Determining the impact of urbanization on land surface temperature by remote sensing and GIS: case of Tay Ho district, Hanoi city, Vietnam.

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Abstract: For ten centuries, the history of Hanoi has been connected to its urbanization process. This urban expansion is leading to the replacement of natural surfaces by various artificial materials. This situation has a critical impact on the environment due to the alteration of heat energy balance. This research reports an investigation into the application of remote sensing, geographic information systems (GIS) to provide information on the impact of urbanization on land surface temperature. The results show that low land surface temperature correlates positively with the coverage percentage of water, and vegetation. This association is negative for built-up and dry barren of land use types. Hence also from the results it can be said that with an increase of built-up area, land surface temperature also increase. Especially as, where the surface is the plant or water becomes impervious, the temperature rises dramatically, from 3 to 7 degree. This information can be used by the municipal authorities and decision makers as input during urban and environmental planning.
Keywords: Urbanization, land surface temperature (LST), remote sensing and GIS, Tay Ho district.

1. INTRODUCTION

Urbanization, the conversion of other types of land to uses associated with growth of populations and economy, is a main type of land use and land cover change in human history. Changes in land cover include changes in biotic diversity, actual and potential primary productivity, soil quality, runoV, and sedimentation rates (Steven et al., 1992), and cannot be well understood without the knowledge of land use change that drives them. Therefore, land use and land cover changes have environmental implications at local and regional levels, and perhaps are linked to the global environmental process (Q. Weng, 1999). Urbanization has a great impact on climate. By covering with buildings, roads and other impervious surfaces, urban areas generally have a higher solar radiation absorption, and a greater thermal capacity and conductivity, so that heat is stored during the day and released by night. Therefore, urban areas tend to experience a relatively higher temperature compared with the surrounding rural areas. This thermal diVerence, in conjunction with waste heat released from urban houses, transportation and industry, contribute to the development of urban heat.

The land surface is a complex feature that can be described as a combination of green vegetation, water surfaces, impervious surface materials and exposed soils. As a result of this complexity, land surface temperature (LST) varies spatially and temporally. Impervious surface differs considerably between urban and suburban areas and it is the main contributor to the SUHI effect (Javed Mallick, et al., (2008)). The results by (Rasul et al., (2017)) from Landsat and MODIS LST indicate the existence of SUCI in semi-arid cities during different times of the day and not only in the morning as stated in other literature. The growth and strength of the heat island areas during this time bring challenges for energy, the health of urban residents, water supplies, urban infrastructure and social comfort (Rhinane, H. et al., (2012)). In addition, it exacerbates heat waves and creates a negative effect on life expectancy on urban inhabitants (EPA, (2008)). Typically, the average surface emissivity in urban areas is about 2% lower than the typical rural areas (Howard, (1818)). Without emissivity correction and neglecting this difference temperature retrievals of urban-rural environments can show differences of 1.5 ◦C or more. Therefore, the urban heat island effect can typically be underestimated.

Remote sensing and geographic information systems (GIS) has been widely applied and been recognized as a powerful and efective tool in detecting urban land use and land cover change (Ehlers et al. 1990, Treitz et al. 1992, Harris and Ventura 1995). Satellite remote sensing collects multispectral, multiresolution and multitemporal data, and turns them into information valuable for understanding and monitoring urban land processes and for building urban land cover datasets. GIS technology provides a • fexible environment for entering, analysing and displaying digital data from various sources necessary for urban feature identiŽ cation, change detection and database development. However, few of the urban growth studies has linked to post-change detection environmental impact analysis. The question of how to develop an operational procedure using the existing techniques of remote sensing and GIS for examining environmental impacts of rapid urban growth remains to be answered.

The goal of this paper is to demonstrate the integrated use of remote sensing and GIS in addressing environmental issues in Vietnam at a local level. SpeciŽ c objectives are to evaluate urban growth patterns in the Tay Ho district, Hanoi city and to analyse the impact of the urban growth on surface temperature.

2. STUDY AREA

West Lake District has been identified as a service center - tourist and cultural center, is a protected area of natural landscape of the capital Hanoi. County is located in the northwest of Hanoi. 24 km2 area, including 8 wards: Grapefruit, Yen Phu Thuy Khue, Tu Lien and Quang An, Nhat Tan, Xuan La, Phu Thuong.

+ Administrative border: the East borders Long Bien district; West Tu Liem and Cau Giay; Ba Dinh District to the south; North by Dong Anh district.

+ Terrain: West Lake District has relatively flat terrain typical of the northern plains. Terrain tends to lower from north to south.

West Lake is the 4th largest county on the natural area after Ha Dong, Long Bien and Hoang Mai. County has about 2401 hectares in total more than 17 878 ha (13.4%) of land area to Hanoi. Oriented growth of capital by the year 2020, the entire West Lake development area in the city's Center. Particularly favorable conditions to attract financial capital resources, human resources and science and technology to promote rapid socio-economic development of society and the County of Hanoi (Fig.1).

Figure 1. Study area in Ha Noi, Viet Nam

3. METHODOLOGY

3.1. Urban expansion detection and analysis

Land cover maps of Tay Ho in 2004, and 2010 were generated from LANDSAT 5 TM images acquired in the aforementioned years. Image pre-processing removed distortions, precision and corrected terrain data (Level 1T) using the Universal Transverse Mercator (UTM) projection and WGS 84 datum (Zone 48, North). The 2004 image was geo-referenced to the 2009 one. Prior to segmentation in eCognition Developer software, the quality of the images was improved using spectral enhancement.

An object-based approach was used to produce LULC map with 4 classes: Imperviuos suface, Water, Vegestation and Barren land. As LULC spatial data became more widely available (either for sale or for free), such data (e.g. LANDSAT satellite images) could be more extensively used in developing countries (Yagoub and Bizreh, 2014). This study followed the following steps to achieve the object based image classification: 1. Segmentation; 2. Classification; 3. Accuracy assessment.

Firstly, the multi-resolution (MR) segmentation algorithms in eCoginition Developer 8.7 softwave (Trimble, 2011) has used in our study. Parameters for the segmentation include scale, shape ratio, and compactness/smoothness ratio was examined at different values. “Scale” is one of the important criteria in segmentation process. Scale value directly affects the size of the segmentation objects. Shape ratio value refers to the form and the structure of individual objects. The change in the shape ratio optimizes the spectral or spatial homogeneity of the resulting segmentation. While, “smoothness” is defined as the ratio of an object’s perimeter to the perimeter of this object’s boundaries that run parallel to the image borders; “compactness” is the ratio of an object’s perimeter to the square root of the number of pixels within that image object. We hereby chose this segmentation as the most appropriate for the purpose of our work. In segmenting these images, the spatial and spectral characteristics of the image pixels were considered. The segmentations of this study were conducted at a scale of 10, color/shape ratio (0.8/0.2), and compactness/smoothness ratio (0.5/0.5).

The second step in the object-oriented method was to classify image objects. The classification stage was done using the segmented image in association with the training data (class signatures) to achieve a good classification of the land cover pattern of the study area. The water in these categories is the most different in spectral with others, especially in near infrared channel. Therefore, water was extracted based on band 3 and band 5 of Landsat TM. After that, the Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI) were used to establish a high quality rule-set for vegestation and Imperviuos suface. Information on image bands, image reflectance, and the relationships between neighbouring objects is required to develop a highly accurate rule-set. To improve the accuracy of the classification, manual editing was carried out.

Finally, to assess the accuracy of the classified maps, the ground truth data was used. The classification accuracy is achieved by comparing the ground truth data points with the classified images, points were sampled along roads, focusing on typical land-cover types in the region. The degree of agreement of the classified image position and the ground truth data points provides the classification accuracy of the image classification process. The accuracy of the resulting maps is based on 98 ground control points taken from high-resolution Google Earth images and fieldwork. The Kappa coefficient, which is calculated according to the Congalton formula (Congalton, 1991), deals with the experiment between the remote sensing data and the in-situ observation.

3.2 Method of determining surface temperature from the infrared thermal images

Signal of a material temperature is obtained by the temperature sensor has been taken to facilitate the numerical value in use. Therefore, to calculate the surface temperature, the first step to carry out calibration of radiation to convert the integer value of the image to the real value of radiation. Besides, the correction radiation also help to reduce the difference to stitch the pictures together.

Radiation calibration method for the generation of LANDSAT images are different. With Landsat TM, ETM +, radiation calibration is performed as follows:

$$L_\lambda = \frac{Lmax - Lmin}{DNmax - DNmin}.DN + Lmin$$

Where,

- L_λ the value of the radiation spectrum;
- Lmax, Lmin: value corresponding radiation spectrum;
- DNmin DNmax in common channel (values are taken from the metadata in the data file Landsat); DNmax - largest numerical value; DNmin - smallest numerical value.

For Landsat TM thermal infrared channel, ETM +, due to be stored as 8 bits (256 levels of gray equivalent), and DNmin DNmax values are taken respectively by 255 and 1.

Table 1 Editorial Instructions

Spectral band	Satellite	L_{max}	L_{min}
6.1	LANDSAT 7/ETM	12.65	3.2
6.2	LANDSAT 7/ETM	17.04	0.0
6	LANDSAT 5 TM	15.503	1.238

4. RESULTS AND DISCUSSION

4.1. Urban expansion in the Tay Ho, 2004 – 2010

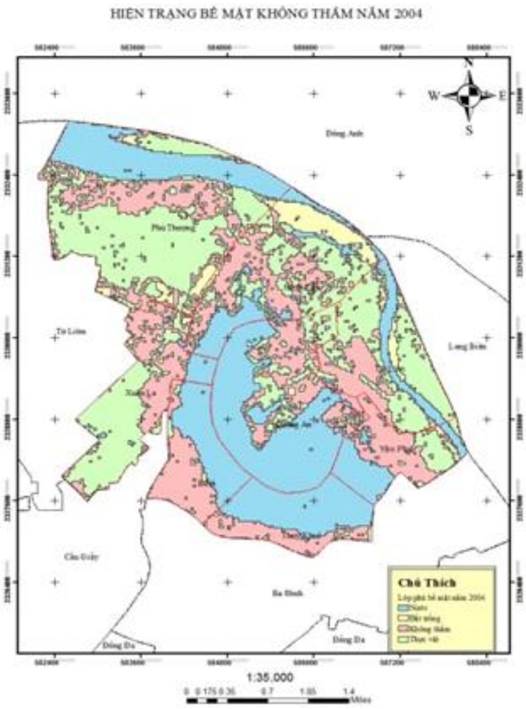

Figure 2. Land cover map in 2004

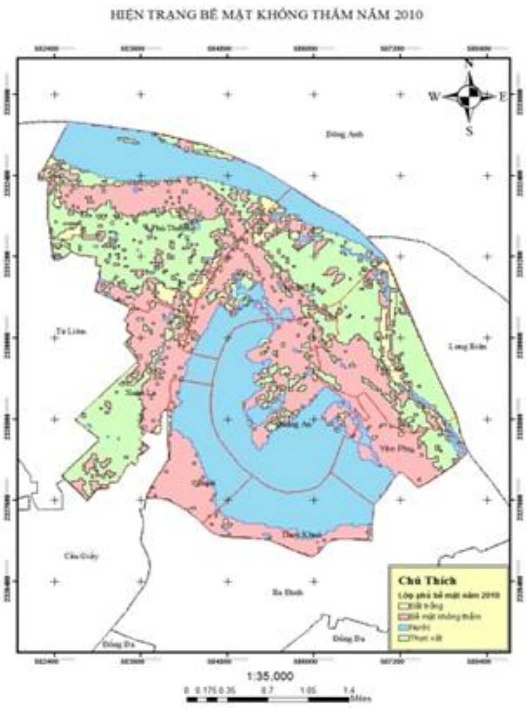

Figure 3. Land cover map in 2010

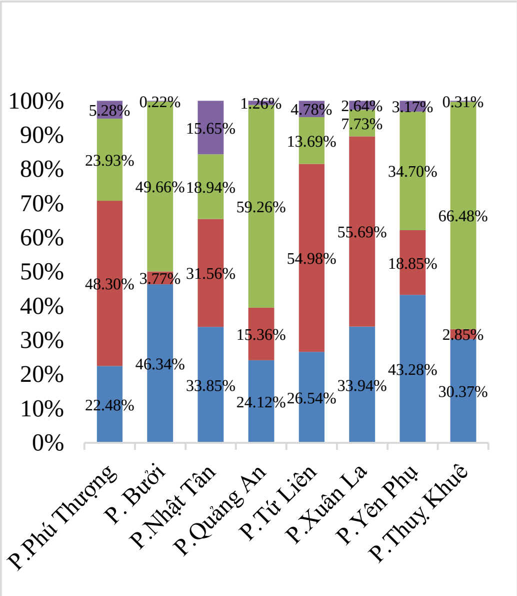

Figure 4. Structure of land cover in 2004

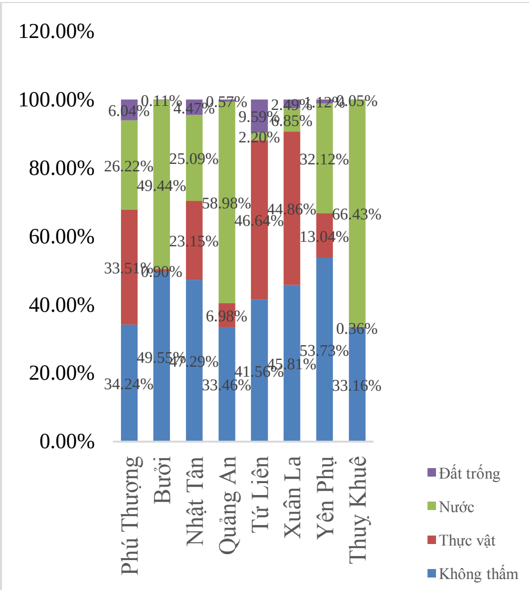

Figure 5. Structure of land cover in 2010

4.2. Spatial distribution of surface radiant temperature in the Tay Ho, Ha Noi

The impact of land use and cover changes on surface radiant temperature can also be examined spatially. The surface temperature change image obtained by image diferencing is recoded into eight temperature zones based on the classification scheme of equal interval. The mapped patterns of temperature change exhibit distinctly diferent spatial patterns among the nine temperature zones (Fig.4) coincides with that of urban expansion.

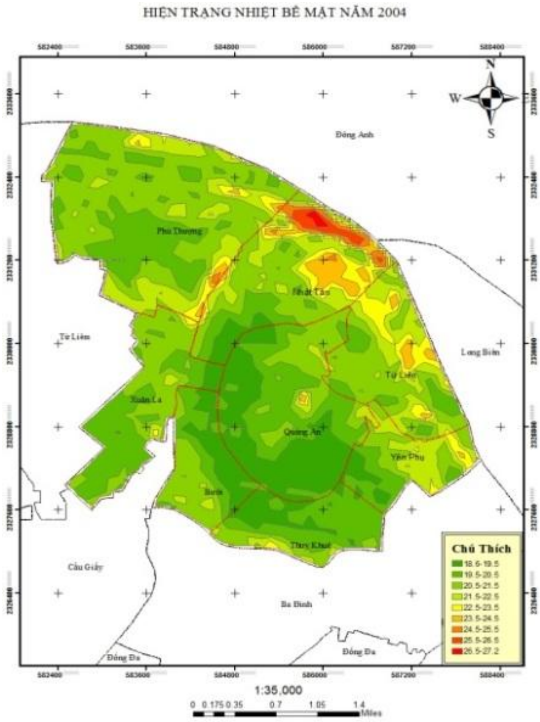

Figure 6. Spatial distribution of surface radiant temperature in 2004

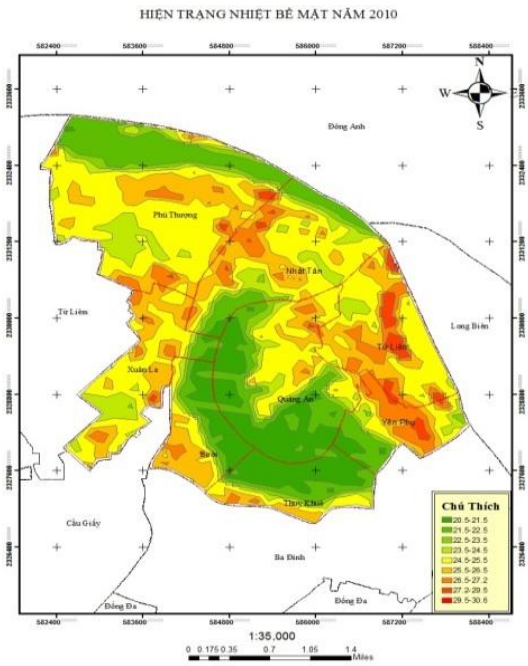

Figure 7. Spatial distribution of surface radiant temperature in 2010

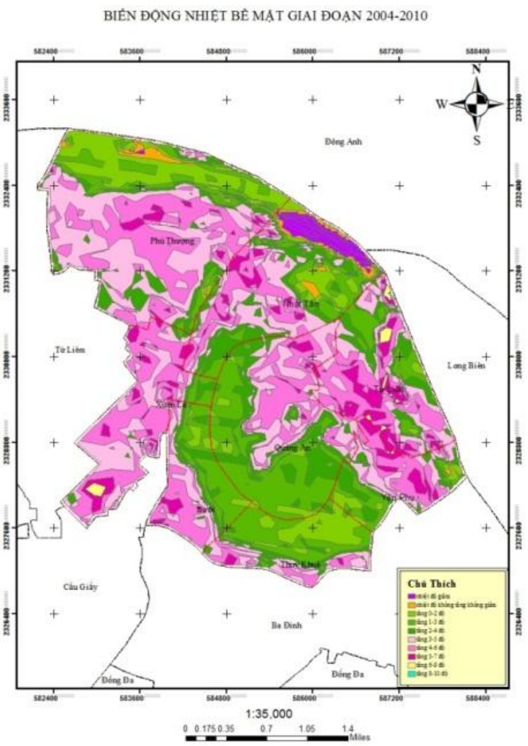

Figure 8. Change of spatial surface radiant temperature in 2004-2010

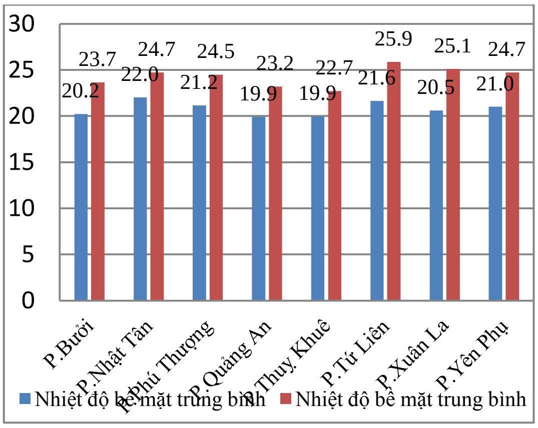

Figure 9. Change of surface radiant temperature in 2004-2010

4.3. Urbanization impact on surface temperature

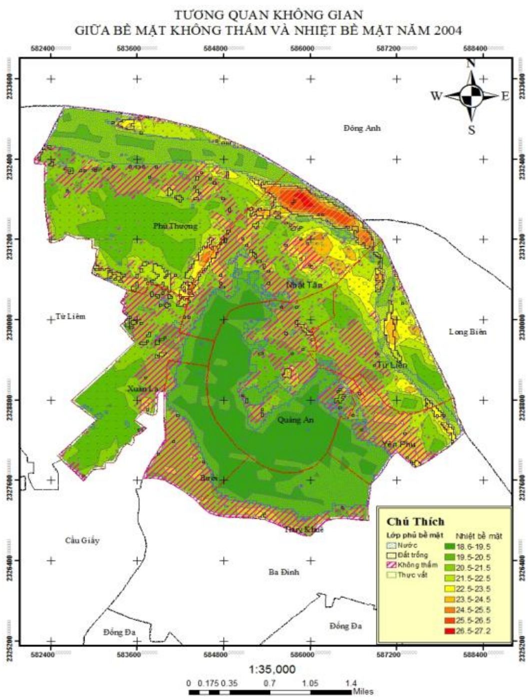

Figure 10. Spatial relationship between landcover and surface radiant temperature in 2004

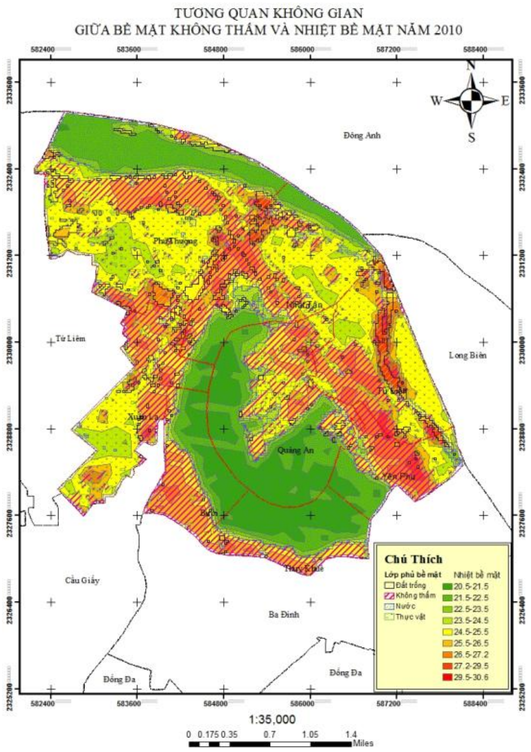

Figure 11. Spatial relationship between landcover and surface radiant temperature in 2010

Through the comparison and data we can see that the government has a real kind of crucial provisions to certain surface temperature. Where vegetation or shrubs distributed seasoned with lower temperature where no vegetation as vacant land. Impermeable surface and then growing and vegetable acreage fell more impermeable surfaces where distributed more sturdy make that place a higher temperature of the rest. In the period from the year 2004-2010 significantly increased the surface area of impermeable demand for housing for people growing led to the emergence of new urban areas such as: urban Nam Thang Long ... Together with the expansion of from single residential complexes populated expand horizontally along the main roads such as Au Co, An Duong Vuong street, Yen Phu, Lac Long Quan. The process of urbanization along with the expansion of traffic lanes, construction of parking lot ... to meet the travel needs of the people. Accompanied by the impervious surfaces, heat reflective surface temperature of the earth increases. And as we all know impervious surfaces heat reflecting much stronger than the absorbent surface. That's why when the impermeable surface increasing surface.

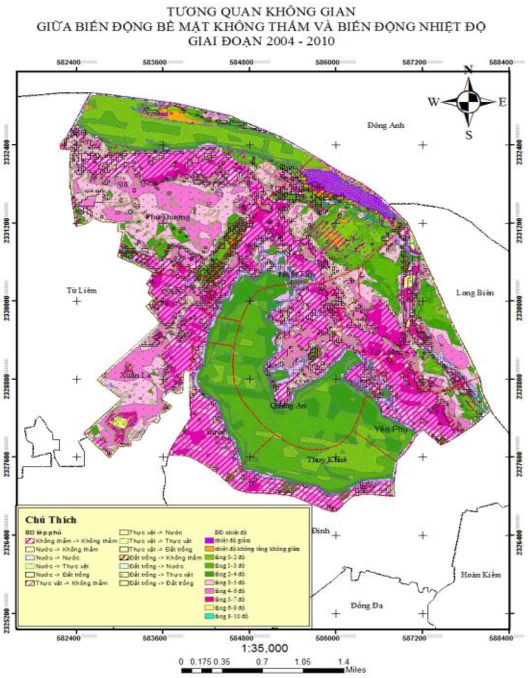

Figure 12. Spatial relationship between change in landcover and surface radiant temperature in 2004-2010.

From the spatial correlation between impermeable surfaces and surface temperature as well as measurements of monitoring the amount of impervious surface area of Tay Ho, we can see the process of urbanization, the growth of the economy leads to a change in the way impervious surfaces strongly. So in 2004 - 2010 area and the size of the piece impervious tend to increase. According to it the temperature also increases. With regard to the areas of surface temperature increase repellent greatly increased, particularly rising temperatures in the points from plant or water become impervious surface and water become bare soil (sand) for the Red River basin area. Reasons leading to increased surface and heat repellent surface is due to the opening of the sộng municipality, the traffic engineering to meet the requirements of increased population and urbanization paced the area Tay Ho. Specifically:

- Buoi and Thuy Khue: temperature increases from 3 to 7 degrees Celsius due to plant in the area turning surface impervious to almost all.
- Xuan La and Phu Thuong: plant objects turn into a lot of repellent should the average temperature of the area to rise. But considering the small region is only increasing from 2 to 7 degrees Celsius.
- Yen Phu and Quang An: increase in temperature from 4 to 10° C, because the area was converted into the plant repellent also relatively many, and 1 branch of small claims have been up into the song the audience you're setting up drums (sand) This is the reason this sector temperatures rise so much.
- Nhat Tan: there are plant converted to a relative, but also repellent simultaneously Riverside sand moving into countries where the temperature of the water is always low. Should this area be increased temperature make the 6-7 degrees but also is the only sector temperatures rising.

From the results above, we see the follow the elements fluctuate over time and space, surface morphology structure do not penetrate very useful help to managers and planning appropriate measures for sustainable urban development and planning source natural resources in a reasonable manner.

Based on the above data analysis we find that for urban environmental management there is a need to balance the overlapping objects in urban areas, as for areas with a large area the area is much lower than the area with many residential areas.

In order to have an urban living space suitable for the temperature environment with human life (from 23^0C to 28^0C), the structure of the urban land surface should be: 50% imperviuos surface, 15-20% are water, 10% or less are bare land, and 20-30% are vegetation.

5. CONCLUSION

In this study, an integrated approach of remote sensing and GIS was developed for evaluation of rapid urban expansion and its impact on surface temperature in the Tay Ho district, Ha Noi city, Viet Nam. Results revealed a notable increase in urban land use/cover between 2004 and 2010. Urban land development was uneven in diverent parts of the delta, and the density of urban expansion showed a tendency of decline as the distance increased away from a major road. The combined use of remote sensing and GIS allows for an examination of the impact of urban expansion on surface temperature. The results showed that urban land development raised surface radiant temperature by ….. The increase of surface radiant temperature was related to the decrease of biomass. The spatial pattern of radiant temperature increase was correlated with the pattern of urban expansion. This is particularly true when all these patterns were referenced to major roads. The integration of remote sensing and GIS provides an eYcient way to detect urban expansion and to evaluate its impact on surface temperature. The digital image classification coupled with GIS has demonstrated its ability to provide comprehensive information on the nature, rate and location of urban land expansion. Biophysical measurements including surface radiant temperature and biomass can be extracted from Landsat TM images. Using the technique of image diferencing the environmental changes over time can be evaluated. To examine the environmental impact of urban expansion, the mapped patterns of environmental changes can be linked to urban expansion pattern by correlation analysis.

The environmental impacts of land use and land cover change can be modelled at local level using the integrated approach ofremote sensing and GIS. This methodology should be possible to apply to other regions in Vietnam or in other nations that undergo a rapid urbanization.

There is a need to utilize remote sensing data in investigating surface temperatures of cities in dry and semi-dry environments on a large scale. That study is a necessary requirement in the description of surface characteristics in this specific environmental climate class. Furthermore, since urban climate archipelagos produces an aggregate impact on temperature, moisture or precipitation, future studies should focus on SUHI archipelagos.

6. REFERENCES

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