

# 行政院國家科學委員會專題研究計畫 成果報告

## 應用衛星影像探討乾燥地區綠洲生態系統動態變遷：以內 蒙古額濟納綠洲為例 研究成果報告(精簡版)

計畫類別：個別型  
計畫編號：NSC 95-2415-H-156-007-  
執行期間：95年08月01日至96年07月31日  
執行單位：真理大學觀光事業學系

計畫主持人：林孟龍

計畫參與人員：博士班研究生-兼任助理：朱健銘  
大學生-兼任助理：陳泰言

處理方式：本計畫可公開查詢

中華民國 96年07月31日



# 行政院國家科學委員會專題研究計畫成果報告

## 應用衛星影像探討乾燥地區綠洲生態系統動態變遷： 以內蒙古額濟納綠洲為例

計畫編號：NSC95-2415-H-156-007

執行期限：95年8月1日至96年7月31日

主持人：蔡博文 真理大學觀光事業學系助理教授

計畫參與人員：朱健銘 臺灣大學地理環境資源學系博士生  
陳泰言 臺灣大學地理環境資源學系大學生

### 一、中文摘要

額濟納綠洲位於中國大陸西北地區，氣候乾燥，綠洲主要依靠來自祈連山山脈融化的雪水。早在漢朝時期，額濟納綠洲即因豐沛水源而在河西走廊成為重要的生活與軍事要地，近年來因為張掖綠洲與額濟納綠洲人口增加，生活與農業用水需求大增，水資源不敷使用，造成黑河年平均斷流日數漸增，也直接造成居延海乾涸與額濟納綠洲逐漸縮小。於2002年，中國大陸政府因實施取水管制措施，使得居延海重新有水注入，且於2005年達成居延海全年有水的狀況。本研究期待以MODIS與ETM衛星影像分析本地1999至2005年間在土地覆蓋的變化。藉由遙測影像的監督性與非監督性分類，區分歷年的土地覆蓋變化，藉由歸一化差異植被指數分析綠覆蓋面積的變化（季節間、年間變化）並綜合土地覆蓋變化資料與歸一化差異植被指數找出「額濟納河河道」與「居延海」的變遷，分析額濟納當地環境在景觀生態變遷的影響程度。

**關鍵詞：**綠洲生態系統、遙測、乾旱環境、歸一化差異植被指數

### Abstract

Land degradation has become an important issue in western China recently. Oasis ecosystem is sensitive to environmental disturbances, such as abnormal /extreme events of precipitations, water supply from upper watersheds, fluctuations of temperatures, etc. Satellite remote sensing of terrestrial ecosystems

provides temporal dynamics and spatial distributions of landscape green covers over large areas. Seasonal green cover data are normally important in assessing landscape health (ex. desertification, rate of urban sprawl, natural disturbances) in arid and semi-arid regions. In this study, green cover data is derived from vegetation indices retrieved from MODIS sensors onboard Terra. The satellite images during the period April 2000 to December 2005 are analyzed to quantify the spatial distribution and temporal changes of Ejin Oasis. The results will help improving monitoring techniques to evaluate land degradation and to estimate the newest tendency of landscape green cover dynamics in the Ejin Oasis.study.

**Keywords:** land degradation, monitoring, green cover, landscape, oasis

### 二、緣由與目的

The study of monitoring vegetation is an important part of applications of remote sensing data. This information is crucial for understanding processes such as carbon cycling, terrestrial primary productivity, hydrologic cycles, and terrestrial energy balance. Remote sensing methods have been applied over a number of regions worldwide to monitor vegetation changes<sup>1-9</sup>. A large number of these works show that remote sensing has been considered to be a useful method for studying arid and semi-arid ecosystems<sup>1, 5, 8-13</sup>. For example,

time-series analyses of satellite data enable observations of seasonal, annual and inter-annual trends in vegetation cover. NOAA-AVHRR images have been utilized to generate a 23-year time series for long-term studies of Sahel region to assess inter-annual trend<sup>9</sup>. They found that this time series reveals two periods; (a) 1982–1993 marked by below average NDVI and persistence of drought with a signature large-scale drought during the 1982–1985 period; and (b) 1994–2003, marked by a trend towards 'wetter' conditions with region-wide above normal NDVI conditions with maxima in 1994 and 1999. Thus, it is useful to use satellite imagery to monitor large regions in vegetation and land surface dynamics because of data availability for lone term periods.

Recently, Moderate resolution imaging Spectroradiometer (MODIS) is providing information from 250m to 1Km spatial level. The MODIS was recently launched onboard the Earth Observing System (EOS) Terra/Aqua platform and provides a suite of vegetation products useful for terrestrial ecosystem studies<sup>15-17</sup>. One attractive advantage of MODIS is that it provides images of the entire globe every 1 or 2 days. Two MODIS vegetation indices, the normalized difference vegetation index (NDVI) and the enhanced vegetation index (EVI), are produced at 250m, 500m, and 1 km resolutions with 16-day compositing periods and are designed for landcover change, ecological processes, and seasonal and inter-annual monitoring of vegetation. The use of MODIS sensor time-series data has significant potential to enhance environmental studies over regional scales.

The term landscape has been widely used in many fields, including landscape ecology, geography, geomorphology, landscape architecture, land use, and environmental studies. Forman defined landscape as “ a mosaic of where the mix of local ecosystems or land uses is repeated in similar form over a kilometer-wide area”<sup>18</sup>. Thus any landscape will almost contain a number of ecosystems as well as a mosaic of different kinds of vegetation. Landscape sensitivity as a concept comes from geomorphology and means the likelihood of change, i.e. of instability and stability<sup>19</sup>. One major problem is that landscape sensitivity varies spatially as a result of inherent landscape patterns (such as rocks, soils, altitude, slopes, plant cover). Therefore, the vegetation index, NDVI, is used to assess and monitoring the integrated characteristics of complicated ecological functions on the land surface.

The objective of this study is to better understand landscape dynamics in arid and semi-arid environments. Therefore, remotely sensed data were utilized to characterize landscape seasonality in Ejin oasis, which located in western China with an arid and semi-arid environment. We also explored seasonal variations of sensitive ecosystems in a landscape for discussing concepts of landscape sensitivity. In this study, we interpreted seasonal green cover maps of Ejin oasis to monitor vegetation dynamics. A comparison of seasonal dynamics for the winter, spring, summer, and fall's spatial extents and distributions of vegetation area was made with NDVI images. The landcover maps in summer season were classified by satellite images to compare the landcover

dynamics in 2000 and 2005. Finally, the landscape sensitivity analysis was developed to assess the sensitivity of ecosystems in the landscape of Ejin.

### 三、研究流程及方法

The method proposed in this study included six processing steps: 1) image processing, including mosaicing, subsetting, and reprojecting, 2) cloud mask generation of time series data sets, 3) NDVI image generation of time-series data sets, 4) land cover interpretation for summer image during the period from 2000 to 2005, 4) seasonal NDVI variation analysis, 5) landscape sensitivity analysis.

Time-series bi-weekly remotely sensed images from the year February 2000 to December 2005 were analyzed for the region of Ejin Oasis. All the MODIS bi-weekly composite images used in this study have a spatial resolution of 250m. The bi-weekly image composition algorithm relies on multiple observations over a 16-day period and operates on a per-pixel basis to generate the images. They involve transformations of the red (620-670 nm), near-infrared (841-876 nm), and blue (459-479nm) bands designed to analyze the vegetation activities and allow for comparisons of spatial and temporal variations in terrestrial ecosystems.

The NDVI is an important parameter to various kinds of local, regional, and global scale models, including general circulation and biogeochemical models<sup>20</sup>. They serve as intermediaries in the assessment of various biophysical parameters, such as green cover, biomass, LAI, and fraction of absorbed photosynthetically active radiation (fAPAR)(Tucker, 1979; Sellers et al., 1992).

Therefore, the NDVI has been played a significant role in monitoring regional and global photo synthetically active biomass processes.

The NDVI utilizes differences in leaf absorptions in the red and near-infrared bands<sup>21-22</sup>, which is a measure by dividing the difference in infrared and red reflectance measurements. It is formulated as follows:

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (1)$$

where  $\rho_{NIR}$  and  $\rho_{RED}$  are the surface reflectances in the 620-670 nm (visible) and 841-876 nm (infrared) regions of the electromagnetic spectrum, respectively.

In this study, we used NDVI to diagnose landscape sensitivity. Seasonal variations in landscape dynamics were compared with the NDVI responses of winter, spring, summer, and fall season. The assessments of landscape sensitivity were used both absolute and relative measures of percent variations. The equations used to depict seasonal variation were modified from<sup>6, 26</sup>:

$$\text{Relative Seasonal Variation} = \left| \frac{\text{Seasonal NDVI}_{(i)} - \text{Seasonal NDVI}_{(j)}}{\text{Seasonal NDVI}_{(j)}} \right| * 100\% \dots\dots\dots (2)$$

where i is the season latter than j, such as i is summer and j is spring.

$$\text{Landscape sensitivity (LS)} = (\text{RSV}_{\text{winter}} + \text{RSV}_{\text{spring}} + \text{RSV}_{\text{summer}} + \text{RSV}_{\text{fall}}) \dots\dots\dots (3)$$

$$LS_{\mu} = \sum_{i=1}^n \frac{LS_i}{n} \dots\dots\dots (4)$$

where LS is i is the LS of different year, n is the number of the evaluated year.

#### 四、研究成果

##### 1. Spatial distribution of green cover dynamics

The green cover time-series of the seasonal composites shows a distinct seasonal pattern. The green cover areas in summer are larger than other seasons for the year 2000-2005 (Table 1). From 2000 to 2005, the green cover area varies from year to year, ranging from 1,999km<sup>2</sup> to 2369km<sup>2</sup>. A sudden expansion of the green cover area in summer was observed in 2004 to reach its maximum area during the study period. The green cover areas began to increase in spring and decrease again in winter with a peak in summer, which conforms to vegetation growth in Mongolia(Yu et al., 2004). The seasonal green cover areas in Ejin show the highly variable nature of most arid and semiarid environments.

Table 1 The seasonal green cover areas (km<sup>2</sup>) in Ejin during the period between 2000 and 2005

	Winter	Spring	Summer	Fall
2000	526	321	2215	1305
2001	1244	222	2022	1258
2002	954	317	2079	965
2003	756	223	1999	972
2004	883	542	2369	1188
2005	1086	491	2183	1475
Average	908	353	2144	1194

##### 4.2 Landscape Sensitivity Analysis

There are innumerable ways that changes to systems and changes to the landscape, and it is not always easy to separate out which is cause and which is effect. In this study, the vegetation conditions are viewed to be a final result after the

complicated ecological functions and interactions on land surfaces. Thus, the NDVI which is used in assessments of various biophysical parameters, such as green cover, biomass, LAI, and fAPAR was selected in assessing landscape sensitivity.

Fig. 2 shows the spatial pattern of landscape sensitivity during the period between 2001 and 2005. The areas with high values in red colors are distributed over the northern part of the study area. These areas are composed of forest and grassland ecosystems. Moreover, there are two belt zones with high values in green color are distributed over the central part of the study area. The land types of these areas are mainly river channels and the transition zones between river channels and deserts. The identified changes in land surfaces are detected by using the index of LS<sub>μ</sub> in this study. The used method is standard remote sensing applications, although generally not used for assessments of landscape sensitivity. The map shows a coincidence between the spatial pattern of sensitive ecosystems (forest ecosystem, grassland ecosystem, and river ecosystem) in Ejin and the result of landscape sensitivity analysis. In the arid and semi-arid environments, this method of assessing landscape sensitivity has proven the usefulness and convenience to quick assessment and monitoring.

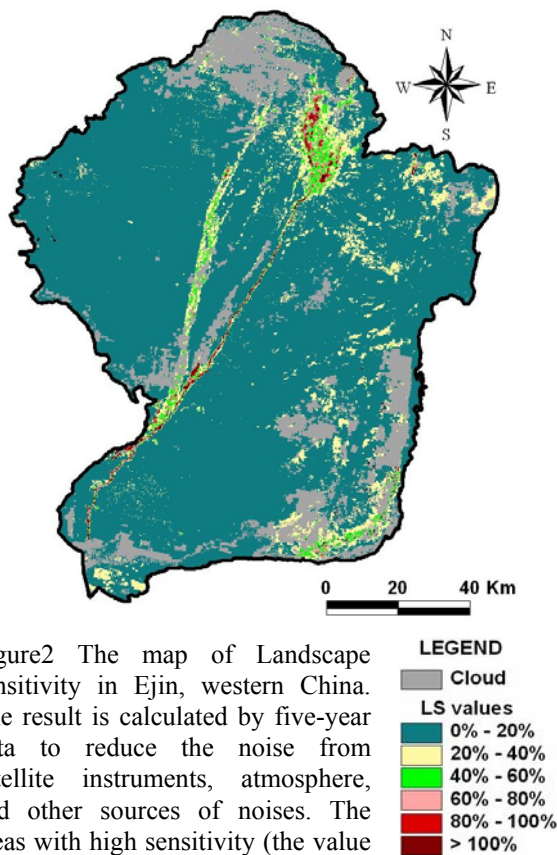


Figure2 The map of Landscape sensitivity in Ejin, western China. The result is calculated by five-year data to reduce the noise from satellite instruments, atmosphere, and other sources of noises. The areas with high sensitivity (the value higher than 60%) are shown with red and dark red colors. The areas with low sensitivity (the value lower than 20%) are shown with turquoise color. The other areas with median sensitivity ( the value ranging from 20% to 40%) are shown with light yellow color.

## 五、結論

Satellite measurements of Ejin green cover dynamics during the period between 2000 and 2005 have provide a comprehensive picture of the patterns of land surface inter-annual variation and trends. The result indicates that the assessment and monitoring using remotely sensed images are effective for understanding the inter-annual and seasonal variations of land surfaces, especially in arid and semi-arid environments. The green cover areas in Summer are the peak of growing season and are larger than other seasons. The seasonal changes of green cover area in Ejin are stable and are shown a regular pattern in vegetation dynamics in a

year. In addition, the green cover areas in spring are smallest, which the total area is usually lower than 300 km<sup>2</sup> (the total area in summer is usually higher than 2000km<sup>2</sup>).

An attempt in combing the concept of landscape sensitivity and remote sensing techniques is successfully shown in Fig. 3. The likelihood of change can be detected by using remote sensing techniques. The average of five year's LS value make the value of LS shown the real condition in NDVI changes. Our study showed that it was possible to derive important parameters linked to landscape sensitivity from MODIS imagery and the derived imagery, such as NDVI time-series data. Such a time-series monitoring system based on MODIS imagery is useful in arid and semi-arid environment. The result of landscape sensitivity analysis has proven the effectiveness of the method in assessing landscape sensitivity of the year of 2001-2005. This information of landscape sensitivity can be used to detect "hot spots" of sensitive ecosystems in arid and semi-arid environments. The spatial distribution of landscape sensitivity will help governments to improve the efficiency in landscape conservation.

## 六、研究成果自評

本研究以 MODIS 影像為分析基礎，探討額濟納綠洲自 2000 年至 2005 年共六年的綠洲生態系統綠覆蓋面積的變遷，發現在這六年的春、夏、秋、冬等四季綠覆蓋面積並無明顯朝增加或減少變遷之趨勢。此外，以春、夏、秋、冬等四季進行綠洲生態系統景觀敏感性指標分析，發現在森林或草地生態系統與水域的景觀敏感性較高。

經過一年的研究後，本研究發現在進行生態調水前、後，似乎無明顯變化趨勢。

未來將持續進行監測分析，並將蒐集額濟納綠洲的降雨量、流量與地下水井之監測資料進行分析。希望能結合觀測資料與衛星影像進行分析，探討綠洲生態系統的變化究竟是由什麼原因所影響，也期待能解析人為因子對於環境變遷的影響何在。

## 七、參考文獻

1. H. Schmidt and A. Karnieli, "Remote sensing of the seasonal variability of vegetation in a semi-arid environment," *Journal of Arid Environments*, 45, 1, 43-59 (2000).
2. G. Dall'Olmo and A. Karnieli, "Monitoring phenological cycles of desert ecosystems using NDVI and LST data derived from NOAA-AVHRR imagery," *International Journal of Remote Sensing*, 23, 19, 4055-4071 (2002).
3. J.T. Al-Bakri and J.C. Taylor, "Application of NOAA AVHRR for monitoring vegetation conditions and biomass in Jordan," *Journal of Arid Environments*, 54, 3, 579-593 (2003).
4. L. Ji and A.J. Peters, "Assessing vegetation response to drought in the northern Great Plains using vegetation and drought indices," *Remote Sensing of Environment*, 87, 1, 85-98 (2003).
5. F. Camacho-De Coca, F.J. Garcia-Haro, M.A. Gilabert and J. Melia, "Vegetation cover seasonal changes assessment from TM imagery in a semi-arid landscape," *International Journal of Remote Sensing*, 25, 17, 3451-3476 (2004).
6. L.G. Ferreira and A.R. Huete, "Assessing the seasonal dynamics of the Brazilian Cerrado vegetation through the use of spectral vegetation indices," *International Journal of Remote Sensing*, 25, 10, 1837-1860 (2004).
7. R. Granados-Ramirez, T. Reyna-Trujillo, G. Gomez-Rodriguez and J. Soria-Ruiz, "Analysis of NOAA-AVHRR-NDVI images for crops monitoring," *International Journal of Remote Sensing*, 25, 9, 1615-1627 (2004).
8. F. Yu, K.P. Price, J. Ellis, J.J. Feddema and P. Shi, "Interannual variations of the grassland boundaries bordering the eastern edges of the Gobi Desert in central Asia," *International Journal of Remote Sensing*, 25, 2, 327-346 (2004).
9. A. Anyamba and C.J. Tucker, "Analysis of Sahelian vegetation dynamics using NOAA-AVHRR NDVI data from 1981-2003," *Journal of Arid Environments*, 63, 3, 596-614 (2005).
10. C.O. Justice, G. Dugdale, J.R.G. Townshend, A.S. Narracott and M. Kumar, "Synergism between NOAA-AVHRR and meteosat data for studying vegetation development in semi-arid west Africa," *International Journal of Remote Sensing*, 12, 6, 1349-1368 (1991).
11. W.G. Kepner, C.J. Watts, C.M. Edmonds, J.K. Maingi, S.E. Marsh and G. Luna, "Landscape approach for detecting and evaluating change in a semi-arid environment," *Environmental Monitoring and Assessment*, 64, 1, 179-195 (2000).
12. A. Karnieli, A. Gabai, C. Ichoku, E. Zaady and M. Shachak, "Temporal dynamics of soil and vegetation spectral responses in a semi-arid environment," *International Journal of Remote Sensing*, 23, 19, 4073-4087 (2002).
13. A. Wezel and E. Schlecht, "Inter-annual variation of species composition of fallow vegetation in semi-arid Niger," *Journal of Arid Environments*, 56, 2, 265-282 (2004).
14. E. Masuoka, A. Fleig, R.E. Wolfe and F. Patt, "Key characteristics of MODIS data products," *IEEE Transactions on Geoscience and Remote Sensing*, 36, 4, 1313 (1998).
15. W.B. Cohen and C.O. Justice, "Validating MODIS terrestrial ecology products: Linking in situ and satellite measurements," *Remote Sensing of Environment*, 70, 1, 1 (1999).
16. W.L. Barnes, X. Xiong and V.V. Salomonson, "Status of Terra MODIS and Aqua MODIS," *Advances in Space Research*, 32, 11, 2099 (2003).
17. A. Savtchenko, D. Ouzounov, A. Gopalan, D. Yuan, D. Nickless and D. Ostrenga, "MODIS Data from Terra and Aqua Satellites," Toulouse, France, Institute of Electrical and Electronics Engineers Inc., (2003).
18. R.T.T. Forman, *Land Mosaics: The Ecology of Landscapes and Regions*, Cambridge University Press, Cambridge, 1995.
19. J. Miles, R.P. Cummins, D.D. French, S. Gardner, J.L. Orr and M.C. Shewry, "Landscape sensitivity: an ecological view," *CATENA*, 42, 2-4, 125-141 (2001).
20. D.L. Peterson, J.D. Aber, P.A. Matson, D.H. Card, N. Swanberg, C. Wessman and M. Spanner, "Remote sensing of forest canopy and leaf biochemical contents," *Remote Sensing of Environment*, 24, 1, 85-108 (1988).
21. C.J. Tucker, "Red and photographic infrared liner combinations for monitoring vegetation," *Remote Sensing of Environment*, 8, 2, 127-146 (1979).
22. P.J. Sellers, J.A. Berry, G.J. Collatz, C.B. Field and F.G. Hall, "Canopy reflectance, photosynthesis, and transpiration. III. A reanalysis using improved leaf models and a new canopy integration scheme," *Remote Sensing of Environment*, 42, 3, 187-216 (1992).
23. T. Purevdorj, R. Tateishi, T. Ishiyama and Y. Honda, "Relationships between percent vegetation cover and vegetation indices," *International Journal of Remote Sensing*, 19, 18, 3519-3535 (1998).

24. R. Lee, F. Yu, K.P. Price, J. Ellis and P. Shi, "Evaluating vegetation phenological patterns in Inner Mongolia using NDVI time-series analysis," *International Journal of Remote Sensing*, 23, 12, 2505 (2002).
25. G. Metternicht, "Vegetation indices derived from high-resolution airborne videography for precision crop management," *International Journal of Remote Sensing*, 24, 14, 2855 (2003).
26. L.G. Ferreira, H. Yoshioka, A. Huete and E.E. Sano, "Seasonal landscape and spectral vegetation index dynamics in the Brazilian Cerrado: An analysis within the Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA)," *Remote Sensing of Environment*, 87, 4, 534-550 (2003).