral; 4) The mechanism for estimate soil heavy metal element content by VIS-NIR-SWIR spectra is the absorption function of organic matter, iron-manganese oxide, and clay minerals; 5) Simulated multi-spectral data have the good ability to estimate soil heavy metal elements content, although the coefficient is slightly less than original reflectance. The third band of TM and the second, forth, and fifth band of ASTER are optimum selection for the prediction of soil heavy metal content. While satisfactory results are obtained by laboratory spectra, there are many more factors should be considered when using field data even satellite data.

4. REFERENCES

[1]A. Palacios-Orueta, S. L. Ustin, "Remote Sensing of Soil Properties in the Santa Monica Mountains I. Spectral analysis", *Remote Sensing of Environment*, vol. 65, pp. 170-183, 1998.

[2]H. A. Zhang, Y. H. Zhu, "Quantitative Spectral Analysis of Main Clay Minerals in Soil", *Remote Sensing for Land & Resources*, vol. 2, pp. 52-54, 1994.

[3]J. W. Hummel, K. A. Sudduth, S. E. Hollinger, "Soil Moisture and Organic Matter Prediction of Surface and Subsurface Soils using an NIR Soil Sensor", *Computers and Electronics in Agriculture*, vol. 32, pp. 149-165, 2001.

[4]K. M. Wu, L. X. Zhu, S. M. Ma, et al, "Analysis of Heavy Metal Speciation in Alluvial Plain Soil ", *Journal of Instrumental Analysis*, vol. 23, pp. 41-43,2004.

[5]L. Kooistra, L. Wehrens, R. S. E. W. Leuven, et al, "Possibilities of Visible-near-infrared Spectroscopy for the Assessment of Soil Contamination in River Floodplains", *Analytica Chimica Acta*, vol. 446, pp. 97-105, 2001.

[6]M. M. Coûteaux, B. Berg, P. Rovira, "Near Infrared Reflectance Spectroscopy for Determination of Organic Matter Fractions including Microbial Biomass in Coniferous Forest Soils" , *Soil Biology & Biochemistry*, vol. 35, pp.1578-1600, 2003.

[7]O. Mutanga, A. K. Skidmore, H. H. T. Prins, "Predicting in Situ Pasture Quality in the Kruger National Park, South Africa, using Continuum-removed Absorption Features", *Remote Sensing of Environment*, vol. 89, pp. 393-408, 2004.

[8]R A V Rossel, A B McBratney, "Laboratory Evaluation of a Proximal Sensing Technique for Simultaneous Measurement of Soil Clay and Water Content", *Geoderma*, vol. 85, pp. 19-39, 1998.

[9]R. F. Kokaly, R. N. Clark, "Spectroscopic Determination of Leaf Biochemistry using Band-depth Analysis of Absorption Features and Stepwise Multiple Linear Regression", *Remote Sensing of Environment*, vol. 67, pp. 267-287, 1999 .

[10]T. H. Demetriades-Shah, M. D. Steven, A. Clark, "High Resolution Derivative Spectra in Remote Sensing", *Remote Sensing of Environment*, vol. 33, pp. 55-64, 1990.

[11]T. Kemper, S. Sommer, "Estimate of Heavy Metal Contamination in Soils after a Mining Accident using Reflectance Spectroscopy", *Environmental Science and Technology*, vol. 36, pp. 2742-2747, 2002.

[12]X. Z. Li, "The Damage of Heavy Metals Lead and Cadmium to Soil and Crops with Reference to the Control Measures", *Economic Forest Researches*, vol. 18, pp. 12-13, 2002.

[13]Y. K. Peng, J. X. Zhang, X. S. He, et al, "Analysis of Soil Moisture, Organic Matter and Total Nitrogen Content in Loess in China with Near Infrared Spectroscopy" , *Acta Pedologica Sinica*, vol. 35, pp. 553-559, 1998.

[14]Y. Z. Wu, J. Chen, X. M. Wu, et al, "Possibilities of Reflectance Spectroscopy for the Assessment of Contaminant Elements in Suburban Soils", *Applied Geochemistry*, vol. 20, pp. 1051-1059, 2005.

[15]Z. W. Wang, L. M. Xu, W. J. Zhang, "Corresponding Relationship between Trace Elements in Soil and Human Activity Intensity", *Chinese Journal of Soil Science*, vol. 33, pp. 303-305, 2002.

[16]Z. Xu, M. L. Tian, Y. S. Jiang, et al, "Aanlysis of Farmland Environment Quality of Sewage Irrigation Area in Tianjin", *Science and Technology of Tianjin Agriculture and Forestry*, vol. 12, pp. 26-28, 1999.