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Futuristic Method for detecting Environmental Stress in upcoming Smart Cities

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Abstract: Urban Heat Island has been one of the factors which can give an insight to the Environment Stress in any region due to the increased urbanisation and other human activities. With the help of LANDSAT satellite images and the retrieval of Land surface temperature. Different methods for LST retrieval have been mention with their accuracy and Mono-window Algorithm has been discussed in details. Correlation with NDVI and NDBI has been explained, further the cooling effect of water and vegetation over an area has been discussed with their effective area of influence. A strong relation has been established on how UHI effect can be used to identify the area under environmental stress, and can help Area Development Authority in better planning of a city, this provides an easy to use tool for planning the upcoming smart cities whereby decreasing the energy consumption and regulating the industry.

Keywords: Environmental stress warning system; Landsat TM; Land surface temperature; UHI; Urban heat island; Smart City

I. INTRODUCTION

Urban heat island (UHI) is one of the most familiar influences caused by land use/ land cover changes due to urbanization [1], which is the direct representation of environment degradation[2]. As urban area develops, change occur in the landscape, building, roads, and other infrastructure replace open land and vegetation. Surface that were once permeable and moist generally become impermeable and dry. This development leads to the formation of urban heat island (UHI). The phenomenon whereby urban regions experience warmer temperature that their rural surroundings. Urban heat island (UHI) was described by Luke Howard[3] as the urbanized areas which have higher temperature than the nearby areas and ever since this subject matter has received a lot of interest[4]. Recently, with the development of society and acceleration of the process of urbanization, the urban heat island has become more and more significant and has had severe impact on urban development and human living environment[5]. UHI can be further divided into two-part Surface Urban Heat Island and Atmospheric Urban Heat Island, Surface UHI is the temperature of urban surfaces whereas Atmospheric UHI is divided into two types Canopy Layer UHI (regions lie between ground level to rooftop) and Boundary Layer UHI (regions lie above rooftop and extends no more than 1.5Kms). Canopy Layer UHI is the most commonly observed and referred in context of UHI. One of the most important factor for observing UHI is the observing time, UHI effect become more pronounced after sunset which is due to slow release of heat from urban infrastructure. The reasons for development of UHI in current modern world is not just due to change in infrastructure and landscape, but also due to pollution produce by various industry. Today most of the countries are launching and supporting concept of smart cities, yet most of them lack in controlling the environmental stresses generated within these smart cities.Urban heat Island can play major role is detecting these environmental stress regions within a city, and these UHI can be calculated using Remote Sensing. which can be easily control using smart tool that provide information about environmental stress developed in any region. UHI effect over an area can be used as an altering system for the municipal corporation for development of cities and taking crucial decision of developing an industrial area or forest area.

Urban heat island can be captured in the spatial distribution of land surface temperature (LST), which is governed by surface heat fluxes and affected by urbanization[6][7]. Acquisition of LST (measuring, calculating or estimating) is one of the primary and key steps to the urban heat island analysis. Traditionally, urban heat island analysis is based on the LST data observed at the meteorological stations with *in situ* measurements. However, the uneven distribution of meteorological observation locations may result in the observed LST data not fully representing the distribution of LST across the region. Since the 1960s, with the advent of high-resolution earth-monitoring satellites, remote sensing technology has been widely utilized to measure LST and provide basic data for the urban heat island analysis. Compared to the traditional meteorological observation method, remote sensing technology has the advantages of high-resolution, wide-coverage and intensive-points, *etc*., which makes large-scale urban heat island research possible[8].

The Landsat TM data is one of the most widely used satellite images for LST retrieving because of its high resolution (30 m) and availability of thermal infrared (TIR) band. Depending upon the satellite data source, different LST retrieval methods have been developed and used, such as the split-window method[9], temperature/ emissivity separation method[10], mono-window method[11], and the single-channel method[12]. For Landsat 5, band 6 records the TIR radiation in the spectral range of 10.4–12.5 μm from the surface of the earth. Three LST retrieval methods: radiative transfer equation, mono-window algorithm, and the single-channel algorithm can be applied to Landsat 5 data. Although all of these methods provide good results, the radiative transfer equation can only be applied when in situ parameters of

atmospheric profiles are available simultaneously when the satellite passes[8]. TIR band is available in a single band in all the missions (Landsat 1-7), however, Landsat 8 data (available from 2013 onwards) have two TIR band (band 10 and band 11, with wavelength 10.60 - 11.19 µm and 11.50 - 12.51 µm respectively). Moreover, the USGS pointed out that, given the larger uncertainty in the Band 11 values, users should work with TIRS Band 10 data as a single spectral band[13].

II. OVERVIEW OF LST RETRIEVAL METHOD

Several models have been developed around the world for the assessment of Land Surface Temperature but Empirical models are generally the simplest and hence the most preferred and widely used models worldwide. The computation of LST using empirical-based model has long been an active research topic. This paper deals with mono-window algorithm due to its higher accuracy.

Table I: Different Method for LST Retrieval with their Accuracy

DATA	TEMPERATURE/EMISSIVITY SEPARATION	SINGLE-CHANNEL	MONO-WINDOW	SPLIT-WINDOW	MULTI-WINDOW
LANDSAT	Yes (In-situ parameter required)	Yes (Lower accuracy)	Yes (Higher Accuracy)	-	-

A. Mono-window Algorithm

Mono-window Algorithm is one of the most efficient and easy to use algorithm for calculating LST. The Mono-window algorithm is based on Thermal radiance transfer equation [11] and requires only three parameters, emissivity, transmittance and effective mean atmospheric temperature to retrieve LST from band 6 and band 10 (Landsat 5 and Landsat 8). It required only two inputs i.e. near surface temperature and relative humidity. The algorithm than includes a series of calculation for find emissivity, NDVI, and transmittance which are than use as an input for the final equation 1 as given by Liu and Zhang[8].

$$T_s = \{a(1-C-D) + [b(1-C-D) + C + D]T_i - DT_a\}/C \quad (1)$$

Where,

$$a = -67.355351$$

$$b = 0.458606$$

$$C = \varepsilon_i \times \tau_I \quad (2)$$

$$D = (1-\tau_i)[1 + (1-\varepsilon_i) \times \tau_i] \quad (3)$$

Liu and Zhang[8] used Mono-window Algorithm to study the UHI effect over Hong Kong area covering three main sub-urban area and then correlated LST with NDVI (Normalized Difference Vegetative Index) and NDBI (Normalized Difference Built-up Index), it indicated that LST has a negative correlation with NDVI and Positive correlation with NDBI. Mono-window Algorithm was applied to both Landsat and Aster Data, but Landsat data showed a little higher accuracy.Kumar & Panwar[14]studied the variation of LST over Delhi NCR using Mono-Window Algorithm for years (1991, 1996, 2000, 2003, 2009, 2011, and 2016) and relate it with NDVI, NDBI and MSARVI. They concluded that the soil characteristic has high influence on SUHI and land cover, and NDBI shows a better depiction of LST. Shi and Zhang [15] studied the Haizhu district in Guangzhou in sunny summer day and found an error of 1C and found that the cooling effect of water and vegetation on surrounding urban lands were effective within distance of 250 m and 350 m, respectively. This study provides reliable techniques for planning and design of urban climate in the hot-humid region.Wang and Qin[16] has provided a new improved version of mono-window algorithm for LST retrieval for images obtain from Landsat 8 satellite launched on February 11, 2013. They applied this Improved Mono-window algorithm for finding the LST over Nanjing in east China and found that their algorithm is efficient for finding UHI effect and the error were moderate.

III. Discussion

UHI has large impact on urban climate, and has positive correlation with NDVI and Negative correlation with NDBI. Landsat image provides more accurate LST value in comparison to other satellite image, not only Landsat 5 but Landsat 8 image can be used to find the UHI effect, which not only increase the resolution of the image but also the accuracy. It is also seen the cooling effect of water and vegetation on UHI limits up to 250 m and 350 m. UHI can provides basis of planning cities and urban area hence decrease overall energy requirement of the area.

IV. Conclusion

Mono-window algorithm is the best method for LST retrieval due to its higher accuracy and easy methodology. LST provides the basic of find UHI effect over an area, further UHI can be used as a tool for planning of smart cities and to mitigate environment stress within a city and hence improving the local climate. This planning can decrease the overall energy consumption of the cities. Municipal corporation can be benefited using UHI for planning such for identifying the area under higher and then planning the area to improve the temperature and energy consumption of the area, these can

be done by providing artificial lake and improving vegetation of certain area as discussed above it can minimize the temperature within a radius of 250 to 350 meters.

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