URBAN CHANGE DETECTION BY RELATIONSHIP OF THERMAL PROPERTIES TO VEGETATION INDICES

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ABSTRACT

The problem of urbanization is now taking place quite rapidly, requiring a method to evaluate the update ability for urban change quickly and efficiently. Currently, remote sensing applications is considered modern methods in the mapping of urban change. To add to the traditional classification methods previously, thermal remote sensing methods in conjunction with vegetation indices for assessing urban change are researched in this paper. Landsat and Aster satellite imagery with average resolution of thermal band are used for research. Land cover classification results based on the relationship of temperature, NDVI and VI_{IR} indices with the Kappa index > 0.8 and overal accuracy > 90% showed that this method is positive and has good reliability.

1. INTRODUCTION

The monitoring elements that change in time and space is very useful for urban planning and management to outline the appropriate urban development strategy. In fact there are methods such as field survey and mapping manually, but they are very inaccurate and can not timely update changes causing the "backward" information. To overcome this drawback we can apply remote sensing method combined with GIS to create the map of changes accurately, effectively and timely responsing to demand of the planning management and information processing. Remote sensing data with the characteristics of multi- date, quickly information process and covering wide areas, along with GIS technology is a powerful tool for monitoring changes in land use in general, and urban land in particular.

Thermal remote sensing has ideal potential for monitoring the environment and natural resources. It captures the radiance from the sun and the earth, and then converts it into the useful information on the physical earth characteristics. Land surface temperature (LST) is one of its products. Besides, thermal infrared (TIR) (8 - 14μm) wave bands have been shown to provide important additional and supplementary information to that provided by the reflectance data measured in visible (0.4 - 0.7μm) and near-infrared (NIR) (0.7 – 1.3μm) bands for land cover mapping (Boyd et al., 1996).

This paper introduces the research results about the possibility of using thermal information and relationships between vegetation indices and land surface temperature in order to provide additional information to the traditional classification methods. Study area is Nha Be District located in the southern of Ho Chi Minh City. Satellite images used in this study are Landsat image on February 13, 2002, Aster image on December 25, 2006 and land use maps of 2000 and 2005 for reference.

2. METHODOLOGY

2.1 Determination of the surface temperature T_s

There are many methods for determining surface temperature and emissivity, but for the purpose of using the thermal band to perform the land cover classification problem the paper do not go into analysing and evaluating the results of object temperature. In order to simplify calculations, this study took full advantage of the functionality available in the ENVI image processing software for calculate quickly surface temperature object. ENVI provides two methods available are: NOR (Emissivity Normalization Method) and REF (Reference Channel Method).

Zhao- Liang Li et al. (1999) has shown in their study that NOR method is slightly superiors to other methods. This method assumes a constant emissivity in all N bands for a given pixel, which enables N temperatures to be calculated for each pixel using formula (1) from their radiance. The maximum of those N temperatures is considered to be the land surface temperature and used to derive emissivity values for the other bands. If the maximum of temperatures for a given pixel occurs in band k (k = 1…N), this means that the emissivity in band k is the maximum for this pixel.

$$T_s = T_k^{\max} = B_k^{-1}\left(\frac{I_k - R_{atr\uparrow} - (1-\varepsilon)R_{atr\downarrow} * \tau_k}{\tau_k * \varepsilon}\right) \quad (1)$$

Where: B_k: black body radiation in k band (ε=1); I_k: radiation measured by the satellite sensor; $R_{atr\uparrow}$: upwelling components of atmospheric radiation; $R_{atr\downarrow}$: downwelling components of atmospheric radiation*;* ε: emissivity of object; τ_k: atmospheric transmittance in k band.

2.2. Land cover mapping

Vegetation index is a number that is generated by some combination of remote sensing bands and may have some relationship to the amount of vegetation in a given image pixel. Rouse et al. (1974) had detected that the ratio of the difference to the sum of the reflectance values of NIR and Red (named Normalized Difference Vegetation Index - NDVI) useful for measuring the amount of greenness in the vegetation cover.

$$\text{NDVI} = \frac{\rho_{\text{red}} - \rho_{\text{NIR}}}{\rho_{\text{red}} + \rho_{\text{NIR}}} \quad (2)$$

In vegetated areas, the NDVI typically ranges from 0.2 to 0.8, in proportion to the density and greenness of the plant canopy. Clouds, water and snow, which have larger visible reflectance than NIR reflectance, will yield negative NDVI values. Rock and bare soil areas have similar reflectance in the two bands and result in NDVI near zero. Besides, Boyd et al. (1996) had shown that the potential of radiance data in mid-infrared and thermal infrared bands combined with green band for detecting forest stages of regeneration and mapping the thermal characteristics of land features.

$$\text{VI}_{\text{IR}} = \frac{\rho_{\text{green}} * \rho_{\text{TIR}}}{\rho_{\text{MIR}}} \quad (3)$$

Land cover was determined using ISODATA classification and scatter diagram of vegetation indices (VI) versus T_s by relationship scheme of Lambin and Ehrlich (1996). According to them variations in surface temperature are highly correlated with variations in surface water content over bare soil, i.e. low VI and high T_s happen to dry bare soil or low VI, low T_s for moist bare soil). As the fractional vegetation cover increases, surface temperature decreases as a result of several biophysical mechanisms: (1) high VI and relatively high T_s happen for continuous vegetation canopies with a high resistance to evapotranspiration and low soil water availability; (2) high VI and low T_s happen for continuous vegetation canopies with low resistance to evapotranspiration on well-water surfaces. The spectral signatures of all classes from unsupervised classification were used to determine the mean values of correlation between T_s and vegetation indices. They were plotted on scatter diagrams to find instances of strong relationship for deciding the land cover class group.

3. RESULTS AND DISCUSSION

3.1. Determinating surface temperature

Temperature was estimated from the thermal band of each sensor. In general, the surface temperature is greater than 34 degrees Celsius are often concentrated in the industrial and densely populated areas without trees or low density plants and dry bare soil, rock asphalt concrete surface of theresidential, land expose surface due to the high thermal conductivity, absorbs heat faster, but the process of evaporation is low so the surface temperature of the area is always higher than trees or soil moisture area (usually <30°C).

3.2. Land cover mapping

Land cover of the study area could be visually identified from the image with different type such as: vegetation, soil and water. ISODATA unsupervised classification result generated 17 classes. The scatter diagrams of vegetation indices and T_s (Fig. 3 and 4) helped to determine and group these classes into 9 classes (in ellipse shapes): Urban area, bareland, wetlands, grassland, annual crop land (TV1), perennial crop land (TV2), water 1 (rivers, canals), water 2 (surface water, ponds, lakes), cloud (Fig.5).

The figure 1 shows the negative T-NDVI slope. The increase in green biomass is often associated with a reduction in surface resistance to evapotranspiration, greater transpiration, and a larger latent heat transfer resulting in lower surface temperature. The T-NDVI scatter diagram shows a clear discrimination of land cover classes and aggregation of classes with similar spectral signatures. Crop in wetlands have warmer surface temperature than do open water bodies, and due to their vegetative cover they have higher NDVI than water. Rangeland (grassland and brush) has higher surface temperature than wetlands because the soil is unsaturated. The infrared reflectance of the rangeland is not much different from that of the non-forested vegetated wetland. Agriculture land has higher NDVI than rangeland, and depending on recent irrigation and growth stage, the temperature varies. Bare land has the highest surface temperature and higher NDVI than the urban and built-up areas. Urban and built-up areas have also higher surface temperature and lower NDVI than all other classes but soil and water. T_s variation in vegetated surfaces results from variations in the proportion of surrounding bare soil and the thermal inertia of the surface. Thermal inertia is the measure of thermal response of surfaces to temperature changes (Boyd et al. 1996). It is a function of thermal conductivity and heat capacity, and is affected by surface characteristics such as soil moisture and albedo. Surfaces with higher thermal inertia possess a strong inertial resistance to temperature fluctuations at a surface boundary hence they show less temperature variation per heating/cooling cycle than those with lower thermal inertia. The thermal inertia of vegetation canopies is lower than that of soils and water has higher thermal inertia than soils.

Figure 2 shows that scatter diagram of VI_{IR}-NDVI has an approximate positive slope unlike the T-NDVI diagram. This scatter diagram contains radiance data from visible, near-infrared, thermal and mid-infrared spectra. Green vegetation has higher green and near-infrared band reflectance and lower red and mid-infrared reflectance. This results in higher values of NDVI and VI_{IR}.

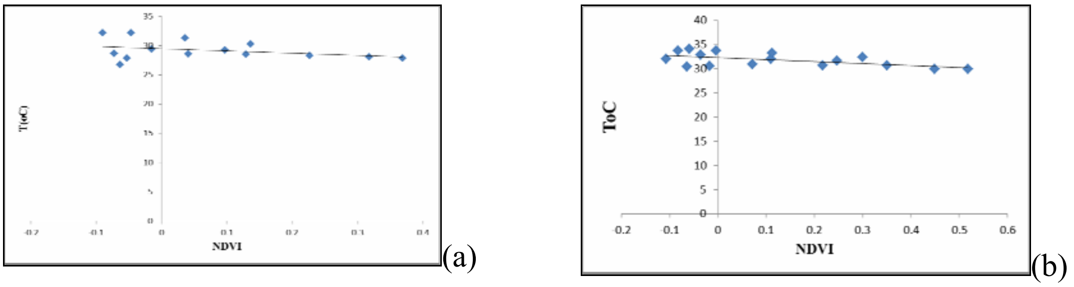


Figure 1: Scatter diagram of T-NDVI from (a) Landsat 2002 and (b)Aster 2006

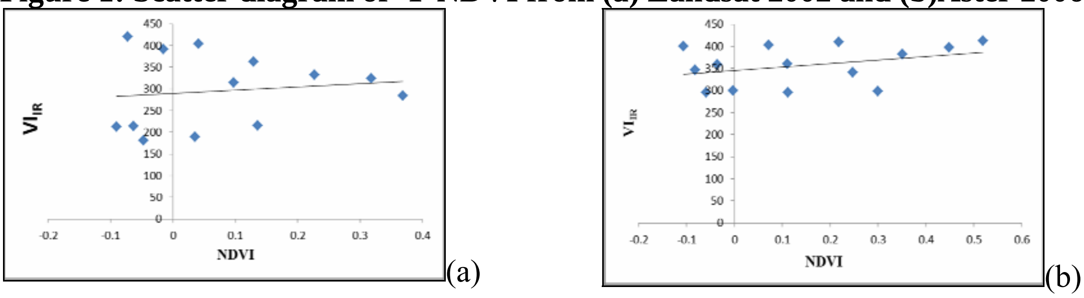
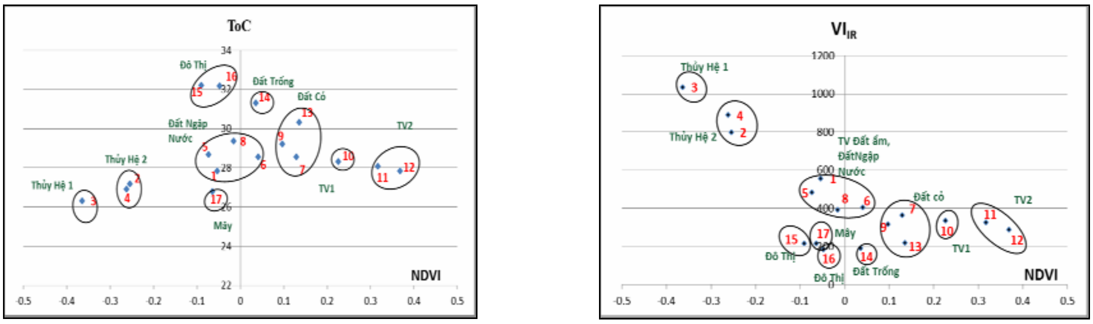
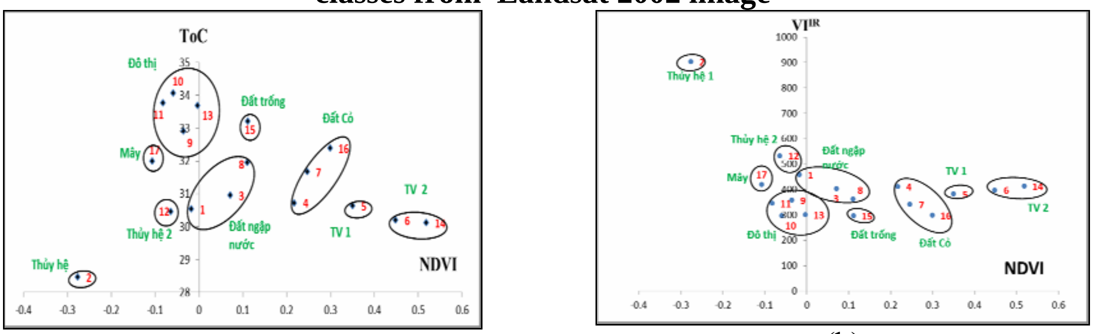


Figure 2: Scatter diagram of V_{IIR} -NDVI from (a) Landsat 2002 and (b) Aster 2006



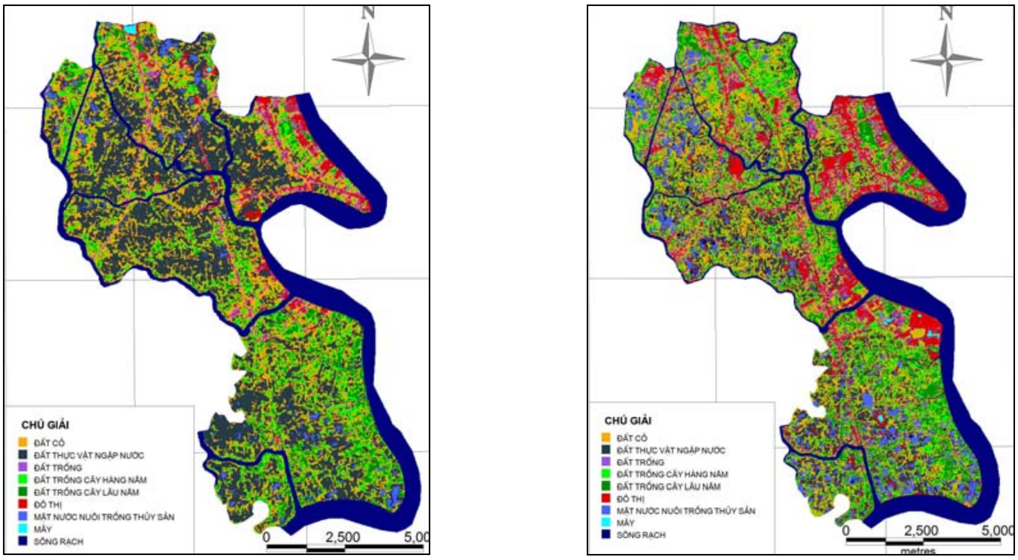
(a) (b)

Figure 3: Scatter diagram of (a) T-NDVI and (b) V_{IIR}-NDVI for unsupervised-classified classes from Landsat 2002 image



(a) (b)

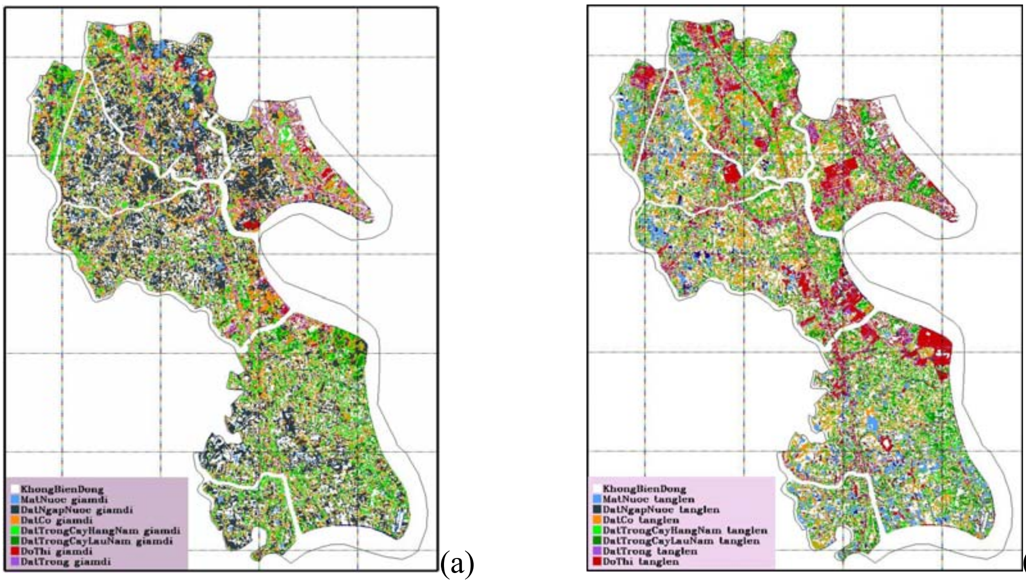
Figure 4: Scatter diagram of (a) T-NDVI and (b) V_{IIR}-NDVI for unsupervised-classified classes from Aster 2006 image



(a) 13-02-2002 (b) 25-12-2006

Figure 5: Classification results from T-NDVI-V_{IIR} relationship

3.3. Land cover change evaluation



(a) (b)

Figure 6: Land cover changes in period 2002-2006 (a) loss, (b) increase

Table 1: Statistics of land cover Nha Be district in the period 2002 – 2006

	Pond, aquatic lake	Wetland	Grassland, shrub	Annual crop land	Perennial crop land	Bare soil	Urban
2002	2,054	35,617	13,879	10,595	4,930	2,640	2,620
2006	6,224	17,767	24,399	11,471	9,275	4,900	8,900
Change times	3,03	0,50	1,76	1,08	1,88	1,86	3,40
Change in 02-06	4,170	-17,85	10,520	0,876	4,345	2,260	6,280

Table 2: Changes from other types of land to urban land in period 2002 - 2006

Other types of land to urban land	Area (km^2)	Ratios (%)
Bare land → urban area	0,931	12,63
Perennial crop land → urban area	0,453	6,15
Annual crop land → urban area	0,680	9,23
Grasslands → urban area	2,367	32,11
Wetlands → urban area	2,790	37,85
Aquatic water → urban area	0,150	2,04
Total area of other types of land → urban area	7,371	100

Calculations shown in Table 1, 2 and Figure 6 wetland area and grassland were transformed to urban land occupied most of the other land types. The main reason is in period 2002-2006, Nha Be district had a lot of urban construction projects, the resettlement areas to reduce the burden of the population for the city center. In addition with cheap price and development potential due to its location adjacent to the new urban district 7 there consequently were a lot of people move to this place to live. Urban area increased rapidly, almost 3.5 times and developed mainly around the main roads. In particular, the area of wetlands and grass land transformed into urban land occupied most of the other land types. Built-up bareland was increased nearly in double from development projects on new urban and industrial areas, but most are underway leveling

4. CONCLUSION

Rapid urban development today, the ability to update the changes in land use is increasingly urgent, requiring more effective methods of image interpretation, quickly and accurately to minimize field labor, to serve the needs of management and urban planning. Thermal remote sensing is an important information band and is quite useful in the study of the environment. Classification of land cover with the supportting of thermal band information will be made by considering the scater diagram of T-NDVI relationship with unsupervised classification results, then additionally examin VI_{IR}-NDVI relationship in combination with knowledge of the expert. Classification classes with similar characteristics will be incorporated into the same group. This method is particularly suitable for the case of unknown study area or lack of observation parallel to the time of acquisition.

REFERENCES

1. Boyd, D.S., Foody, G.M., Curran, P.J., Lucas, R.M. and Honzák, M., (1996), An assessment of Landsat TM middle and thermal infrared wavebands for the detection of tropical forest regeneration. *International Journal of Remote Sensing* 17: 249-261.
2. Lambin E F, Ehrlich D (1996). The surface temperature-vegetation index space for land cover and land-cover change analysis. *International Journal of Remote Sensing*, 17: 463–487
3. Rouse, J. W., Haas, R. H., Schell, J. A., and Deering, D. W. (1974) Monitoring Vegetation Systems in the Great Plains with ERTS. *Proceedings of Third Earth Resources Technology Satellite-1 Symposium*, Greenbelt: NASA SP - 351, 3010 – 3017
4. Zhao- Liang Li, F. Becker, M. P. Stall and Zhengming Want, 1999, Evaluation of Six Methods for Extracting Relative Emissivity Spectra from Thermal Infrared Images, *Remote Senisng of Environment*, 69: 197-214