Observation of Urban Thermal Regime using Satellite Remote Sensing

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1. The abstract

Surface urban heat island of Abu-Dhabi is studied using satellite-sensor data from the period of January, 2010 to March, 2015 . MODIS(Moderate Resolution Imaging Spectrometer) sensor was used to understand the variations in land surface temperature variations during day and night times in number of urban and rural areas in and around the city. In this contribution sub-pixel land-use classification is computed using vector data of building-footprint and road-ways in Abu-Dhabi. Our analysis shows that roads as a built-up land use class have a marginal contribution towards the surface heat island effect in Abu-dhabi city.

2. Introduction

Abu Dhabi (24.28 N 54.22 E) is a coastal city in the Middle-East with an arid and hot climate, Temperatures in the city crosses 40°C during the months of May to October. The local temperature variations are important aspect to create more sustainable urban habitations in the region. One of the parameters to understand local temperature variations is studying the Land Surface temperature (Voogt & Oke, 2003). Abu-Dhabi is a T-shaped island, consisting of dense urban, semi-rural, industrial regions, it has seen structural growth in built-up infrastructure after the 1970's with very recent development outside the main city, to accommodate the cities industrial and residential needs. The newly built residential-suburban areas follow a homogenous pattern with low-rise building structures and civic infrastructure, while the Urban areas are full with tall-structures with more human density and activity.

The phenomena of Urban heat Island (UHI) effect is well known to have environmental consequences (Oke, 1982). The more the tree canopy is replaced with man-made material, the more solar radiation trapped by such materials which is then released back in the night, keeping the city warmer than the sub-urban inhabitations. The Urban heat island has been studied by different using various satellite-sensors including MODIS (Huang Tran, 2006). Generally to study the effects of the UHI, three different types of areas are studied: Urban, Sub-urban and rural (Nasarallah et.al, 1990). In this study we use data from MODIS to study spatial and temporal thermal variations in selected parts of Abu-Dhabi.

3. DATA AND ANALYSIS

In this study use of raster data is used to create a time-series of LST values ,while support of vector data is taken to compute geometric analysis to compute land-classification classes like roads and building-footprint areas. MODIS is a satellite mission with high frequency of revisit over Abu Dhabi. It passes by the region around 13:00 for Terra (EOS AM) and around 22:00 for Aqua (EOS OM). In our study we used the MODIS MOD11A1: Land-surface temperature /Emissivity Daily L3 Global product. MOD11A1 has 1km spatial resolution .Day and Night LST values are stored in a Sinusoidal projection.

Following four locations in Abu-dhabi are considered for the study:

- Urban : JW Marriot(24.412499, 54.483696), Qasr El Bahr(24.470826, 54.399040), Dalma st.(24.470830, 54.389878),KhalifaPark(24.429166,54.463431),Karahmah school(24.462499, 54.367972),Mushrif park(24.454162, 54.382689),Mushriff mall(24.429164, 54.408511),Emirates Foundation(24.462492, 54.386284),AL Hosn mil-camp(24.470832, 54.362415),AL Sola tower(24.487492, 54.369612),ADCB Bank(24.495831, 54.373216),SBR interchange(24.420828, 54.478138), Hamdan Center(24.487494, 54.360460)
- Rural : Al-Dhafra Air Base (24.23 N, 54.56 E)

Building foot-print and area covered by roads in the urban areas mentioned above are also computed . The following map illustrates the areas in Abu-Dhabi with the aggregate of % of Building-foot print and % of roads in overlay of raster (MODIS) pixel. The urban areas of interest are shown with a corresponding pixel-identifier (alphabet).

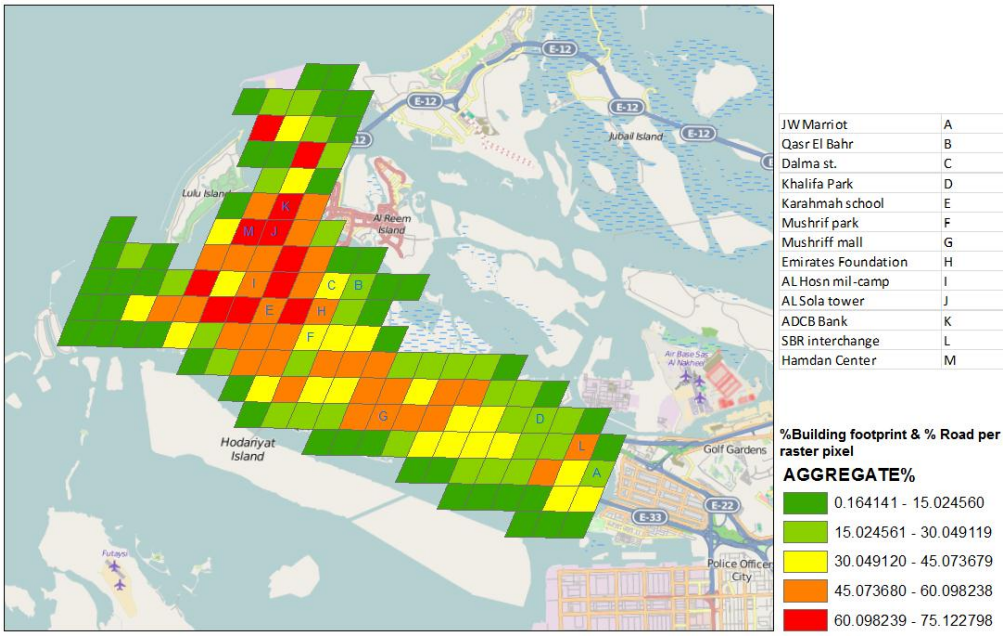


Figure 1:Thematic map of Abu-Dhabi showing Aggregate % of Building-footprint and Road ways constructed Per Raster Pixel (1 sq km.)

The areas listed in the map were selected only if the sub-pixel area has no(or minimum) surface water content. Consequently those areas with varying aggregate built-up were selected to study the correlation between these land-use classes and LST. Following are the calculated values for Roads and Buildings for corresponding pixel-identifiers(urban areas).

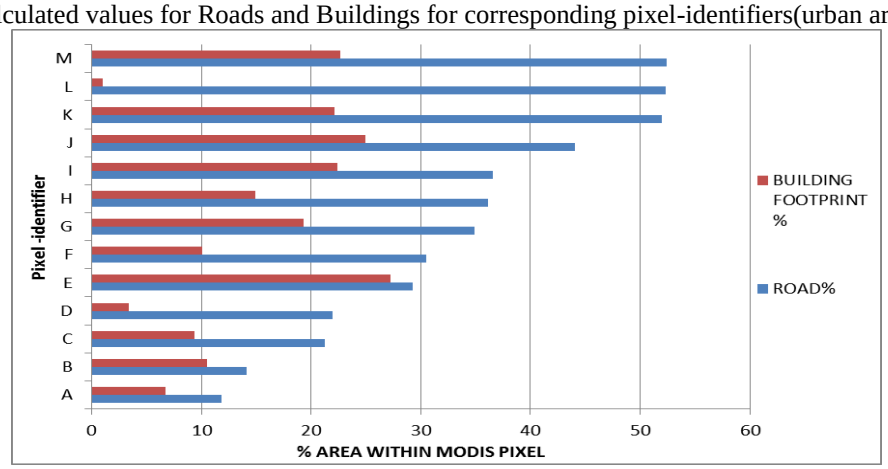
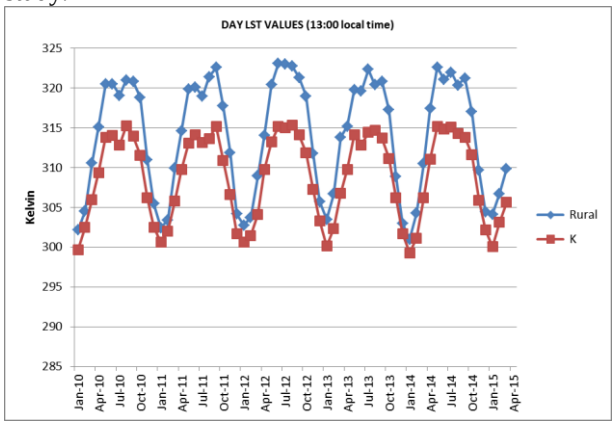
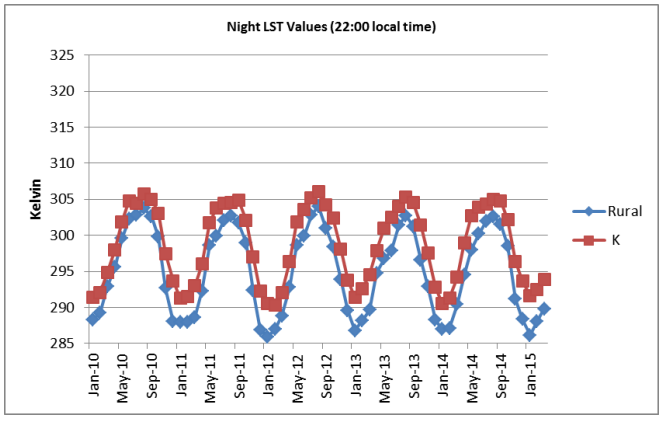


Figure 2:Distribution of Built-up classes in the selected raster pixel (see fig 1)

Abu-Dhabi has broad roads and is well connected , hence , the road surface area in all given areas (**A-M**) is greater than the area of the building footprints correspondingly. Areas like **M,K,J,I,E** consist of high built-up surfaces and areas like **A,B,C** relatively have greater areas of barren surfaces within Abu-Dhabi city. The area **L** is interesting, in that, it has built-up surface of more than 50% consisting of roads but negligible building footprint. With the above data urban LST is analyzed.

A reference rural pixel(Al-Dhafra air base) ,about 20kms outside the city is used to understand the LST variations within the city. The temperatures in the main urban areas like **M,K,J,I,E** show inverse-surface urban heat island effect (SUHI) during the day, The desert pixel values being consistently higher during the summer months of May-August of the every year under study.

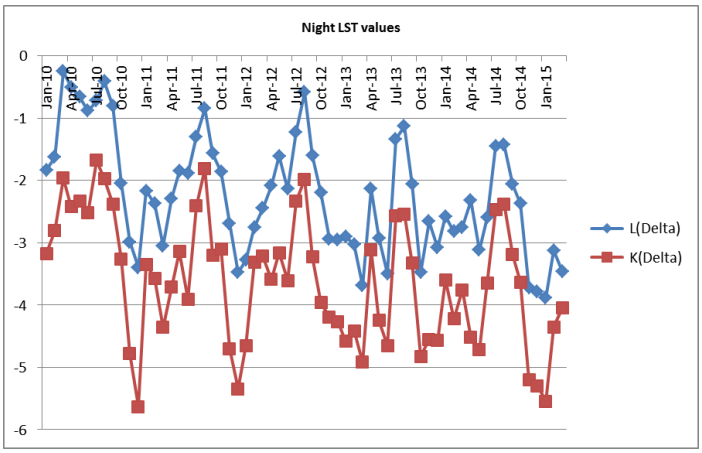


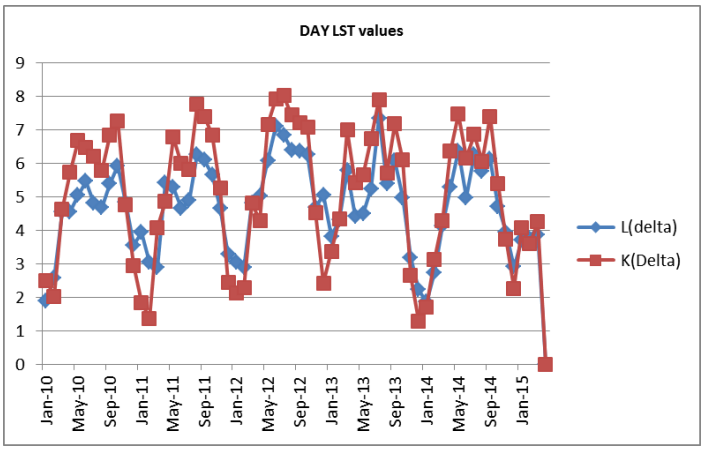


The figure above shows that there is a considerable SUHI-effect present in the urban(down-town) area of abu –dhabi. The graph represents the area **K (**salam street). Using the reference pixel we further study the impact of built-up surfaces on LST. Certain areas in the city have great number of sky-scrappers (**M,K)** while certain areas have low-rise villas within the island city (**G**) .
Following are some analysis of LST patterns during day and night using following formula :

Delta=Rural LST value – Urban LST value

-AREA **L** : 52.3 % covered by Roads , 1.7 % covered by buildings
-AREA **K** : 52 % covered by Roads , 22.5 % covered by buildings





The above chart shows that during the night the rural LST values are cooler than both the area L and area K . The road areas in both these study areas are the same. The difference being the built-up area in **K** is 21% more than area **L**. The differences in night peak in the month of January every year.

The chart also shows that area **K** remains much cooler than area **L** during the day time .Area **K** stays particularly cooler in the months of summer.

4. Conclusion

In this work,we study the effects of UHI in arid climate of Abu Dhabi. We use vector data to understand the sub-pixel built-up land classes . We are able to establish that urban climate variations in Abu-Dhabi are dominant in the areas with dense and high-rising man-made structures also we are able to show that built-up areas like roads contribute marginally to the heat island effects within Abu-Dhabi city.

5. Acknowledgment

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