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A comparative study for the indentification of Factors, Causes and Effects on the variation of surface temperature distribution in Pune City

THINK GLOBAL & ACT LOCAL

TERRE magazine for youth

INKING INNOVATIONS
ISBN : 978-81-930643-7-5

March 2016, Vol 3 | Issue 1

TERRE Policy Centre
Technology, Education, Research and Rehabilitation for the Environment
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Abstract:

Urbanization has become the universal trend which turn out to be the imperative aspect of climate change in 21st century. Changes in surface temperature is one of the significanteffectthat results from anthropogenic activities and urban growth due to the drastic changes in land use and land cover. This study tries to investigate the changes in temperature distribution and its causal factors in the city to excerpt the measures for avoiding the greenhouse effect contribution and severe heat island effects. The surface temperature of Pune city is calculated using Erdas model maker and a comparative study of Pune city has been carried out using Landsat 5 image of 2001 and Landsat 8 image of 2015 from USGS (United States Geological Survey). The analysis showed that the temperature variation has changed from 16-370C to 28-480C within a span of 15 years with less temperature in waterbodies, thick vegetated areas and high in urban barren and stone mining quarries. The loss of vegetation cover, unregulated urban sprawl, increase in the number of roads and emerging mining quarries are responsible for the rise in surface temperature around Pune city.

Keywords:

Urbanization, Surface Temperature, Climate Change, Pune, Landsat.

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Introduction:

Urbanization generates huge social, economic and environmental changes, which provide a chance for sustainability with pressure for the wise use of resources with more efficiently, to mold more sustainable land use and to protect the biodiversity of natural ecosystems. In cities, where there is less vegetation cover and open soil most of the solar energy is instead absorbed by buildings and asphalt leading to higher surface temperatures. Vehicles, factories and industrial and domestic heating and cooling units release even more heat. The modification of land surfaces in urban areas are the mainsource of surface temperature rise. The materials which use for the modification can effectively store short-wave radiation. Built surfaces are composed of high percentage of water resistant and non-reflective construction materials. So they tend to absorb a significant proportion of the incident radiation which released as heat. High surface temperature effect inhibits atmospheric cooling due to horizontal air circulation generated by the temperature gradient between urbanized and urbanized areas. A number of factors contribute to the occurrence and intensity of surface temperature; these include; weather particularly wind and cloud, geography, time of day/season, city form, city functions. The climate modifications that have occurred in large cities over the past century show similarities in terms of the rates and magnitude expected with projected future climate changes.

Data and Methods :

The methodology used for the identification of surface temperature distribution across the city of Pune is preparing the surface temperature map using Landsat 5and Landsat 8 satellite imagesprovided by United States Geological Survey (USGS).

Steps to make the surface temperature map

a) DN to Radiance conversion of Landsat 5 image

The equation used in Erdas model maker tool for DN to radiance conversion is:

$$L = LMIN + (LMAX - LMIN) * DN / 255 \qquad \text{--- (1)}$$

L = Spectral radiance, *LMIN = 1.238 (Spectral radiance of DN value 1)*

LMAX = 15.600 (Spectral radiance of DN value 255), *DN = Digital Number*

b) Conversion of Radiance to Temperature in Celsius

$$T_c = \frac{K_2}{\ln\left(\frac{K_1}{L} + 1\right)} - (273)$$

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ISBN : 978-93-85311-04- 8
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K1= Calibration Constant 1 (607.76) *K2 = Calibration Constant 2 (1260.56)*

Tc = Surface Temperature in Celsius

c) Calculation of surface temperature

The temperature in Celsius is then opened in ArcMap software for making the surface temperature map of Landsat 5.

i. DN to Radiance conversion of Landsat 8 image

The Landsat 8 image is converted to radiance value using the equation by creating a model maker using model maker tool in Erdas software.The equation used for DN to radiance conversion which is applicable to both band 10 and band 11 of Landsat 8 is:

$$L = 0.0003342\ (DN) + 0.1 \qquad \text{--- (3)}$$

Where

L = Spectral radiance

Radiance Mult Band 10 & Band 11= 0.0003342 (Spectral Radiance of DN value at 1)

Radiance Add Band 10 & Band 11 = 0.1 (Spectral radiance of DN value 65536)

ii. Conversion of Radiance to Temperature in Celsius

The radiance value calculated above using the equation (3) is then converted to temperature using the thermal constants provided in the metadata file:

$$T_c = \frac{K_2}{\ln\left(\frac{K_1}{L} + 1\right)}$$

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Where

K1= Calibration Constant 1 *K2 = Calibration Constant 2*

K1 of band 10: 774.8853 *K2 of band 10: 1321.0789*

K1 of band 11: 480.8883 *K2 of band 11: 1201.1442*

iii. Calculation of average surface temperature

Band 10 and Band 11 are the two bands in Landsat 8 for surface temperature. So it is necessary to calculate the surface temperature of both bands separately and took average of those two bands to get the final surface temperature and surface temperature map of Landsat 8 in ArcMap.

Comparison of temperature distribution

The surface temperature of 2001 is made by using Landsat 5 image and that for 2015 is by using Landsat 8 image. Landsat 8 image is performed resolution image process to enhance the spatial properties and become the same resolution of Landsat 5 TM using Resolution Merge tool of Erdas software to make the comparison possible.

Results and Analysis :

The surface temperature distribution in May 2001 is from 160Cto370C(Fig -1) and in April 2015 from 280C to 460C (Fig -2).The temperature distribution is classified into seven categories; Very low, Low, Low to Moderate, Moderate, Moderate to High, High and Very High.

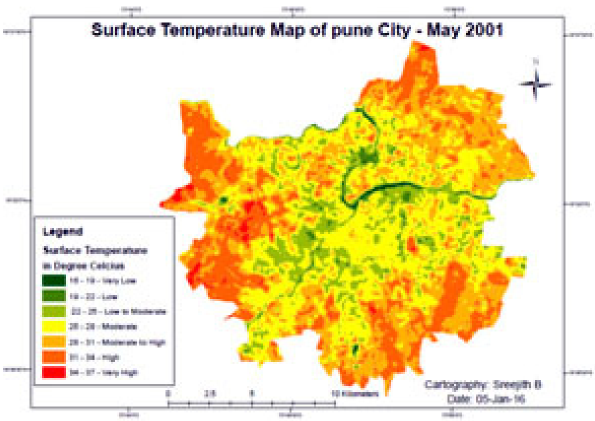

Fig - 1: Surface Temperature distribution of Pune in May 2001

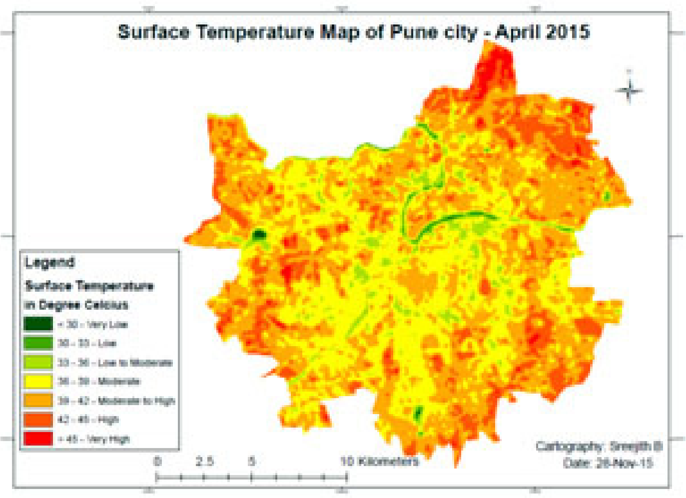

Fig - 2: Surface Temperature distribution of Pune in April 2015

In 2001 the areas coming under lower temperatures - 160C to 220Care waterbodies, Low temperature 220C to 250C are residential areas with thick vegetation cover, Low to moderate temperature 250C to 280C are residential areas with moderate vegetation, Moderate temperature 280C to 310C are residential areas with low vegetation and High temperatures from 310C to 370C are areas with no vegetation cover and highly exposed to sun includes barren lands and mining areas. In 2015 the areas are same but the temperature distribution is from 280C to 470C. In 2001 the lowest temperature was 160C but in 2015 it was 280C. Likewise the highest temperature was 370C and in 2001 andincreased up to 470C in 2015.

Comparison of surface temperature distribution

The temperature distribution of both the years were reclassified into same resolution and made possible for comparison. The new five categories includes temperature less than 280C as very low, 280C to 310C as low, 310C to 340C as moderate, 340C to 370C as high and temperature higher than 370C as very high. The temperature less than 280C is concentrated in the central areas of the city in 2001 but in 2015 the same areas were experienced the temperature from 280C to 340C. The high temperature is experienced always towards the boundary of the city. The trend of temperature distribution is from the centre of the city to the boundary of the city and in an increasing trend. The following maps (Fig - 4 and Fig - 5) and table (T - 1) are showing the scenario in which the temperature rise in the same city within short span of 15 years.

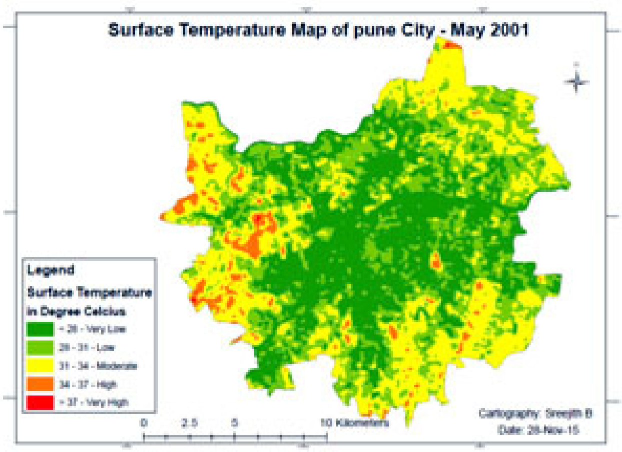

Fig - 4: Reclassified surface temperature-distribution of May 2001

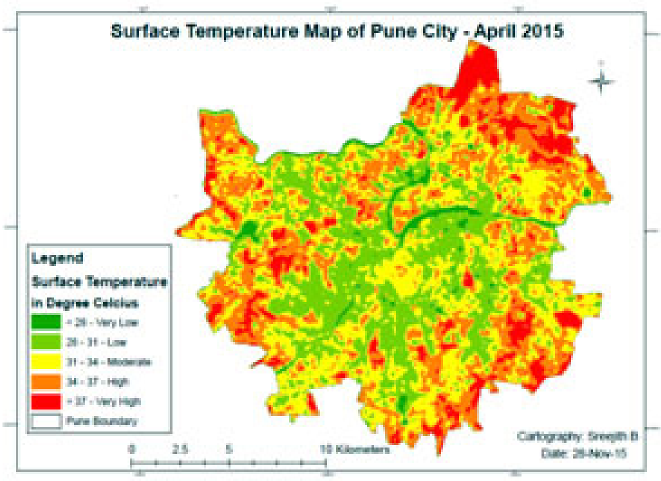

Fig - 5: Reclassified surface temperature distribution of May 2015

Table of surface temperature distribution in Pune

Temperature Range	***Zone***	***Analysis***
Less than 280C	*Waterbody*	*Presence of deep water and vegetation along the banks*
280C - 310C	*Residential areas with thick vegetation cover*	*Green cover is managed and maintained properly*
310C - 340C	*Residential areas with moderate vegetative cover*	*Increased urban settlements (built-up areas)*
340C -370C	*Commercial zone Industrial zone*	*Anthropogenic exhaustion from buildings and vehicles*
Higher than 370C	*Barren Lands Mining Quarries*	*Highly exposed to sun*

T-1 – Analysis of temperature distribution

Discussion

Climate change has become one of the present hot topic of the globe and surface temperature is one of the inevitable part of it. So it is important to the find the root causes and factors for the rise in temperature distribution with its effects and mitigation measures. In the city of Pune the rise in surface temperature has affected the consumption of electrical energy as well as air conditioners which are again making problems like CHG gas emissions. Lack of vegetation and decrease of vegetation cover day by day affected human health as well as wind flow. The areas having thick vegetation can experience the cooling effect of atmosphere with proper winds in areas like Koregaon Park, Prabhat Nagar etc. During summer lot of people are used to get sun burn and related heat sicknesses.

According to Memon et al., (2009) the generation of surface temperature and urban heat was caused by anthropogenic heat from heat re-radiated and stored in the urban structure, vehicles and their emission, air conditioners and power plant. Uncontrolled factors are mainly weather parameters such as diurnal conditions, seasons, cloud cover, wind speed and anticyclone conditions. Controllable factors are divided into population related factors and urban designed related factors.

ISBN : 978-93-85311-04- 8

The vegetation cover has an inevitable influence on the thermal performance of urban buildings and the modification of the urban climate. Plants can function as a solar barrier that prevents solar radiation absorption. So the high temperatures that appear are essentially lower with the richness of plant-coverage buildings (Eumorfopoulou EA, Kontoleon KJ, 2009).A reduction of 10% in green roofs in an area can result in an increase of 70C to 8.20C surface temperature in 2080s under high emission (Gill SEet al., 1978). The studies related to urban parks resulted the existence of such parks had an effect on the air temperature of the surrounding built up.

The factors which affecting surface temperature in Pune are different than other studies and study areas due to the difference in city structure and city functions are mainly urban sprawl, vegetation cover, increased number of asphalt and cement roads, human settlements and buildings, barren lands and stone quarries. Urban sprawl is happening due to the increase in population the people are supposed to go for low density areas which finally turns into the rise of high buildings and roads. The vegetation cover in the centre of the city is good compared to the boundary areas due to the presence of public gardens, residential areas with thick and moderate vegetation cover, roads with thick canopy due to the presence of old trees etc. The lack of vegetation in the boundary results the lands to turn into barren lands. As barren lands are highly exposed to sun the temperature is always high throughout the day and it remains at night also resulted in high surface temperature causative factor. Also presence of rocky escarpments and especially stone mining quarries are also play an inevitable role in surface temperature.

Green roofs can replace the vegetated footprint which was damaged while constructing the building. Intensive green roofs involve intense maintenance and include shrubs, trees, and deeper planting medium. Extensive green roofs have less maintenance and usually consist of shallower soil media, different plants such as herbs, grasses, mosses, and drought tolerant succulents (Getter KL and Rowe DB, 2006). Plants absorb a significant amount of solar radiation for their growth and biological functions, functioning as a solar barrier that prevents solar radiation absorption extensively and can improve the microclimate of the built environment.

The possible mitigation measures for the rise in surface temperature in Pune include; the presence of garden and other green spaces in the city can cool the environment than the surrounding areas. The cooling effect of green spaces can be enhanced the surrounding by supplementary methods related to the urban features. So maintenance and improvement of parks and green spaces, construction of large-scale greenbelts are very important. The greening of building rooftops and walls can adopt as a method for controlling the surface temperature. Like in ground, the plants can also give cooling effects to the building surfaces.Application of light colored paint to exterior walls. So that the walls would not absorbing much heat inside in daytime and release the heat outside at night. Use of reflective roofing materials also a considerable solution for mitigating surface temperature. Along with that *control of building exhaust heat at the regional levels should be practice.*

Acknowledgement

I am very grateful to Mr. Mahesh Kulkarni, Dr. Shamita Kumar, Dr. Kranti Yardi and Dr. Erach Bharucha (Director, BVIEER) and Ms. Prachi Dev for their guidance, supervision, suggestions and continual inspiration.I would like to record my sincere thanks to my colleagues and parents for their co-operation and support for helping me in designing of my work.

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