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Influence of urban areas on environment: Special reference to building materials and temperature anomalies using geospatial technology

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ABSTRACT

Scientists and researchers have employed various techniques to study the Earth and its features using satellites revolving around the Earth, which in general terms can be named as the field of remote sensing. This spatial technology has found its way in identifying the minute details of Earth surface elements. Global warming has been a topic under study for various scientists all over the world. Studies are being done by the environmentalists and scientists to identify the adverse changes that are caused to the environment due to human activities to figure out a way to mitigate the current crisis. The present study investigated in Vellore city, Tamil Nadu; India gives a systematic way to analyze the causes for the changing climate by interlinking various parameters like land use and land cover classes, wind direction and urban building materials such as concrete, tile, brick and cudjan leaves. Satellite data's acquired by Landsat-8 and hyperspectral imaging sensors are utilized in this study to evaluate the temperature distribution patterns and spectral reflectivity of diverse building materials. The varying pattern of the response curves given by hyperspectral data can be referred to as the effect of atmospheric transmittance in difference wavelength regions. The effect of absorption and reflectance is predominant in the spectral curves obtained using hyperspectral data which shows high and low reflectance values. The impact of various factors considered in this study was found to be significant in causing temperature variations on the Earth's surface.

1. Introduction

Global warming and urbanization are terms that we often hear in the present scenario. From the very beginning of evolution of homosapiens, the human settlement patterns have been spread in small patches, with less number of houses and land area used. In the developed as well as developing countries, the need for job and demand for high standard of living gave rise to spread of settlements to urbanized areas from rural areas. Humans have been modifying the diverse features on the Earth's surface for different purposes for centuries. The magnitude of human impact on the Earth has become so large that the scientists are calling this new epoch in the history of Earth as the Anthropocene i.e. when human activity alters the global climate and ecosystems. Aerosol pollution, biodiversity loss, climate change, changes in land use and ocean acidity are few environmental limits which we might not want to transgress in the Anthropocene. The rapidly growing human population, which now stands at roughly 7 billion, is projected to reach 9 billion by 2045. Human activities are pushing the Earth toward a tipping point; that could cause sudden, irreversible changes in relatively stable conditions that have allowed civilization to flourish (Morello & Climate Wire, 2012; Teja, Mandla, Srinivas, & Mahendra, 2014). Scientists at the Intergovernmental Panel on Climate Change (IPCC, 2001) have gathered compelling evidence to state unequivocally that there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.

Cities in modern age are growing in area and they occupy 2% of the Earth's surface but their inhabitants consume 75% of the world's energy resources (Gago, Roldan, Pacheco-Torres, & Ordonez, 2013). Global warming is increasingly affected in all the regions of the world which causes imbalance in the natural phenomena for example: variations in seasons. Cities will be exposed to climate change from greenhouse gas induced radiative forcing, and localized effects from urbanization such as the urban heat island (Deep & Saklani, 2014; Franco & Mandla, 2012; McCarthy, Best, & Betts, 2010). Most greenhouse gas emissions that contribute to global climate change come from urban areas (Voogta & Okeb, 2003). Variation in temperature is one of the major impacts of urbanization. The isotherms, or lines of equal temperature, form a pattern that resembles an

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"island" loosely following the shape of the urbanized region, surrounded by cooler areas. Jusuf, Wong, Hagen, Anggoro, and Hong (2007) studied the influence of land use types on the heat island in the city of Singapore. They identified different land uses and analyzed their effect on the higher ambient temperature in the city. The corrected estimate of the trend in daily mean temperature due to land use changes is 0.35 °C per century (Kalnay & Cai, 2003). Shudo, Sugiyama, Yokoo, and Oka (1997) analyzed the connection between air temperature and land uses based on data collected in Hokkaido, a city in northern Japan. They concluded that throughout the year, urban areas had a warming effect of approximately 2.1 °C in their mean and minimum temperatures. The heat island effect is mainly due to the lack of greenery and the high level of solar radiation absorbed by the urban surface (Gago et al., 2013).

Remote sensing technology has brought to vision the new technique of estimating the temperature of land surface using satellite imageries. Assessing the urban thermal environment spatially is being used in recent years widely as the land surface temperature (LST) is highly correlated with the near-surface air temperature. The proportion of landscape types, such as water, vegetated, and impervious areas, is found to have an essential impact on the spatial variations of the LST (Matthew, Rao, & Mandla, 2014). Alipour, Sarajian, and Esmaeily (2010) have studied the land surface temperature (LST) estimation from thermal band of Landsat sensor using different techniques for the Alashtar City in Iran.

Studies conducted by Energy Department Administration in United States (2008) reveal that buildings in the United States contribute 38.9% of the nation's total carbon dioxide emissions, including 20.8% from the residential sector and 18.0% from the commercial sector. US EPA (U.S Environment Protection Agency) states that the annual mean air temperature of a city with 1 million people or more can be 1–3 °C warmer than its surroundings. Study by Cui and Shi (2012) shows that the growth of urban heat island (UHI) has been driven by the continuous increase of buildings, paved roads, buses, population, as well as the decrease of cultivated land. Urban materials properties, in particular solar reflectance, thermal emissivity, and heat capacity, also influence UHI development, as they determine how the sun's energy is reflected, emitted, and absorbed. Urban areas typically have surface materials, such as roofing and paving, which have a lower albedo than those in rural settings. As a result, built-up communities generally reflect less and absorb more of the sun's energy. This absorbed heat increases surface temperatures and contributes to the formation of surface and atmospheric UHI's. Many building materials, such as steel and stone, have higher heat capacities than rural materials, such as dry soil and sand. As a result, cities are typically more effective at storing the sun's energy as heat within their infrastructure. Building and street materials like tar, asphalt, brick generally have dark surfaces and thermal properties that cause them to absorb and hold heat during the day and release it during the night. Urban materials like concrete and asphalt rapidly absorb water and retain heat when they are exposed to solar radiation (Gago et al., 2013).

Spectral reflectance curves of building materials serves as a tool to understand and analyze the reflectance characteristics of solar radiation in different wavelength regions. Ezaty, Nasarudin, Zulhaidi, and Shafri (2011) conducted studies using hyperspectral data and field spectroradiometer to examine the spectral characteristics of urban materials to develop a spectral library of urban materials and demonstrate its application in remote sensing analysis of an urban environment. The study was mainly conducted for old and new roof materials in a specific region in the urban area of University Putra Malaysia. Mori, Iwata, Minami, Kato, and Akamatsu (2008) also examined the spectral response patterns of different materials like brick, concrete, asphalt etc. in Japan using high resolution datasets with the materials of each building known. Heiden, Segl, Roessner, and Kaufmann (2007) have conducted studies to identify the spectral features of urban materials in the German cities; the analysis was carried out based on confusion matrices method for each material obtained by classification results using hyperspectral satellite data. Kerekes, Strackerjan, and Salvaggio (2008) show the high resolution spectral reflectance and emissivity curves for man-made surfaces like asphalt, concrete, roofing shingles, and vehicles under varying amounts of sand and water; also hyperspectral data are used species identification (El-Magd & El-Zeiny, 2014; Tanushri, Swetha, & Mandla, 2013).

Two primary weather characteristics affect urban heat island development: wind and cloud cover. In general, urban heat islands form during periods of calm winds and clear skies, because these conditions maximize the amount of solar energy reaching urban surfaces and minimize the amount of heat that can be convected away. Conversely, strong winds and cloud cover suppress urban heat islands. The distribution of air temperatures corresponded to the distributions of humidity and surface temperature. The cooling area moves with the wind direction (Saito et al., 1991). Emmanuel and Kruger (2012) show that there will be differences between the temperature values recorded by different weather stations which were the result of local land cover/land use conditions. The presence of various land covers like forests, rivers, agricultural land, barren land etc. are also shown to influence the temperature distribution pattern along with wind direction.

It is very essential to know the factors which are enhance the urban heat island at the regional level. In order to address these kinds of questions this study attempted on how the influencing the building material and temperate anomalies in urban environment. Therefore, in the present study, the parameters like land use land cover, wind direction and building materials are taken into consideration to analyze its effect on the temperature distribution in the urban environment. Temperature measurements using satellite data are the base for the analysis purpose. The temperature distribution identification and the factors causing the urban heat islands are looked into here.

2. Study area and data's used

The present study is basically carried out in the Vellore district of Tamil Nadu, India. Among the different taluks of Vellore district, three are considered here namely Vellore, Gudiyattam and Vaniyambadi. Vellore also known as the Fort City, is at 12.92° N 79.13° E, 220 m above the mean sea level and lies 135 km west of the state capital Chennai (Fig. 1). The city has a semi-arid climate with high temperatures throughout the year and relatively low rainfall. Vellore lies in the Eastern Ghats region and Palar river basin. The topography is almost plain with slopes from west to east. It experiences hot and dry weather throughout the year. The temperature ranges from a maximum of 40.5 °C to a minimum of 18.4 °C. Like the rest of the state, April to June are the hottest months and December to January are the coldest. Vellore receives 996.7 mm of rainfall every year. The southwest monsoon, with an onset in June and lasting up to August, brings scanty rainfall. The bulk of the rainfall is received during the northeast monsoon in October, November and December. The humidity ranges from 40% to 63% during summer and 67% to 86% during winter (Vellore Municipal Corporation, 2011). According to the 2011 census, the taluk of Vellore had a population of 686,422 and the population of Vellore district as a whole was 3928106 (Provisional Population Totals – Tamil Nadu-Census 2011, Census Tamil Nadu).

The thermal band-11 of Landsat-8 satellite data obtained on 24th March 2014, with a spatial resolution of 30 m was used in this study to determine the temperature in the study area. Hyperspectral satellite data of 24th April 2010, comprising 220 narrow bands were used to obtain the spectral reflectance curves of building roof