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Analysis of the impact of Land use/Land cover change on Land Surface Temperature with Remote Sensing

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Abstract

Nowadays, more than 40% of the population lives in Chinese cities. The rapid urbanization process brought about many eco-environmental problems, such as the drastic change of land use and development of urban heat island. Three Landsat TM and ETM+ images data of Beijing acquired on April 9, 1995 and April 30, 2000 were selected to this research. The land surface temperature (LST) and land use and land cover (LULC) classes were retrieved and extracted. The temperature-vegetation index (TVX) space was constructed to investigate the influence of land changes over LST. The result showed that the land use change was an important driver for LST increase, the temporal trajectory of pixels in the TVX space migrated from the dense-vegetation-low temperature condition to the sparse vegetation-high temperature condition.

Keywords: Land surface temperature, TVX space, vegetation cover, land use and land cover change

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1. Introduction

Urbanization transforms the natural land surfaces to modern land use and land cover such as buildings, roads and other impervious surfaces, making urban landscapes fragmented and complex and affecting the inhabitability of cities[2] . The enormous changes with land use/cover lead to the urban heat island (UHI). The urban temperatures are 2-5℃ higher than those in rural surroundings[3].

In recent years, the researches on the applications of thermal remote sensing of urban areas were mainly in following respects: study on the land surface temperature or the spatial structure of urban thermal pattern and their relationship with surface parameters; urban surface energy balances and fluxes[8,10]; the relationship between atmospheric temperature and land surface temperature. Some studies examined the effect of land use/land cover change on LST[6-7,15], which was found to be positively correlated with impervious surface .Some studies

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estimated the relationship between the land surface temperature and vegetation abundance[14], different vegetation indices such as normalized vegetation index (NDVI) and fractional vegetation cover were used to indicate vegetation abundance. The results revealed that the negative correlation between land surface temperature and NDVI, and the cooling effect of green areas. Two methods were usually used to observe the relationship between vegetation index and LST: statistical analysis and the temperature/vegetation index (TVX)approach. TVX is a method of combining LST and a vegetation index in a scatterplot. The initial location of the migrating pixels in the TVX space determined the magnitude and direction of the path[9].Carlson and Sanches-Azofeifa analyzed the effect of rapid urbanization on surface climate using TVX method[5]. Amiri provided a method for addressing the uncertainty in the TVX space[4].

The changes of Land surface temperature were related to many factors, including changes in land use, land surface parameters, seasonal variation, climatic condition and economic development, etc. To study the effect of land use/land cover change on land surface temperature, we should choose the Landsat TM，ETM+ images dated on roughly the same season. In this research , the TVX method was used to perform pixel trajectory in the TVX space in order to investigate the influence of land changes over LST. The research is important for urban planning and environmental protection.

2. Study area

The city of Beijing , the capital of China(39°54′，116°23′)is located on north china plain with an area of 16,410km^2 and with a population of almost 18 million(2009). West，north and northeast of Beijing are surrounded by mountains and the southeast is a plain. Because of the warm temperate semi-humid climate, Beijing experiences a long summer and winter and a short spring and autumn. The average annual temperature is 13.1℃ and the annual precipitation is 430.9mm, which falls mostly in summer.

Beijing is a center of Politics and culture in China, especially at the same time, as the core of the beijing-tianjin-hebei metropolis circle , which is the one of most Economically prosperous region, the Beijing city is increasing in population and in area rapidly since the 90s last century. As the result, the land use/cover (LULC) changes dramatically and the issue of urban heat island (UHI) catches more attention during the urban development. We choose the Beijing for my study, the relationship between LULC changes and land surface temperature (LST) is very important in future planning of city.

3. Data and methods

3.1Data and Image pre-processing

Three Landsat TM and ETM+ images data acquired on April 9, 1995 and April 30, 2000 were selected to this research. These images had a clear weather condition and cover the whole Beijing except the south of Fangshan and Daxing. A digital topograghic maps of 1:25,000 scales were used to rectified the images for geometric errors and then MODTRAD was adopted to correct atmospheric errors in order to remove the atmospheric influence and acquire the true surface characteristics. After these process，the vegetation coverage was computed and the detailed LULC classes were extracted too.

3.2Derivation of LST from Landsat TM and ETM+ imagery and LST-vegetation fraction space

The LST were derived from the ETM+ thermal infrared band (band 6) and its spatial resolution is 60m.

First, the DN values were converted to spectral radiance using reference values by the following formula:

$$L_\lambda = gain * DN + offset \tag{1}$$

Where, the gain and offset can be acquired from the header file of the images.

The next step is to transform the spectral radiance to at-satellite brightness temperature under the assumption of a uniform emissivity by the following formula:

$$T_b = \frac{K_2}{In(K_1 / L_\lambda + 1)} \tag{2}$$

Where, T_b is the effective at-satellite temperature in Kelvin; K_1 and K_2 are calibration constants. For Landsat-7 ETM+, $K_2 = 1282.71K$ and $K_1 = 666.09mW\ cm^{-2}\ sr^{-1}\ \mu m^{-1}$, for Landsat-5 TM,

$K_2 = 1260.56K$ and $K_1 = 607.76mW\,cm^{-2}\,sr^{-1}\,\mu m^{-1}$; and L_λ is the spectral radiance in $W/(m^2\ ster\ \mu m)$.

In the end, The land surface temperatures were calculated as follows[1]:

$$T_S = T_b / [1 + (\lambda T_b / \alpha)\,\mathrm{In}\,\varepsilon] \tag{3}$$

Where, λ =wavelength of radiance(λ =11.5μm), $\alpha = hc/k$

To retrieval the LST, the calculation of surface emissivity was critical. The surface emissivity could be obtained using a theoretical approach of considering the surface as a mixture of bare soil and vegetation[11]. If we assumed the land surface is homogeneous and flat, is calculated as follows[12]:

$$\varepsilon = \varepsilon_v f_v + \varepsilon_s (1 - f_v) \tag{4}$$

Where, fv is the fractional vegetation cover. ε_v and ε_s are the emissivities of vegetation and soil, respectively. The values for Landsat thermal band were 0.985 and 0.96.

So, the emissivity value could be determined by the following formula[13]:

$$\varepsilon = 0.985 fv + 0.96(1 - fv) + 0.06 fv(1 - fv) \tag{5}$$

Normalized difference vegetation index (NDVI) was used as an index of vegetation abundance and fractional vegetation cover (f_v) calculated using NDVI.

$$NDVI = (NIR - RED)(NIR + RED) \tag{6}$$

$$f_v = [(NDVI(x,y) - NDVI_{\min}) / (NDVI_{\max} - NDVI_{\min})]^2 \tag{7}$$

Where $NDVI_{\min}$ and $NDVI_{\min}$ are for vegetation and bare soil

Temperature values were scaled between the minimum and maximum values in order to compare the data at different times.

$$T_S^* = (T_S - T_{\min}) / (T_{\max} - T_{\min}) \tag{8}$$

3.3Image classification

Unsupervised and Supervised classifications were adopted together to extract detailed land use and land cover classes, including cultivated land，forestland，grassland, water, built-up land and unused land . The classification scheme, with six level 1 classes mentioned before and twenty-five level 2 classes , was based on the land cover and land use classification system (Table1). The results are usually better than those using only one method. A maximum likelihood classifier was employed for preliminary classifications based on the results of the unsupervised classifications. To improve the accuracy of interpretation, some areas which were difficult to distinguish were inspected by ourselves or confirmed with the help of various maps and data. For example, build-up areas in urban were easily classified to agricultural land due to the similar spectral characteristics, and water in the center of city is also difficult to discern under the shadows of high buildings. Finally , the overall accuracy of the 1995,2000 and 2005 maps were up to 98.72%.

Table1 Land cover classification scheme

Land cover class	Description
cultivated land	paddy fields and dry lands
forestland	Forest land, bush forest, open forest land and other forestlands,such as slash, nursery and every kinds of garden plots
grassland	High coverage grassland, moderate coverage grassland and low coverage grassland
water	Rivers, lakes, reservoirs, glaciers, permanent snow cover land seabeach and beach
built-up land	Urban land, rural residential land and other build-up land, such as industrial, oil , quarry and transportation land
unused land	Sandy land, gobi, saline land, marsh land, bare land, barren land and other unused land such as tundra

4. Temporal dynamics of the LST-vegetation fractional space

From 1995 to 2000, urbanization main occupied cultivated land. The TVX space was constructed by normalizing the land surface temperature and vegetation index. The trajectories revealed the effects of certain types of LULC alteration on LST. The change paths of Forestland and cultivated land in the TVX were showed in Fig.1. In1995, Forestland and cultivated land were in the upper-left corner of TVX space, corresponding to high vegetation coverage and low temperature. With the development of Urban, Forestland and cultivated land were converted to built-up land. The changed types of LULC moved to lower-right corner all along the diagonal path, suffering hot conditions with a low vegetation coverage and high temperature. From 1995 to 2000, the changes of normalized land surface temperature and Fractional vegetation cover were obvious. Compared to cultivated land, forestland showed a notable increase in surface temperature with a decrease in factional vegetation cover.

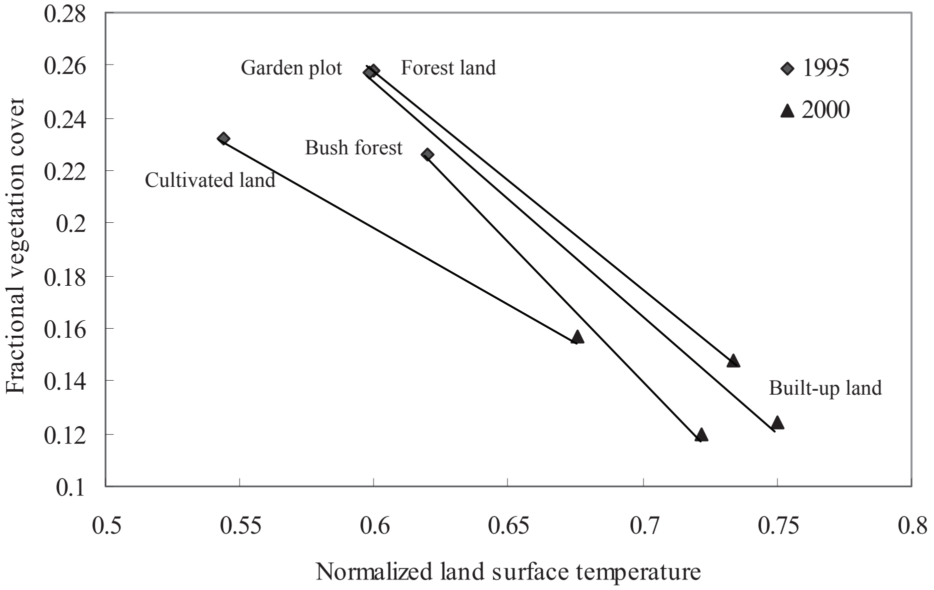

Fig.1The change trajectory of TVX space

5. Conclusions

This research analyzed the impact of land use change on land surface temperature in the TVX space by using TM and ETM+ imagies and further demonstrated a strong positive relationship between them. In other words, the change of land use is the important reasons leading to increase in land surface temperature.

The land use change(urbanization) led to the migration of pixels from cool to hot surface condition. In this study, LULC classes were used as the unit of analysis instead of geographical subsets and subdivided the green space into forest land, bush forest and various garden plots. We can investigate the effect of specific LULC change type on LST. From 1995 to 2000, cultivated land and Forestland were converted to built-up land, the progress of urbanization affected pixels tended to converge. the temporal trajectory of pixels in the TVX space migrated from the dense-vegetation-low temperature condition to the sparse vegetation-high temperature condition.

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