Investigating Feature of Urban Surface Temperature with Distribution Of Land Cover Types in Hochiminh City using Thermal Infrared Remote Sensing

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Abstract: During the last decades, Hochiminh City became the biggest industrial, commercial center in Vietnam with population more than 6 millions people. The population growth and socio-economic development results rapid increasing transportation, urban expansion has reached to suburban areas. It effects a change of microclimate in urban areas, most evident that the increasing of urban surface temperature is compare with suburban areas, formed "head island" in the atmosphere boundary above urban; it could simultaneously pose serious environmental problems for its inhabitants (e.g., urban waterlogged and thermal pollution). Thermal infrared remote sensing proved its capacity in monitoring temperature field. The purpose of this study is to evaluate the use of Landsat ETM^+ data for indicating temperature differences in urban areas and compare the relationships between urban surface temperature and land cover types. The urban temperature distribution map and the analyses of thermal-land cover relationships can be used as the reference for urban planning and the solution to head island effect reduction.
Keywords: Urban temperature, land cover type, thermal band, NDVI.

1. Introduction

The thermal environment in urban areas is characterized by the heat island phenomenon affected energy demand, human health and environmental conditions. Ground-based observations reflect only thermal condition of local area around the station. We can not establish the number of meteorological stations with expected density. Nowadays thermal remote sensing has been used over urban areas to assess the urban heat island.

To estimate the thermal condition of land surface by satellite, it is necessary to find the relationship between the surface temperature and land cover type. Surface temperature can be daily estimated using thermal bands of NOAA/AVHRR. However, the data with 1.1 km spatial resolution was suitable only for urban temperature at the macro-level, which does not allow the recognition of different land cover types within the pixels. The Landsat ETM+ with 60m spatial resolution of thermal infrared band enables the users to define the more detailed surface temperature.

This research aims to evaluate the use of Landsat ETM+ data for indicating temperature differences in urban areas, to analyze and compare the relationship between urban surface temperature and land cover types.

2. Study Area and Urban Development

The study area is located at the North of Hochiminh City, which is the tropical area with high temperature. It composes of major part of Hochiminh City and parts of surrounding Long An, Tay Ninh, Binh Duong and Dong Nai provinces, which is reported to have rapid built-up expansion since the last decade (fig. 1).

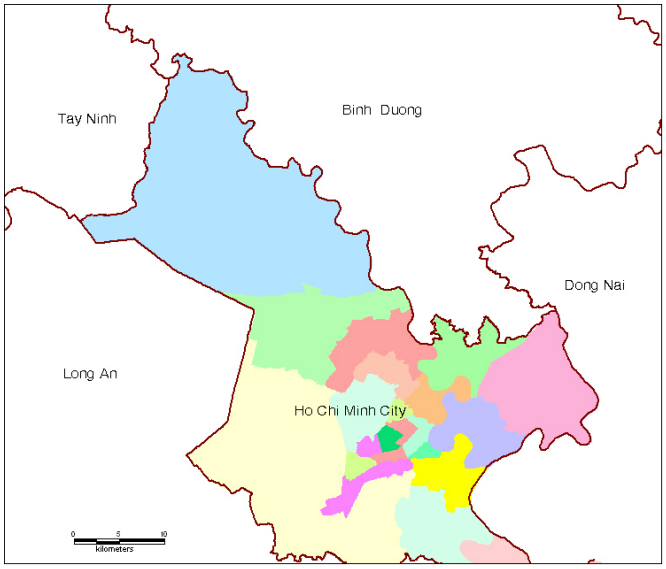

Fig. 1: Map of the study area

Hochiminh City, one of fast expanding area with more than 6 millions, is the biggest industrial, commercial center in Vietnam. The high economic growth and abundant employment opportunities caused influx of labor immigration. The urban population has increased 2 times from 1975 to 2004. The population density in the inner city according to statistical data of 2004 is reported as of 10,313 persons per square kilometers [1]. As housing demand and city development, agriculture land, forests and water basins are transformed into land for housing, roads and industry. The more surface land is concreted, the more vegetation disappears. As a result, the temperature of urban surface is increased in compare with of rural area. Besides that, the urban activities impact on the environment such air pollution and greenhouse gas emission problems, causing the human life be threatened seriously.

3. Methodology

The following procedure was carried out to derive the surface temperature, generate the temperature color map and analyze the data.

3.1. Conversion of the Digital Number (DN) to Spectral Radiance (L_λ)

The spectral radiance (L_λ) is calculated using the following equation [2]:

$$L_\lambda = ((LMAX - LMIN) / (QCALMAX - QCALMIN)) * (QCAL - QCALMIN) + LMIN$$

Where,
- QCALMIN = 1, QCALMAX = 255 and QCAL = Digital Number.
- The LMINs and LMAXs are the spectral radiances for band 6 at digital numbers 1 and 255 respectively.

3.2. Conversion of the Spectral Radiance to Temperature

The ETM+ thermal band data can be converted from spectral radiance black body temperature which assumes surface emissivity = 1 [2]:

$$T = K2 / \ln(K1 / L_\lambda + 1)$$

Where,
- T = Effective at-satellite temperature in Kelvin
- K1 = Calibration constant 1 (watts/meter squared*ster*µm) (666.09)
- K2 = Calibration 2 (Kelvin) (1282.71)

- L_λ = Spectral radiance (watts/meter squared*ster*μm)

3.3. Emissivity Corection

The visible wavelength bands of ETM+ image were classified into three main land cover classes: vegetation, non-vegetation and water using a supervised classification. Corrections for emissivity differences were carried out according to the land cover type by ratioing the black body temperature image with the classified image in which the pixel values for the land cover class were replaced with the corresponding emissivity value. The emissivity corrected surface temperature can be computed as follows [3]:

$$T_s = T / (1 + (\lambda T / \alpha) \ln\varepsilon)$$

Where,
- λ = wavelength of emitted radiance
- $\alpha = hc/K$ (1.438×10^{-2} mK)
- h = Planck's constant (6.26×10^{-34} J.sec)
- c = velocity of light ($2.998 \times x10^{8}$ m/sec)
- K = Stefan Bolzmann's constant (1.38×10^{-23} J/K)

The following surface emissivity (ε) values were used for the correction:
- Non-vegetation (soil / asphalt / sand / mixed pixels) ($\varepsilon = 0.96$)
- Vegetation ($\varepsilon = 0.97$)
- Water ($\varepsilon = 0.98$)

4. Results and Discussions

The Landsat 7 ETM+ used in this study was acquisted in the hot part of the year February, 2002. Band combination of channels 4, 3 and 2 is chosen for further classification analysis (fig. 2). This combination will give maximum information in the land cover classification. Results show that in this study there are kinds of land use/cover such as industrial zone, residential area of inner city with high density, new established residential area, residential area with orchards, dry bare soil, wet bare soil, grow-up paddy field, forest, water.

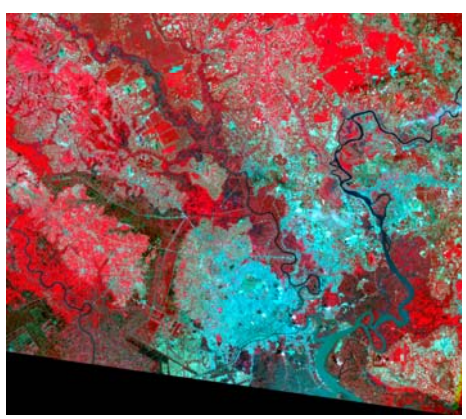

Fig. 2: Band combination of channels 4, 3 and 2 of ETM+ in 2002

The thermal energy responses of different landforms in study area indicate the variation in surface temperature of different surface patterns. Land surface temperature was extracted from thermal band of Landsat 7 ETM+ (fig. 3). Analysis from imagery indicates that the industrial, residential areas are places with highest surface temperature relative to vegetation and water exhibiting lower temperature. Figure 4 shows the color palette of surface temperature in compare with the land cover types. Industrial zones in red color exhibit the highest temperature (from 35°C to 39°C) due to the aluminum roof material plus the thermal energy from production activity. Residential areas in 3 kinds (inner city, new established, with orchards) exhibited different orange color of gradient temperature show the urbanization expanding to rural areas. A lot of building is one of the factors that more heat reflection occurs and it will raise the surface temperature

at urban area rather than the development area. The roof and asphalt makes the reflectivity occur and it causes surface temperature and overall ambient air temperature in urban area to rise [4]. The cooler areas with temperature between 24°C to 28°C in green and cyan color are suitable to areas with abundance vegetation (grow-up paddy field, forest). This is results of dissipate solar energy by absorbing surrounding heat and through an evaporation process from the leaves. The relationship between surface temperature and land cover types is shown in figure 5.

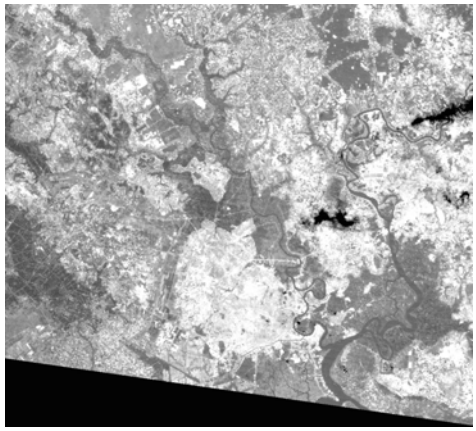

Fig. 3: Thermal band of Landsat 7 ETM+ of the study area

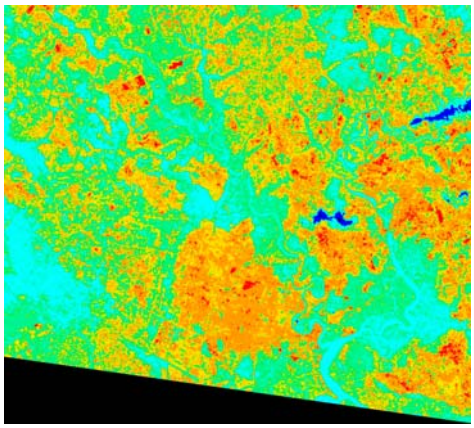

Fig. 4: The surface temperature distribution map of the study area

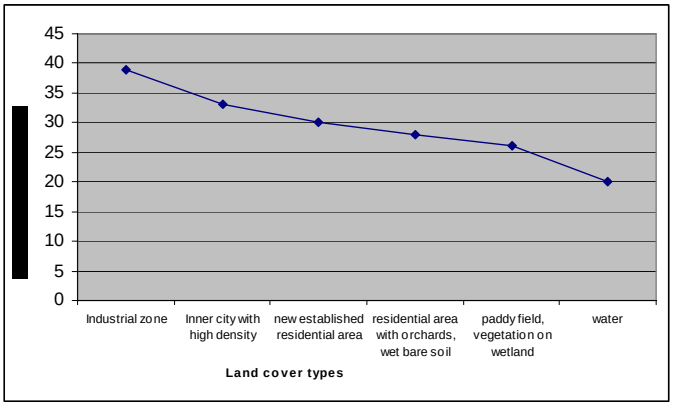

Fig. 5: Thermal signature of land cover types

3. Conclusions

Hochiminh City, one of fast-expanding Vietnam cities, has many aspects of active development under urbanization. It becomes the biggest industrial, commercial center. People live in more comfortable conditions. But that high economic growth brings many of the impacts of high pollution levels in the urban area.

Surface temperature and land cover types can be directly derived from remotely sensed data, which provides a powerful way to monitor urban environment and human activities. This information enhances our understanding of urban environment and can be further used to improve environment quality.

The ETM+ data with 60m resolution of thermal band 6 helps in estimation of more detailed surface temperature variations and more accurate estimation of the urban temperature. Relationship between urban surface temperature and land cover types help us to find out the best solution for urban environment quality improvement and the planning strategies for heat island reduction.

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