Remote sensing-based analysis on temporal and spatial changes about environmental elements in the northwest of Junggar basin, China

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Abstract. This paper presents a study of revealing the environmental elements change during the process of local industrialization based on remote sensing technique in the western part of China. Spatio-temporal evolution of vegetation cover derived from NDVI and land surface water distribution was analyzed by time-series analysis of MSS and Landsat data from 1977 to 2011. Results show that remote sensing provide a way for monitoring the influence of local industrialization on regional environment elements in gobi region.

1. Introduction

The western China covers vast territory with the typical landform of gobi desert, exists a mass of energy enterprises. Energy industry has great significance on promoting local industrialization, especially in the northwest of Junggar basin, China. Population growth and economic development occurred simultaneously with increasingly rapid development of energy production. Regional environmental elements are affected by human activity and undergoing continuous change. Due to the large geography extent, inaccessible parts and low population density, it is essential for environment supervision to timely acquire the distribution information of base environmental elements and track their evolution during the industrialization process. Periodic monitoring is required to control the possible and potential environment problems.

Vegetation and land surface water are two fundamental elements of ecological environment. It is important for characterizing the regional environment state by obtaining the overview of their spatial and dynamics. Remote sensing provides a complement way to accomplish the monitoring on regional vegetation cover and land surface water distribution[1-6]. This is beneficial to get better understanding of local environment feature and its evolution.

With a large coverage, short repeatability, convenient acquisition and long term data series, Landsat TM imagery has been proven to be a useful tool for field environmental monitoring. The aim of this study was to reveal the spatio-temporal evolution of regional environment based on vegetation cover and land surface water during the industrialization process by remote sensed technique.

In this paper, we present results obtained from time-series analysis performed over selected Landsat imageries. The paper is organized as follows. Section 2 focused on the description of the research conducted. Section 3 illustrated the results and discussion. Remarks and conclusions were summarized in section 4.
2. Materials and methodology

2.1. Study and dataset

The study area is located in the northwest margin of Junggar basin in the west of China, with the typical landform of gobi desert, between longitudes 84° 30′ E and 85° 30′ E, latitudes 45° N and 46° N. After the discovery of China's first large scale oil field in Karamay in 1955, oil industry has been the main industry of local economic development. This area consists of a wide range of ecosystem types, including desert communities, wetland, grazed grassland, irrigated agriculture and urban land cover.

In this study, the image time series of the MSS and Landsat between 1977 and 2011 was exploited. In order to analyze the trend of environment variation, the time series covers the same month of September except MSS image for the reason of poor data quality. Five different temporary of satellite images were selected which acquired on 11 July 1977, 2 September 1998, 21 September 2002, 11 September 2007 and 6 September 2011 respectively.

The image processing was performed by the following steps. Firstly, the reflectance-based multispectral image was derived based on image. Then, Vegetation cover extraction was performed by the thresholding setting based on NDVI index. Finally, water extraction was performed by the combined application of NDVI and NDWI. MSS image was not used to extract water information for the haze condition and low resolution.

![Figure 1](image1.png)

**Figure 1.** Mapping of results derived by time-series analysis
- a. Spatial distribution of surface water recurrence in September from 1998 to 2011;
- b. Spatial distribution of vegetation cover variation tendency from 1977 to 2011.

2.2. Methodology

2.2.1. Time series analysis on land surface water

In the research, land surface water is classified into two categories of permanent water body and free water body[7]. Permanent water body is mainly the stable water like the water in the reservoir, while free water body is mainly the natural water like river and so on. The analysis of the time series is concentrated on free water.
Percentage of occurrence as free water \( (O_{fw}) \) is used to analyze the regional land surface water environment. \( O_{fw} \) is defined as the following:

\[
O_{fw} = \frac{n_w}{n_{nw}} \tag{1}
\]

where \( n_w \) is the number of the pixel detected as free water, and \( n_{nw} \) is the number of the time-series image used. The map of regional surface water distribution state was obtained by thresholding setting of \( O_{fw} \).

2.2.2 Time series analysis on vegetation cover

For vegetation cover data derived from NDVI, simple linear regression method\(^{[8-9]}\) was used to make time-series analysis on the trend of spatial distribution of vegetation. The slope \( k \) of the regression equation was defined as:

\[
k = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{2}
\]

where \( x_i \) and \( y_i \) are acquisition year of image and NDVI value of vegetation cover respectively, \( \bar{x} \) and \( \bar{y} \) are mean value of \( x_i \) and \( y_i \) of time-series data, \( i \) is the order of satellite image sequence, and \( n \) is the number of images. The slope of \( k \) reflects the trend of vegetation cover variation over years. The value of \( k \) indicates the degree of vegetation cover improvement when \( k > 0 \) and the degree of vegetation cover degradation when \( k < 0 \). The map of vegetation cover distribution variation tendency was obtained by thresholding setting of \( k \).

3. Results and discussion

Figure 1.a shows the state of surface water distribution by time-series analysis of Landsat data in September from 1998 to 2011 within the study area. Permanent water is the water in the reservoir which one of them existed in 1998 and the other two were built after 2000 along the inhabitation communities. Spatial distribution of actual surface water occurrence exhibits slow increasing of permanent water around inhabitation area and the seasonal recurrence of water bodies in humid regions.

Figure 1.b shows the distribution of vegetation cover evolution from 1977 to 2011. The statistical results of vegetation cover percentage with different variation degree are summarized in table 1. Degradation percentage of vegetation cover is only 3.19%. It mainly occurred along the inhabitation zone. Vegetation cover presents a significant and long-lasting increasing over 34 years. Given the increasing geographic extent of vegetation cover throughout region, the expanding trend shows the correlation with the distribution of inhabitation communities and irrigated agricultural region related to the activities of regional industrialization.

| Table 1. Statistics of vegetation cover variation tendency |
|----------------|-------------------|----------------|
| \( k \) | variation | pixels | percentage |
| --- | --- | --- | --- |
| \( k<0 \) | Degradation | 36087 | 3.19 |
| \( 0<\ k\leq0.05 \) | Slight improvement | 421800 | 37.25 |
| \( 0.05< \ k\leq0.1 \) | Middle improvement | 306116 | 27.04 |
| \( 0.1< \ k\leq0.2 \) | Remarkable improvement | 368288 | 32.53 |

In the research, satellite image sequence includes five temporal data over 34 years. The impact of uneven time interval of the sequence and inadequate images on the time-series analysis should be taken into account. The accuracy of spatio-temporal evolution analysis depends to a great extent on the design of a scientific sequence with consideration of factors corresponding to the specific objective.

4. Conclusions

By using MSS and Landsat data, Spatio-temporal evolution of regional environment was analyzed based on elements of vegetation cover and land surface water with time-series analysis. The temporal consistency between variations in vegetation cover and land surface water distribution implies the environment improvement during the industrialization process within study area. Research demonstrated that big
data in remote sensing can be of great help in monitoring the influence of local industrialization on regional environment elements in the western part of China by time-series analysis.

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