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Land cover change detection based on satellite data for an arid area to the south of Aksu in Taklimakan desert

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Abstract: An experiment is made to detect the land-cover change in the area located to the south of Aksu in the northern Taklimakan desert through analyses of satellite data pixel by pixel basis. The analyzed data are those observed in the late summer and early autumn of 1973, 1977, 1993 and 1995. As a parameter of land-cover, SAVI (Soil Adjusted Vegetation Index) derived from the data of Landsat MSS and JERS-1 OPS (Optical Sensor) is used. The result indicates the increase of vegetation in the oasis areas, confluent area of the Yarkant and Kashgar Rivers and around reservoirs while little change occurs in the desert area. The 1973 satellite image shows the abundant flow in the Yarkant River while the river is almost dried up in the satellite images of later years. The trend of the decrease in the Hotan River flow is recognized although not so dramatic as that of the Yarkant River.

Keywords: Taklimakan Desert; SAVI; Landsat MSS; JERS-1 OPS; vegetation; false color; landcover change

1 Introduction

During the Japan-China Joint Study on Desertification (1989–1994) under the sponsorship of Science and Technology Agency (STA) of Japan and Chinese Academy of Sciences (CAS) one of the authors, Tsuchiya participated in this project as the leader of the group to study the landcover and land use based on in situ surveys and satellite data. Cooperating with the remote sensing group of Xinjiang Institute of Biology, Pedology and Desert Research the ground truth surveys were conducted at selected key areas with portable multispectral radiometers and meteorological instruments. The target area of this study attracted our interest, however due to the severe limitation of time and man power we could not cover all areas. At the end of Japan-China Joint study we could acquire two old Landsat MSS image data covering the area together with those of JERS-1 OPS. We decided to extract landcover change of the area through pixel by pixel basis of the image data. The years of observation of Landsat are 1973 and 1977 while those of JERS-1 are 1993 and 1995.

To extract landcover from these data it is necessary to eliminate all kinds of distortions in addition to the effect of sensor degradation. Furthermore adjustments of the observed values and the pixel size difference between the images of 2 satellites, registration of 4 images is indispensable. The distortions are eliminated to a certain extent during the data processing at the receiving station (Tsuchiya et al., 1980), however it is far from the level required for extraction of a land cover change pixel-wise. The causes of radiometric distortions are extremely complicated (Tsuchiya et al., 1982, 1996). Just a viewing direction difference affects the observed values (Ishiyama et al., 1999; Martonchik et al., 2000). Thus very complicated time consuming processing is required. A preliminary result of the analysis was presented by Tsuchiya at the Desert and Desertification Session of Desert Technology VI International Conference held at Urumqi, China during September 16–24, 2001. Recently Tsuchiya developed a method to extract landcover change from the data of different spatial and spectral resolu-
tion observed from different satellites at different time (Perera and Tsuchiya, 2009). An attempt is made to extract the land-cover change between the time of satellite observation by pixel by pixel basis from the 4 image data through application of the method developed by Tsuchiya.

2 Selection of a vegetation index

Rouse et al. (1973) introduced NDVI (Normalized Difference Vegetation Index) to represent a vegetation feature. Huete (1988) pointed out the importance of the effect of the background soil reflectance and introduced SAVI (Soil Adjusted VI), Eq. (1) by adding an adjusting term L to NDVI.

$$SAVI = \frac{(NIR - R)(1+L)}{(NIR + R + L)}, \quad (1)$$

where, NIR and R denote the spectral reflectance of a target in NIR (Near Infra-Red) and R (Red) spectra respectively. The relationship between NDVI and SAVI is more explicitly shown in Eq. (2).

$$SAVI = \frac{NDVI (1 + L)}{[1+L/(NIR+R)]}. \quad (2)$$

Eq. (2) indicates that SAVI is larger than NDVI if (NIR+R) is larger than one and vice versa, while SAVI is equal to NDVI if L= 0 or if (NIR + R) is equal to 1. Since SAVI and NDVI are derived from the ratio of reflectance of 2 bands the effects of the atmosphere, observation and illumination directions, temporal degradation of the sensor, etc. are reduced to a certain extent. Richardson et al. (1977) introduced another index PD (Perpendicular Distance) which is the distance from an arbitrary pixel point to the soil line in 2 dimensional space consisting of the observed values of R and NIR. In this 2 dimensional space the soil line is determined from the observed pixel values of R and NIR. In this 2 dimensional space the soil line is determined from the observed pixel values of R and NIR over the bare land surface. Based on this idea, Pickup (1989) introduced PD54 which utilizes the observed spectral reflectance of Band-5 (Red) and Band-4 (Green–Orange) of Landsat MSS instead of R and NIR. According to Pickup, PD54 is better than the original PD derived by Richardson et al. (1977) to represent land cover especially for vegetation of a semi arid Australian rangeland.

Tsuchiya (2000) made a review and a test for an applicability of 18 VI's to an arid area and made comparison of the indices utilizing the arid area in the central Australia with abundant ground truth data. The result indicates that SAVI, PD-54 and NATVS (Normalized Area of Triangle for Vegetation Pattern) (Tsuchiya and Suga, 1998) show comparatively stable and satisfactory result followed by NDVI and modified SAVI. Based on the studies by Ishiyama et al. (1997), Tsuchiya (2000), Kasimu et al. (2008) and for the sake of simplicity, SAVI is adopted as the index to represent land-cover feature in this study.

3 Study area

A very rough map of the study area is shown in Fig. 1. To extract a land-cover change from multi temporal and multi satellite image data, a strict registration of all the image data is necessary. To satisfy this condition several clearly recognizable targets, such as crossing points of highways, lakes/reservoirs, junctions of rivers, etc. are necessary in the scenes. As a study area, the existence of various kinds of land-cover, such as forests, agricultural lands, shrubs, salt planes, complete bare lands in the scene is also desirable. The present study area satisfies these conditions so the area is selected as the ideal experimental study area.

![Fig. 1 A schematic representation of the study area to the south of Aksu in the northern edge of Taklimakan desert. A, B and C are the confluent point of the two rivers, a reservoir and the old Yarkant River respectively. The area surrounded by heavy lines is the area reported in this paper.](image-url)
4 Analyzed satellite data

The false color composite satellite images of the study area are shown in Fig. 2, which were observed on 16 September of 1973, 12 July of 1977, 19 September of 1993 and 24 August of 1995, respectively. The color composite was made in such a way that blue, green and red colors were assigned to the data of Band 4 (green), Band 5 (red) and Band 7 (near infrared), in case of OPS data Band 1, Band 2 and Band 4 respectively. The red color means that the infrared spectrum of the solar radiation is strongly reflected. Since vegetation reflects near-infrared spectrum strongly red color denotes vegetation cover, light blue part is the bare land/desert respectively. Since salt and cloud reflect all the bands strongly, they appear white, while the reflectance of the water is very low in all bands, resulting in the dark color.

In the Fig. 2, the red part is the area covered with vegetation; the dark parts are water and wet land; the light blue part is the bare land (desert); and the white part is the land with salt deposit or cloud. In Fig. 2 (b) white patchy parts to the north of the reservoir are clouds. The parts of red, white, light blue are indicated with the letters R, W, and LB respectively in Fig. 2 (d) to help interpretation of the figures printed in black and white. A rough feature of the land cover change can be visually recognized in these images. The increase of vegetation cover is seen in the upper part of the figure and the confluent area of the Yarkant and Kashgar Rivers. A fairly large change in the flow amount of the Yarkant River and the size of the swampy area along the old Yarkant River are recognized. The abundant river flow and swampy areas in 1973 image (a) disappeared in the other 3 images of later years with the driest appearance in the image of

![Fig. 2 False color composite images of the study area. (a) Landsat MSS, September 16, 1973. Letters A, B and C correspond to those in Fig.1; (b) Landsat MSS, 12 July 1977; (c) JERS-1 OPS, 19 September 1993; (d) JERS-1 OPS, 25 August 1995. Red (R), white (W), light blue (LB) and black (B) colors denote vegetation, land with salt deposit or cloud, bare land, and water respectively. Parts corresponding to respective colors in the original false color are shown in (d) to help interpretation of the figures printed in black and white. The small white part with letter Cd and small white patchy parts in the north and to the east of the reservoir in (b) are clouds.](image-url)
1993 (c). It seems this fact contributed to the desertification of the areas.

5 Satellite data processing

The detail of the methodology is well explained in the paper by Perera and Tsuchiya (2009), so here significant points are explained in this paper.

5.1 Registration of different satellite image data

To extract the land-cover change by taking the difference of pixel-wise value of SAVI, a strict registration of image data is necessary. It was decided to select the oldest image (16 September of 1973) as the reference image, and the other 3 image data were registered to those of the reference through application of the image to image registration algorithm utilizing clearly recognizable ground targets as the control points. The pixel size of OPS was also adjusted to the size of MSS. Then SAVI value of each pixel was computed based on Eq. (1). Since in situ spectral observation data were not available, 0.5 for L was adopted as suggested by Huete (1988).

5.2 Consideration on radiometric calibration

If a target is observed simultaneously with MSS and OPS, the values of SAVI derived from the MSS and OPS data must be the same, otherwise the changes in the land-cover from the data of different satellites can not be obtained. The errors in NDVI time series due to degradation of sensors were reported by Kogan et al. (2001). The first and the 2nd data are those of Landsat-1 and Landsat-2 MSS, while the 3rd and 4th data are those of JERS-1 OPS of 2 years apart, therefore, special care was necessary to guarantee the accuracy of SAVI. A check was made on the calibration source data of the satellites and comparisons of the values of SAVI of unchanged targets, such as the water, a part of the desert was also made, and a slight adjustment was made taking the value of the first satellite data as the reference. Through these procedures the values of SAVI were finalized for the 4 satellite images and one of them computed from the image data of JERS-1 OPS of September 13, 1993 is shown in Fig. 3. In the figure white and dark parts denote large and small values of SAVI respectively. The numerical value of SAVI corresponds to density and vitality of vegetation coverage. The whitest part is the area covered with the dense healthy vegetation while the darkest place is the vegetation free clear water area.

Fig. 3 A SAVI (Soil Adjusted Vegetation Index) image computed from the image data of JERS OPS, 13 September 1993. The gray scale is such that the whiter, the larger SAVI values.

6 Results of analysis

To detect a temporal land cover change, the temporal change of SAVI is computed by subtracting the old SAVI values from those of the new as follows:


The result is grouped into 3 categories in terms of the standard deviation of the difference of SAVI, σ (=0.065) and indicated in Fig. 4.

Increased vegetation cover: New SAVI values−old SAVI values > σ,
Decrease d vegetation cover: New SAVI values−old SAVI values < −σ,
No change: −σ ≤ New SAVI values−old SAVI values ≤ σ.

The increased vegetation cover means the increase of vegetation cover on the land compared with that of the previous, while in case of the water surface although it means the increase of vegetation cover, it means decrease of vegetation-free water surface and vice versa for the decreased vegetation cover. From the analysis of Fig. 4 together with Fig. 2 the following features are obtained in vegetation cover and river flow.
6.1 Vegetation coverage

Between 1973 and 1977, Fig. 4 (a) shows the decrease and increase areas are mingled in the upper part except around the reservoir. Around the reservoir sharp increase is recognized while extensive decrease is recognized along the Hotan River. The increased area, indicated with letter A (hereafter called Area-A), is the area around the confluent point of the Kashgar and the Yarkant Rivers; swampy areas along the old Yarkant River indicate with the letter C (hereafter called Area-C) and the reservoir area. The increase at Area-C is due to the fact that swampy areas changed into grasslands.

Between 1977 and 1993, Fig. 4 (b) shows a well recognizable increase in the northern part of the study area including Area-A. The recovery of vegetation is recognized along the Hotan River.

Between 1993 and 1995, Fig. 4 (c) represents similar tendency to the previous case.

Between 1973 and 1995, Fig. 4 (d) represents that a sharp increase is recognized in the upper part of the figure which is the area in the south of Aksu oasis and Area-A. Increase is recognized also in Area-C. The value along the Hotan River decreased in 1977 then recovered later. No change was observed between 1973 and 1995.

6.2 River flow

The analyses of Figs. (2) and (4) indicate following features. The river flow of the Yarkant River which was abundant in the image of 1973 decreased in 1977 and no recovery occurred in the later images. Similar to the Hotan River flow, the trend of decrease is recog-
nized although not so dramatic as that of the Yarkant River.

7 Concluding remark

The foregoing analyses lead to the following conclusion. Land-cover change for a long period can be extracted by a pixel basis through an effective use of the multi-temporal and multi-satellites data with high accuracy if the various distortions inevitably included in the satellite data are eliminated. In view of the fact that various new sensors of higher spectral and spatial resolutions are under development, it is strongly desired that a reliable method for fusion of the data obtained with sensors of different specification and characterization be completed.

References


Tsuchiya K. Vegetation indices derived from the data remotely sensed from the satellites. Journal of Arid Land Studies, 2000, 10(2): 37–145.