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Analyzing control of respiratory particulate matter on Land Surface Temperature in local climatic zones of English Bazar Municipality and Surroundings

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ABSTRACT

Local climatic zone (LCZ), a systematic classification of internal urban morphology based on physical and thermal, radiative, land cover and geometric properties of the urban area, is identified in English Bazar Municipality and its surrounding region. Spatial land surface temperature (LST) and respiratory particulate matter (RPM) are also identified in each LCZ for characterizing the ecological milieu for living. It is also attempted to correlate RPM and LST in each LCZ for determining the impact of RPM on LST. Landsat satellite images, google earth images are employed for extracting LST, RPM and LCZ characters. Validation process using both ground control points, air temperature data and data from Pollution Control Board are applied for establishing the degree of sensitivity of the LCZ, LST and RPM models. Nine LCZs e.g. compact low-rise, open mid-rise, open low-rise, light weight low-rise etc. zones are recognized in this study area. Relatively high LST and RPM with significant spatio-seasonal variation is recognized in compact low-rise, open mid-rise, open low-rise, light weight low-rise and bare soil zones. Positive linear regression model with strong coefficient of determination (R^2) is identified between RPM and LST in the built up dominated LCZ ($R^2 > 0.8$).

1. Introduction

The studies of urban climate have long been concerned about the magnitude of the difference in observed air temperature as well as surface temperature between cities and their surrounding rural area, which is collectively known as the urban heat island (UHI) effect (Kim and Baik, 2005). This surface temperature can be both higher and more alterable than the ambient air temperatures due to the variation of urban morphology and its surface forms (Grover and Singh, 2015). The surface of urban area heats and cools more rapidly than atmosphere. Several studies on urban heat island have been conducted by different scholars and scientist over the world, but one of the earliest study was conducted by Nieuwolt (1966) in 1964 in Southern Singapore. Latterly, a host of scholars (Ogashawara and Brum Bastos, 2012; Grover and Singh, 2015; Pal and Ziaul, 2016; Wang and Ouyang, 2017) have investigated in this field emphasizing different cognitive issues. At the time of the investigation of UHI, several scholars and scientist have tried to identify the factors which control the UHI. As the artificial landscape substituted of natural landscape, the change of surface material quality has caused a series of changes in the surface radiation. These changes have collectively created an ambient state of urban heat island formation (Yue et al., 2007). Besides waste heat generated by factories, air conditioners and motor vehicles in the urban area contribute to the UHIs formation (Zhang et al., 2013) and intensification. Built-up areas consist of artificial impervious surfaces such

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as roads, buildings, pavements, parking lots etc. The pattern of LULC e.g. the composition of vegetation, water and built-up and their changes influence the intensity of UHI (Grover and Singh, 2015). The material composition, form, and configuration of the built environment directly influence the formation of heat island (Golany, 1996). In this present study area, English Bazar Municipality and its surroundings, Pal and Ziaul (2016) have carried out a work focusing changes of LULC and its impacts on surface temperature where they advocated that surface temperature changes significantly with changing LULC. Besides these above mentioned vectors, the present paper is also concerned with the quest that is there any other factors responsible for the changing temperature character in the urban area.

Atmospheric aerosols basically are the suspended particles in the air in the form of liquid or solid, originated from natural processes and human activities (Wong et al., 2009). Sharma et al. (2003) reported that in case of Indian cities aerosol (PM10) concentration ranges from 100 to 400 μg/m^3 exceeding the standard limit (100 μg/m^3) as defined by CPCB (2009). Sivertsen (2002) also documented that in Southeast Asia this amount ranges from 100 to 300 μg/m^3. Atmospheric aerosol is caused for air pollution (Dubey et al., 2012) and consequently, problem in human and ecosystem wellbeing (WHO, 2005; Nowak et al., 2013). Thus a host of the scholars have emphasized on the impact of respiratory particulate matter on human health (Ling et al., 2012; Teo, 2013). Shindell et al. (2012) and Lal et al. (2017) documented that air pollution in South Asia is caused for 1 million premature deaths and about 10 million tons of crop failure per year. But few of them (Amanollahi et al., 2013; Houghton et al., 2001; Lawrence and Lelieveld, 2010; Popoola et al., 2017) investigated the effects of respiratory particulate matter on earth's radiation balance as well as earth's climatic system. Lawrence and Lelieveld (2010) reported that in last two decades, South Asia has witnessed a fast rise of population, industrialization, urbanization and amount of energy consumption and all these together enhanced 2–6 fold increase of aerosols and other pollutants in the atmosphere. Aerosols have the important role in the earth's radiation balance by scattering and absorbing the solar energy (Yan et al., 2014). It also plays vital role in the changing face of the Earth's climatic system (IPCC, 2013) specifically aerosol optical thickness (AOT) (Liu et al., 2007), earth's radiation balance, photosynthesis character of the plants (Yan et al., 2014).

The concentration of primary aerosols depends upon their rate of emission, dispersion, transportation and removal from the atmosphere (US EPA, 1996). Scale of concentration of aerosols differs seasonally in Indian subcontinents because of the pattern of temperature, rainfall, wide speed, direction etc. (Mahapatra et al., 2017) Nature of heating of the atmosphere due the presence of aerosols is not uniform. Yu et al. (2002) asserted that absorption of heat through aerosols may heat up the atmosphere, as well as steady scattering of incoming radiation may enhance the cooling effect to the atmosphere. Intergovernmental Panel on Climate Change (IPCC, 2013) explained the feasible negative impact of aerosols on radiation, resulting in cooler surfaces (Houghton et al., 2001). Altitudinal concentration of aerosol within the atmosphere, density of the aerosol, composition, structure, size of aerosols, timing and duration of staying aerosols jointly affect the degree and direction of temperature change in the atmosphere (Mahapatra et al., 2017). Concentration of sulphate rich aerosols in the atmosphere enhances the atmospheric albedo and it consequently creates cooling effects (Charlson et al., 1992) and contrarily, black carbon rich aerosols significantly absorbs visible and infrared rays leading to the warming of the atmosphere (Ramanathan et al., 2001). Position of aerosol concentration (even black carbon) well above the surface may create cooling effect on earth's surface (Ramanathan et al., 2001). Aerosols can also indirectly regulate the cloud formation process, life span of a cloud, speed of condensation process (Heymsfield and McFarquhar, 2001). The effect of large size solid aerosols in most of the cases is highly localized and therefore, in a *meso* level town also, significant spatial variation of temperature is observed. With decreasing size of the aerosols its effect may be widespread (Popoola et al., 2017). A good number of statistical model centric studies on aerosol concentration in the atmosphere were conducted by many reputed scholars. Khodeir et al. (2012) used factor analysis, Otaru et al. (2013) used Gaussian predictive model, Holnicki and Nahorski (2013) exercised Gaussian puff dispersion and regional-scale transport models for air quality modeling. Along with statistical models, application of remote sensing data for measuring and predicting atmospheric aerosols is well illustrated and popularized by Xu et al. (2014), Sun et al. (2016) and Amanollahi et al. (2013).

Morphological unevenness in urban growth is vividly noticed in the cities and towns of developing nations. Parts of the area is extremely affluent comprising with high rise buildings, metallic thoroughfares, pavements, concrete and metallic building materials, tapered spacing, scarce open and green spaces and parts of the area are still underprivileged both in terms of economic progress and fabric of urban growth e.g. dwarf buildings composed with mud or semi-concrete materials, spacious building arrangement, wider open and green spaces (Song et al., 2014). Therefore, expectedly high local climatic (temperature, humidity, wind speed) variation is the outcome within the urban space (Yuan and Bauer, 2007). To capture this sort of local climatic variation, some comparable parameters are essential. Stewart and Oke (2012) designed a comparable topology for identifying local scale micro or *meso* levels urban landscapes. This scheme of classification is familiarly known as the local climatic zone (LCZ). This scheme is encompassed with 17 standard categories at the local scale. Each class is distinctive in its characteristics like surface structure (like building/tree height and spacing), cover (pervious fraction), fabric (albedo, thermal admittance) and metabolism (anthropogenic heat flux) (Stewart and Oke, 2014). Therefore, identification of local climatic zone (LCZ) effectively links the urban heat state with urban morphology and this sort of relation is very necessary for urban planning and urban renewal (Stewart and Oke, 2012).

English Bazar Municipality (EBM), a *meso* level town, is highly pressurized with dense population and vertical and horizontal urban growth. Growing concretization, traffic density, the sharp rise of metallic infrastructure, growing energy consumption, breaching of vegetated lands and water bodies are some of the major characteristics of this region (Pal and Ziaul, 2016). To accommodate excessive population vertical growth of the town, in the last 10 years, high rise residential and commercial buildings have been increased significantly. At present total number of such mid-rise apartments in this town are 91(Ziaul and Pal, 2016). Total study area covers 5465.43 ha (100 ha = 1 km^2) comprising both urban mainland and surrounding suburban region (Fig. 1). The climate of this region is characterized by the sub-tropical monsoon with seasonal wet and dry spell of rainfall, cold and hot spell of temperature. Four seasons i.e. (1) winter season (January and February), (2) Pre monsoon season or summer (March to May) with