Mapping soil degradation by topsoil grain size using MODIS data

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Abstract:

MODIS BRDF reflectance data at the end of April 2004 was selected to make a desertification map base on topsoil grain size by using Gain Size Index at arid and semiarid Asia. After data processing, GSI was applied into desertification mapping, and we find that high GSI area distributed at the desert and its' marginal area, degraded grassland, desert steppe. The desertification map was output according to the correlation between GSI and grain size distribution, the classification of desertification is no desertification, light desertification, middle desertification, and severe desertification. The result can manifest the soil degradation very well.

1 Introduction

Desertification is land degradation, manifested by "desert-like" conditions in dryland areas. Climatic conditions together with geomorphologic processes help to mould desert-like soil surface features in arid zones. The identification of these soil features serves as a useful input for understanding the desertification process and land degradation as a whole (Shrestha et al,. 2005). Soil degradation mapping is very useful for land management and soil evaluation, the changing of soil properties like texture**,** organic matter (OM), pH, phosphorus and potassium is important for the world because it has close relation with the food and living condition for human being. Grain size distribution is one of important characteristics of soil texture, and coarsen of the soil surface is an indicator of soil degradation.

Soil reflectance spectra have a direct relationship with soil texture, as well as to other parameters such as soil moisture, and organic matter. Remote sensing technique is proved as an available method for detecting and monitoring the change of land cover. Analysis of remotely sensed data involves identifying features and correlating ground-based measurements with recorded reflectance or emittanee values (Mattikalli, 1997). Earlier studies have identified significant relationships between some of these properties and spectral reflectance of soils in the visible and near infrared portions of the electromagnetic spectrmn (e.g., Gerbermam et al., 1979; Stoner anti Baumgardner, 1981; Horvath et al., 1984; Baumgardner et al., 1985; Jeyasingh, 1986; Mattikalli, 1997). And recently, also many studies concern about this topic, Shrestha et al (2005) analyzed absorption feature parameters in the spectral region between 0.4 and 2.5 µm wavelengths and correlated with soil properties such as soil colour, soil salinity, gypsum content and applied Linear unmixing and spectral angle matching techniques to assess their suitability in mapping surface features for land degradation studies. Chikhaoui et al., (2005) characterized the state of land degradation in a small Mediterranean watershed using ASTER data and ground-based spectroradiometric measurements, developed land degradation index, and applied this index for assessing and mapping land degradation.

Very few studies concerned about soil degradation mapping by topsoil grain size in arid and semiarid area, even recently there isn't one grain size distribution map or a desertification map base on the topsoil grain size. And it cost time and resource to obtain the map of soil physical properties in regional or continental scale using traditional method, in this study, it will become very quick and economical to get the topsoil grain size content map. The present study will apply the grain size index which base on the field survey and laboratory analyses, to the mapping of soil degradation by manifesting the topsoil grain size distribution using remote sensing images.

2 MODIS data and processing

2.1 MODIS data

In the present study, the surface reflectance data production name MODIS/TERRA Nadir BRDF-Adjusted Reflectance 16-DAY L3 Global 1 KM SIN Grid Product (MOD43B4 NBAR) were chosen for mapping the soil degradation in arid and semiarid area of central east Asia. Every 16 days, the MODIS BRDF/Albedo Product (MOD43B) algorithm relies on multidate, atmospherically corrected, cloud-cleared data and a semiempirical kernel-driven bidirectional reflectance model to determine a global set of parameters describing the Bidirectional Reflectance Distribution Function (BRDF) of the land surface. These one kilometer gridded parameters are then used to determine directional hemispherical reflectance, bihemispherical reflectance, and nadir BRDF-adjusted reflectance (NBAR) for seven narrow spectral bands and (in the case of albedo) three broad bands. Since the parameters of the simple kernel-based BRDF model (RossThickLiSparseR) are also provided, along with extensive quality information, the MODIS BRDF/Albedo Product offers members of the global observation and modeling community the additional flexibility to derive reflectance and albedo measures particularly suited to their specific applications. MOD43B is a MODLAND Level 3 Product and is provided globally as discrete 1200 by 1200 element tiles in an Integerized Sinusoidal Grid projection in a HDF-EOS format. MOD43B1 provides the BRDF model parameters, MOD43B2 provides an alternative set of model parameters, MOD43B3provides the black-sky albedo (at a solar zenith angle of 45 degrees) and the white-sky albedo, and MOD43B4 provides the NBAR value at the mean solar zenith angle of the 16 day period (source from: http://edcdaac.usgs.gov/modis/mod43b4.asp).

The BRDF gives the reflectance of a target as a function of illumination geometry and viewing geometry. The BRDF depends on wavelength and is determined by the structural and optical properties of the surface, such as shadow-casting, mutiple scattering, mutual shadowing, transmission, reflection, absorption and emission by surface elements, facet orientation distribution and facet density. (Lucht, http://geography.bu.edu/brdf/brdfexpl.html, last updated: 1, Aug 2000)

MOD43B4 NBAR Product is computed for each of the MODIS spectral bands (1-7) at the mean solar zenith angle of each 16-day period. Since the view angle effects will have been removed from the directional reflectance, this will result in a more stable and consistent product. NBAR values could be directly used as the primary input to the advanced technique classifiers used in the production of the global MODIS Land Cover Product. It is expected that the user community will be quick to take advantage of the NBAR data for those situations where composited surface reflectances may have been traditionally used (Schaaf et al., 2002 and http://geography.bu.edu/brdf/userguide/nbar.html, last update, Apr 2004). The Original Data Set Characteristics are:
Area = ~ 10 x10 lat/long
Size = 1200 x1200 rows/columns
Volume = ~31MB
Resolution = 1 kilometer
Projection = Integerized Sinusoidal
Data Type Reflectance = 16-bit Signed Integer
Data Type Quality = 32-bit Unsigned Integer
Data Format = HDF-EOS

Science Data Sets (SDS) = 2 (http://edcdaac.usgs.gov/modis/mod43b4.asp last update at 13 June, 2005)

2.2 Data processing

The data set is come from Land Processes Distributed Active Archive Center (LPDAAC) of NASA's Earth Observing System (EOS). The chosen area showed by the MODIS/TERRA Nadir BRDF- Adjusted Reflectance 16-DAY L3 Global 1 KM SIN Grid Product by RGB color composition, the date range of this image is 10-25, June 2004, Fig.1, vegetation cover is in green color while the desert, sandy land and bare ground is in pink, orange or thistle. The location is at arid and semiarid area of Asia, including China, Mongolia, Kazakhstan, Uzbek, Turkmen, Afghan, Pakistan, Tajikistan, Kyrgyzstan and so on. Most of these countries in this area suffering the severe land degradation, especially China. The images for GSI and soil texture mapping were from 23, April to 8, May in 2004.

The original data set was preprocessed before using, including into image mosaic one by one by using MODIS reprojection tool (MRT) software, and then change the original Integerized Sinusoidal projection into geographic Latitude and Longitude WGS 84. Geometric correction was done to the images, Landsat ETM^+ images were used and considered as a reference. Landsat ETM^+ images were downloaded from Global Land Cover Facility Earth Science Data Interface of University of Maryland (http://glcfapp.umiacs.umd.edu: 8080/esdi/index.jsp). The images are georeferenced to Geographic map projection for WGS84 Reference datum. (The work of mosaic, reprojection and geometric correction has been done by Al-Bilbisi et al., 2005). And then made a spatial subset to the image to choose arid and semiarid area of Asia only using ENVI software.

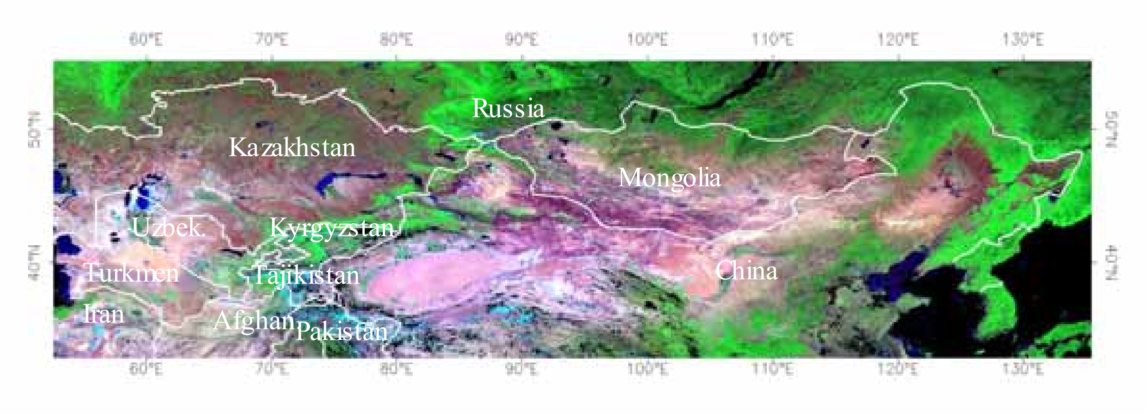

Fig. 1 Arid and semiarid area in Asia.

There are some fill values in this data set, so the mask was applied into the images to delete noisy, and then calculated the reflectance data of every band for the preparation for the calculation of GSI. In this study, the data of 23 Apr to 8 May 2004 was chose from MOD43B4 NBAR data set for desertification mapping.

3. Soil degradation mapping by using GSI

Topsoil Grain Size Index (GSI) was developed by Xiao et al in 2005, it is base on the field survey and laboratory analyses. After the analyses of the correlation between grain size distribution and reflectance data of topsoil samples, we found that the reflectance data changing accompany with the changing of grain size distribution, especially fine sand content and clay+silt content. Then GSI was applied into local area, we obtain the GSI map of the local area, high GSI area means fine sand rich area. Then according to the correlation between GSI and fine sand content, fine sand content distribution map was output as the result, it could manifest the fine sand content very well.

It is calculated by the equation (1):

$$GSI=(R-B)*(R+B+G) \tag{1}$$

Where R, G, B, mean the red, green, and blue visible band of MODIS image that band 3, 4, and 1. In this study, GSI will be applied into the arid and semiarid area of Asia to describe the land degradation of this area.

4. Result

Grain size of topsoil is one of the important characteristics of the soil, and coarsen of the topsoil manifested the soil degradation turning serious. In this study, the fine sand (0.0075-0.425mm in diameter) content of topsoil was obtained by using the GSI map in arid and semiarid Asia.

GSI was classified into seven classes according to the value (Fig.2), and higher GSI value points concentrated at the desert area and sandy land while the highest value points are not located at the large area desert. From the GSI map of 2004, the white color area (GSI is in the range of 0.1-0.15) is only lies on the North part of China and the South part of Mongolia, while it can be found at the south part and some part of Taklimakan desert in China.

Also the desertification maps based on the GSI map were drawn in this study. The Grain Size Index was coming from the correlation between the reflectance and the grain size content, so in this study, the fine sand percentage was found through calculating the reflectance, classified into <15%, 15-30%, 30-45%, and >45%. Then the desertification map were made according to the content of fine sand, classified into no desertification, light, middle and severe desertification, showed by Fig.3, the desertification map manifested the content of the particle which grain size from 0.0075mm to 0.425mm in diameter of arid and semiarid Asia in 2004. From the desertification map, we can find the severe desertification area (in gray color) is in desert area and northeast part and north part of Inner Mongolia, China, some south part of Mongolia and north part of Tibet high plateau of China. If long-term data are possible, change detection can be conducted. In addition, this desertification map can be used for other analyses. It will benefit for analyzing the correlation between desertification and other contributing factors.

This is the first desertification map which base on the topsoil grain size. It is very easy to find the topsoil grain size content in large scale by very economical and quick way. The topsoil grain size map can be used as a tool for land degradation process assessment and change detection.

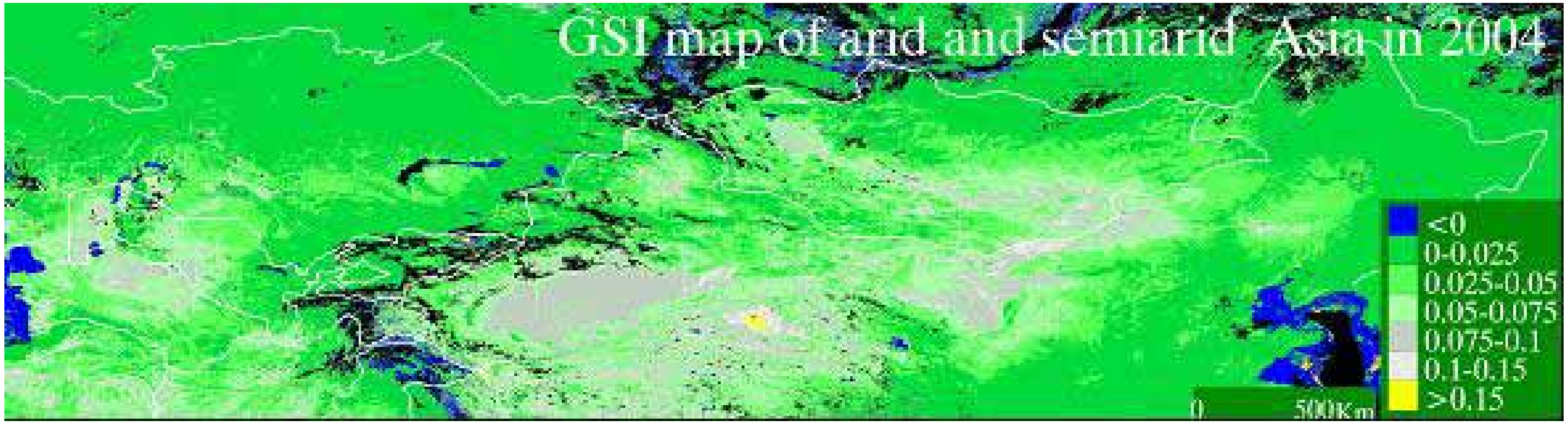

Fig. 2 GSI map of arid and semiarid area of Asia at 2004

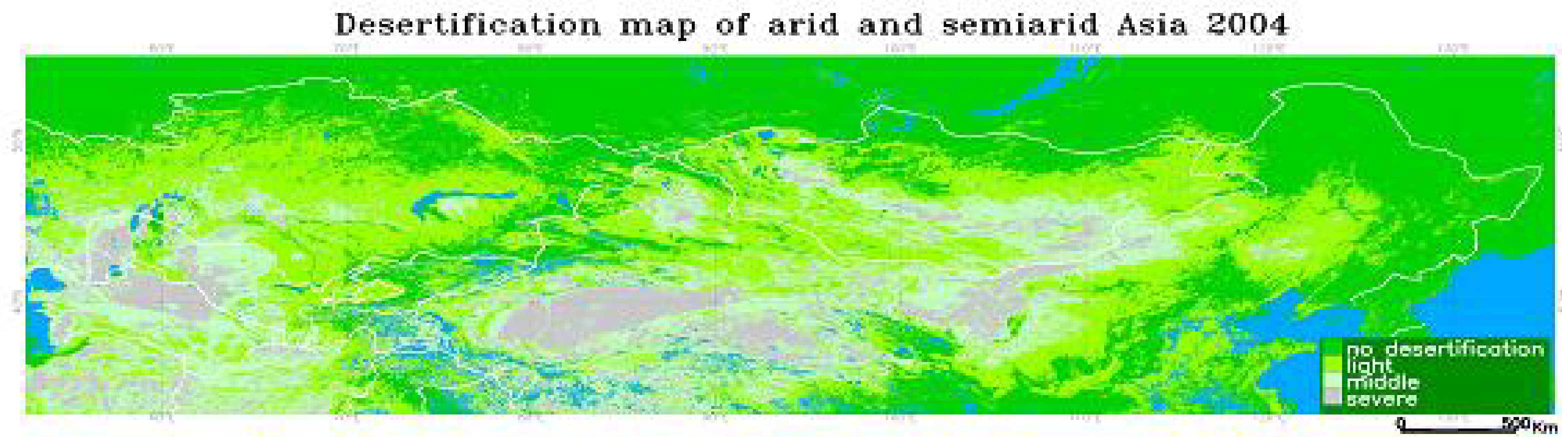

Fig. 3 Desertification map of arid and semiarid area of Asia at 2004

Reference:

Shrestha D.P., Margate D.E., Meer F., Anh H.V. 2005, Analysis and classification of hyperspectral data for mapping land degradation: An application in southern Spain. International Journal of Applied Earth Observation and Geoimformation. Volume 7, Issue 2, pp85-96.

Gerbermann, A. H., and Neher, D. D. 1979, Reflectance of varying mixture of clay and sand. Photogramm. Eng. Remote Sens. 45, pp1145-1151.

Stoner, E. R., and Baumgardner, M. F. 1981, Characteristic variations in reflectance of surface soils. Soil Sci. Soc. Am. **J.** 45, pp1161-1165.

Horvath, E. H., Post, D. F., and Kelsey, J. B. 1984, The relationships of Landsat digital data to the properties of Arizona rangelands. Soil Sci. Soc. Am. J. 48, pp1331-1334.

Baumgardner, M. F., Silva, L. F., Biehl, L. L., and Stoner, E. R. 1985, Reflectance properties of soils. Adv. *Agron.* 38, pp1-44.

Jeyasingh, V. K. tt. 1986, Development of a technique of modeling and predicting soil characteristics based on spectral reflectance. Ph.D. thesis, Indian Institute of Technology, Powai, Bombay.

Chikhaoui M., Bonn F., Bokoye A.I., Merzouk A., 2005, A spectral index for land degradation mapping using ASTER data: Application to a semi-arid Mediterranean catchment. International Journal of Applied Earth Observation and Geoimformation, Volume 7, Issue 2, pp 140-153.

http://modis.gsfc.nasa.gov/about/

http://modis.gsfc.nasa.gov/about/specifications.php

Lucht, http://geography.bu.edu/brdf/brdfexpl.html, last updated: 1, Aug 2000

Schaaf, C. B., Gao F., Strahler, A. H., Lucht W., Li X., Tsang T., Strugnell N. C., Zhang X., Jin Y., Muller J.-P., Lewis P., Barnsley M., Hobson P., Disney M., Roberts G., Dunderdale M., Doll C., d'Entremont R., Hu B., Liang S., and Privette J. L., First Operational BRDF, Albedo and Nadir Reflectance Products from MODIS, Remote Sens. Environ., 83, 135-148, 2002.

http://geography.bu.edu/brdf/userguide/nbar.html, last update, Apr 2004

http://glcfapp.umiacs.umd.edu: 8080/esdi/index.jsp

Al-Bilbisi Hussam, Tateishi Ryutaro, Rokhmatulah and Arihara Kota, et al., 2005, Pre-processing of global MODIS data form USGS, Proceedings of the 39th Conference of the Remote sensing society of Japan (submitted).

Mattikalli, N, M., 1997, Soil color modeling for the visible and near-infrared bands of Landsat sensors using laboratory spectral measurements. Remote Sensing of Environment, Volume 59, Issue 1, pp14-28.

http://edcdaac.usgs.gov/modis/mod43b4.asp last update at 13, June 2005

xiao, J, Y., Shen, Y.J., Tateishi R. Development of topsoil grain size index for monitoring desertification in arid land using remote sensing. International Journal of remote sensing, (conditional accept, 2005).