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RESEARCH ARTICLE

Measuring the relationship of land use land cover, normalized difference vegetation index and land surface temperature in influencing the urban microclimate in northeast Delhi, India

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Abstract

Urbanisation is a process for conversion of spaces into build up areas, long-term conversions led to shrinkage of open lands to unplanned growth for residential areas or commercial purposes to accommodate the increasing population. Open green spaces and parks have strategic role in regulate the urban environment and mitigate the effect of urban heat island (UHI). Also, its spatial arrangement in an area impacts the surface heating so their spatial distribution within the residential sectors, has become an integral part of sustainable development for the city. They have direct socio-cultural and health benefits by providing spaces for physical activity, social interaction, and fresh air, which depends upon the accessibility, quality, attractiveness, and regularity of people using it. In North East Delhi district, distribution of parks shows huge disparity between planned and unplanned residential areas which is impacting the surface temperature and micro climate. A quantitative analysis is used with geo-informatics-based indexes of biophysical parameters for parks, vegetation quality Normalized Difference Vegetation Index (NDVI) and land surface temperature distribution (LST) with the land use pattern for accessing the impact of parks on mitigating the heat island effect. The result obtained from analysis shows a negative relation between the LST and NDVI. The unplanned regions have big parks with negative NDVI values (-0.04) lacking vegetation cover and are poorly maintained and accessed by many people, on the other hand the parks with NDVI values (0.12) are well distributed in planned colonies and maintained. Maximum of the existing parks is below 10 km^2 area and has poor quality. This study shows healthy vegetation in parks is important for wellbeing of the city rather than merely open spaces.

Keywords: Urban parks, Planned and unplanned areas, Vegetation index, Land surface temperature, Micro-climate.

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Introduction

Urbanization is a process where the population concentration increased in a localized area (Roberts and Kanaley, 2006; Seto *et al.* 2010, 2012). The population in urban areas is increased in leaps and bounds. It has already been predicted that around 70% of population will be living in urban areas by 2050. The fastest increase in population is occurring among few megacities, housing over 20 million inhabitants and located mostly in developing countries (United Nation 2012). This exponential growth leads to an unparallel challenges in sustainable development of cities, the urban green spaces are among those urban resources which can be utilized for planning sustainable development within cities (Breuste, 2002; Currie and Bass, 2005; Fang and Ling, 2003). These green spaces are input component of urban ecosystem and help to keep urban life healthy. The access to the green spaces to the city inhabitants helps to reduce health inequalities, improve wellbeing, aid in treatment of mental depression and provides a platform for social cohesion (Chiesura, 2004; Shanahan *et al.* 2015, 2015; Fang and Ling, 2003). It has been estimated by WHO that around 3.2 million deaths per year due to physical inactivity is estimated as being a cause of breast and colon cancer, 27% of diabetes and 30% of ischemic

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heart disease so parks have a very distinct place in urban lifestyle (WHO, 2010). Sustainable development is merely not a societal change rather it was a great falsification of lifestyle in any defined environment (White *et al.*, 2016; Mitchel, 2013; Jennings *et al.*, 2016). The newly adopted SDGs 2030 goals focus on the sustainable urban development, with SDG 11 solely dedicated to the cities and human settlements and the others are SDG 9 and SDG 16 which emphasis to develop a model which along with urbanization, development can also give its citizens a healthy life.

The green spaces on the earth is the single matter which acts as sinks of CO_2, these spaces have been increasingly considered in urban planning as the components for the sustainable development of cities (Santamouris,2001; Li *et al.* 2013; Park *et al.*, 2016; Wolch *et al.*, 2014). These green spaces play a interruption in continuous heat island formation in moderates the micro-climate of urban areas and regulates the thermal behavior in extreme summers (Chang *et al.*, 2014; Akpinar *et al.*, 2016; Chen *et al.*, 2012; Shashua and Hoffman,2000; Santamouris,2001). As a result, there are many environmental scientists are continuously studying the neutralizing effect of thermal islands using green spaces in various region (Choi *et al.,* 2014; Chang *et al.*, 2014; Shashua and Hoffman, 2000; Hamada and Ohta 2010; Susca *et al.*, 2011). To achieve the goals of sustainable development for city, it is important to analyses the quality of the vegetation and the horizontal distribution of urban heat generation, the relation between these two parameters is important to maintain a healthy wellbeing in cities. For the purpose land use and cover change study become important along with the distribution of urban parks and spaces to mitigate the UHI effect specially in metropolitan city where the availability of green and open space is big issue also the mapping and the distribution of the parks help city planners to prepare the city resilience to climate change.

Regardless of the economic status of the country worldwide, many countries cities are facing one of the most important challenges that is satisfactory development of sustainable cities. There are many approaches applied to study the interrelationship of urban green spaces and climate for the analysis of human well-being and comfort. The remote sensing-based quantification of the various biophysical parameter normalized difference vegetation index (NDVI) and land surface temperature (LST) status of each park can contribute to a potential solution to the local environmental sustainability. In Chicago it has been studied that the increase in tree cover reduces the 10 % of the heat generated by the core of the city. The quality of the vegetation in park drastically reduces the amount of pollutants as vegetation directly trap them reduces the air pollution by 85% and noise.

Here an attempt has been made to determine and evaluate the spatial pattern of the existing green areas in residential and non-residential areas for analyzing the social impact of urban parks. NDVI values of urban parks were used as the ecological indicator where the vegetation cover, size of the park, and temporal growth rates of these parks with different size in North East Delhi were determined by using remote sensing application. Although the total vegetated areas in the parks were less than total park area layouts, this expression is not enough to discuss the efficiency of the parks in terms of vegetation quantity and quality its not important how green we see parks but vegetation condition is also important. Therefore, it is the core study of this paper to analyses the vegetation cover amount in planned and unplanned residential colony which should be taken under consideration for temporal and spatial distribution in determining and evaluating along with monitoring of urban parks. NDVI and LST are important indicators to compare the effects of ecological values of different parks. The north-eastern part of the Delhi one of the congested areas in Delhi and can fine both condition of planned and unplanned growth of urban areas. The planned region has well demarcated parks with good green coverage; on the other hand, the unplanned areas have small or no parks. This difference has a huge impact on the social wellbeing of people in this area.

Materials and Methods

Study Area

The study area is the North-east district of Delhi which is geographically situated between latitude 76.21 °N to 77.32°N and longitude 28.67°E to 28.78° E (Figure 1). The study area is one of the most populated districts of Delhi with and area of 62 km^2 and population density of 3,6155/km^2. District statistical report demarcates the district as highly urbanized with 92% of its population marked as urban. It is well connected to the rest of Delhi and NCR through roads and Delhi metro. The urban land except giving place to live, provide a place to recreation for healthier life. With this increase in population the green spaces are squeezing with increasing built up area. The region has two distinct characteristics, the Northern region is unplanned and densely populated, where hardly anyone can spot parks, on the other hand the southern part has planned colonies where there are well demarcated green areas as parks.

Data

Landsat 8 (OLI) and 7 for the year 2020 and 1996, respectively, with a resolution of 30 m has been used for the month of October. The detail for the imagery has been given in Table 2. The thermal bands are used for the calculation of LST by using mono window method and vegetation health has been deducted from NDVI. Figure 2 gives the details of methodology followed for the study.

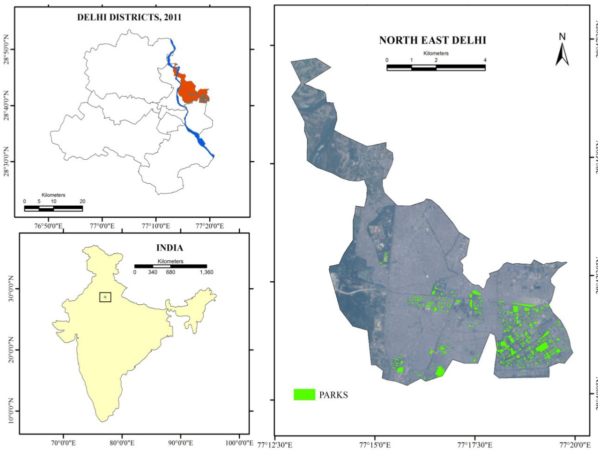

Figure 1: Study area

Land Use Land Cover Mapping

A supervised classification method has been used for land use/cover mapping using ERDAS 14 to identify the vegetated areas. Visual interpretation with Google map and ground data using GPS has been used to distinguish between the parks and vegetation. The land use has been categorized into five classes based on field visit to study area residential complexes as planned residential areas, unplanned residential area, river as water body, vegetation included mainly the parks vegetation cover and the last category of bare or open land. The kappa accuracy for the land use and land cover mapping was 97%.

Normalised Difference Vegetation Index

The NDVI is very well-known vegetation index to study the vegetation condition. It is remote sensing based normalised index. The range varies from -1 to +1, it depicts every positive value for vegetated areas and negative value for area where there is no vegetation. Based on the other literature it has been concluded that the NDVI spectral signature values for the areas of barren rocks, sand and urban shows 0.01 to negative 1, sparse vegetation such as shrubs and grasslands or cropped area shows moderate values of NDVI approximately positive 0.2 to 0.5, the dense vegetation found is temperate and tropical forest or any other area shows high positive values like 0.6 to 0.9, where the vegetation is at its peak growth stage. The NDVI is calculated using Eq 1

$$\mathbf{NDVI} = \frac{(\mathbf{NIR}-\mathbf{RED})}{(\mathbf{NIR}+\mathbf{RED})} \quad \text{...Eq. 1}$$

For the study area, the proposed emissivity values for NDVI area that is the values of NDVI less than (<) 0.2 are bare soil, <0.2 and<0.5 are mixture of bare soil, vegetation and hard surfaces and more than > 0.5 are fully vegetated.

For the purpose of analysing role of the parks which includes vegetation quality of the parks, the regulating impact on land surface temperature thereby influencing the microclimate of the region; in the study area, 552 parks were digitised from Google earth and surveyed.

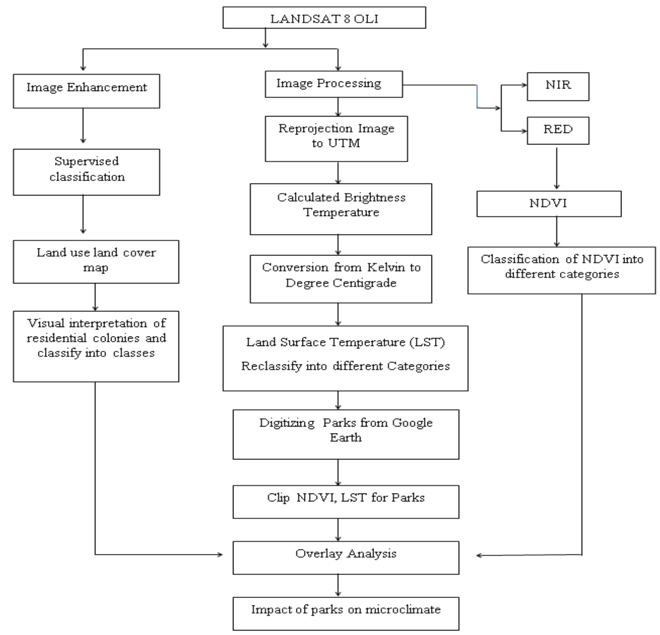

Figure 2: Workflow chart

Land Surface Temperature

For the purpose of Land surface temperature thermal band 10 of LANDSAT 8 has been used for calculating reflectance and top of the atmosphere brightness temperature referred by USGS hand book (5 ref.). The digital numbers (DN) values are converted to top of the atmosphere brightness temperature as given by USGS handbook LANDSAT 8.

The DN is converted in reflectance (Eq. 2) and then to temperature (Eq. 3). The output map give temperature in Kelvin which here has been converted to degree centigrade (Eq. 4)

$$\mathbf{L\lambda} = \mathbf{ML} * \mathbf{Qcal} + \mathbf{AL} \quad \text{...Eq. 2}$$

where:

L_λ = Spectral radiance (W/(m2 * sr * µm)) M_L = Radiance multiplicative scaling factor for the band (RADIANCE_MULT_BAND_n from the metadata). A_L = Radiance additive scaling factor for the band (RADIANCE_ADD_BAND_n from the metadata). Q_{cal} = L1 pixel value in DN

TIRS data can also be converted from spectral radiance (as described above) to brightness temperature, which is the effective temperature viewed by the satellite under an assumption of unity emissivity.

The conversion formula is as follows:

$$\boldsymbol{T} = \frac{\mathbf{K2}}{\mathbf{ln}\left(\frac{\mathbf{k1}}{\mathbf{L\lambda}}\right)} + \mathbf{1} \quad \text{...Eq. 3}$$

where:

T = OA Brightness temperature, in Kelvin.L_λ = Spectral radiance (Watts/(m^{2*} sr * µm)) K1 = Thermal conversion constant for the band (K1_CONSTANT_BAND_n from the metadata) K2 =Thermal conversion constant for the band (K2_CONSTANT_BAND_n from the metadata)

Temp °K - 273.15 = °C ... Eq. 4

Images are processed in units of absolute radiance using 32-bit floating-point calculations. These values are then converted to 16-bit integer values in the finished level-1 product. These values can then be converted to spectral radiance using the radiance scaling factors provided in the metadata file.

The regression analysis has been applied to understand the strength and degree of relation between vegetation on land surface temperature, (NDVI and LST). In the regression equation models parks are the independent variables and LST is dependent variable.

Results

In north east Delhi, considering the land use and land cover change the western part is most developed in terms of residential area in terms of urban area than the eastern side. Eastern area is more vegetated than the western part. In few pockets near Yamuna there is cultivated land where the other green patch is Sonia Vihar forested area and state protected forest area which can be observed in (Figure 3). Based on the statistical relationship between the two biophysical parameters, it is determined that NDVI and LST is inversely related to each other, means the more the good quality of vegetation there will be low surface temperature than the build-up area, so the presence of vegetation somewhere limits the temperature increase. With refer to the land use and land cover map (Figure 3) it can be observed that highest temperature (Figure 4) ranging from 30 to 36°C is in pockets over the unplanned densely built-up area and around the bare sand beds, whereas the lowest temperature is over the parks and river area where the range goes 26 to 29°C. The urban areas are mainly constituted of concrete and cemented material which reflects heat has the temperature range between 31 to 32ºC. From comparing the two maps (Figures 4 and 5) NDVI and LST it is observed that the temperature in urban area is mainly regulated by the presence of vegetation, this difference can be easily spotted between the central and southern part of the North-East Delhi (Table 4).

The south of this district has more parks than rest of the area, this presence of parks shows decline of 1ºC from it adjoin area where there is minimum to no existence of green area. The above statements can be evident with statistically with correlation and regression, the NDVI and LST correlation matrix (Figure 6) showing perfectly negative correlation of (-) 0.88, which clarifies with every increase in NDVI value the LST reduces so, it can be concluded that the green parks help in eliminating the increasing temperature effect. On the other hand, the regression analysis show, the same trend within variables, the negative dependency of variable when surface temperature is dependent on NDVI. With every increase in NDVI values the LST is decreasing. So, it is important to

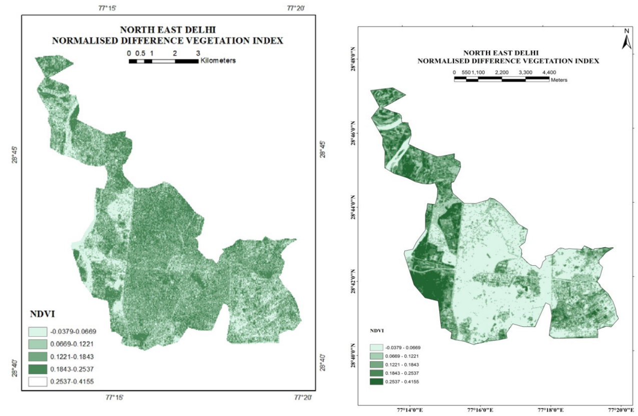

Figure 4: NDVI 1996 and 2020

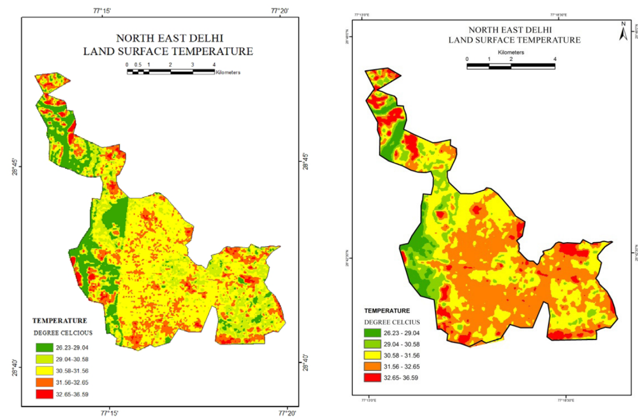

Figure 5: Land surface temperature 1996 and 2020

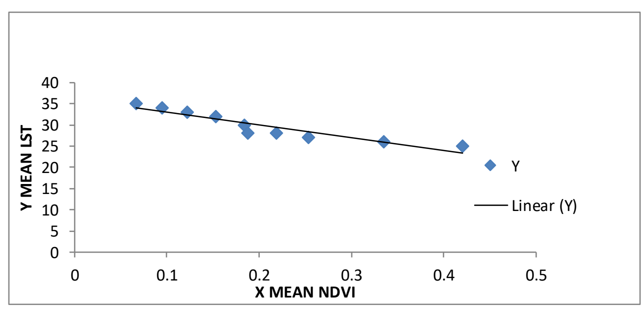

Figure 6: Negative relation dependency between LST and NDVI.

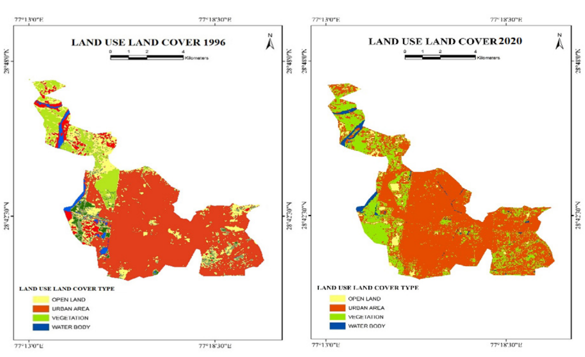

Figure 3: Land use land cover map

Table 1: Land use change in North East Delhi 1996 and 2020

Classes	*1996*		*2020*	
Land use classes	area km ²	%area	area km ²	%area
Open land	12.2	19.69	8.8	14.12
Urban land	30.3	48.87	37.2	59.6
Vegetation	10.7	17.25	12.5	20.18
Water body	8.8	14.19	3.5	6.1
Total	62	100	62	100
NDVI change in area				
	1996		*2020*	
NDVI classes	area km ²	%area	area km ²	%area
Good	0.01	0.02	3.49	5.63
Moderate	11.6	18.71	5.36	8.65
Low/No vegetation	50.39	81.27	53.15	85.73
Total	62		62	
LST change in area				
	1996		*2020*	
LST classes	area km ²	%area	area km ²	%area
above 30˚C	21.49	34.66	28.87	46.56
29–30˚C	14.87	23.98	14.37	23.18
28–29˚C	8.97	14.47	18.76	30.26
below 28˚C	16.67			
Total	162		62	

Table 2: Percentage of parks under various NDVI range

NDVI range	*No. of parks*	*% of parks*	*Vegetation condition*
0.066–0.136	83	15.90	Poor
0.136–0.206	247	47.31	Poor
0.206–0.276	161	30.84	Moderate
0.276–0.345	30	5.74	Good
0.345–0.415	1	0.19	Good

Source: Computed by authors

Table 3: Percentage of parks under various surface temperature range

Land surface temp (°C)	*No. of parks*	*% of parks*
Below 29.42	37	7.09
29.42–31.21	334	63.98
31.21–33.01	110	21.07
33.01–34.80	40	7.66
Above 34.80	1	0.19

Source: Computed by authors

maintain this greenery to sooth the microclimate of urban area for healthy living. (Figure 6) shows few dominant green parks of the study area which act as urban cool islands and shows that the existence of vegetation in parks and the size of park is directly related to the low range of temperature and diluting the heat generated from built up land. This depicts the role of parks in to reduce the urban heat effect by cooling the microclimate due to the presence of vegetation.

Discussion

In detailed study of parks from Figure 7 it shows the distribution of NDVI and LST over the parks based on the areal coverage of parks. There are few parks which are big having an area of more than 40,000 sq. m shows elevated temperature of 35 °C, on the other hand the parks below 10,000 sq. m which are 482 in numbers has temperature of 30 ºC. this because the small parks are well maintained than the big parks, also the big parks show bare surfaces which is evident from (the LULC map) than the small parks, the big parks are accessed by much of the population as playground purpose, so there is the less development of grass and vegetation (Table 2 and 3).

Table 2 shows percentage of parks under various NDVI ranges which states the condition of green vegetation of parks. Around 63% of the parks are not in good state based on remote sensing derived vegetation index ranging from 0.06 to 0.2 which states the vegetation is not there, it is mainly reflect the NIR Soils generally exhibit a near-infrared spectral reflectance somewhat larger than the red, and thus tend to also generate rather small positive NDVI values (say 0.1–0.2) rest 37% are from moderate to good state. This shows values from 0.2 to 0.4 moderate to good values represent shrub and grassland and few dense trees with good canopy cover.

Only 7% of the parks irrespective of its size has the lowest range of temperature from 27 to 29°C in north East Delhi district rest 93% parks are having temperature more than 30ºC which shows the degraded quality of parks and more bare surfaces than vegetation cover. Presence of the parks compromises the effects of temperature in region but the temperature in each individual park is not very soothing.

If we consider the health of the parks categorized based on area, most of the parks in north east Delhi district are of less than 10,000 sq. meters which constitute of total 482 numbers of parks and are of poor quality with the minimum average temperature of 30°C. There are 26 numbers of parks of area ranging from 10000 to 20000sq m. There are few big parks only 7 of area more than 50,000 sq m, though all has average temperature between 34 to 35°C.The big parks are mostly of poor condition as mostly left bare for playground purpose without any vegetation cover, less maintained used by mainly low-income group people and surrounded by unplanned residential area. According to Tables 1-4 the change in land use land cover, LST and NDVI shows that if relate the changes in area of LULC, NDVI and LST, it is evident that though there is minor increase in vegetation cover by 3% and urban area increased by around 11% in the same manner if we see the LST changes in area the area above 30°C increased by 12% and there is no area exists below 28°C after

Table 4: Microclimatic influence of parks

SN	*Location of parks*	*NDVI range*	*LST(°c) range*
a	Unplanned residential with no parks	-0.04	32.65
b	Planned residential areas with parks	0.07	31.56
c	Planned residential areas with proximity to parks	0.12	30.58
d	Parks with normal green	0.18	29.04
e	Parks with rich green	0.25	26.23
f	River yamuna flood plain farms/other farms	0.25	26.23

Source: Computed by authors

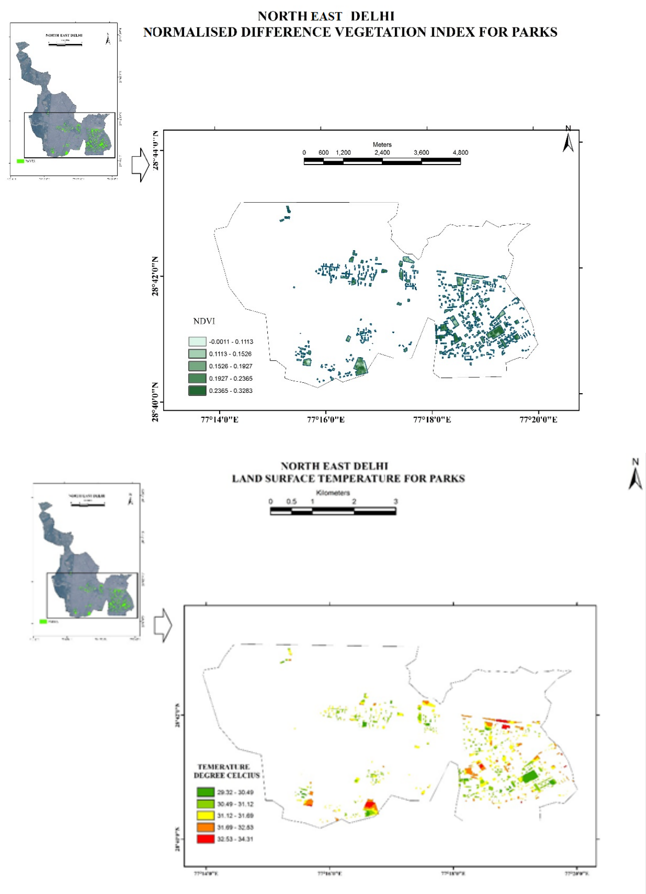

Figure 7: NDVI and LST in parks

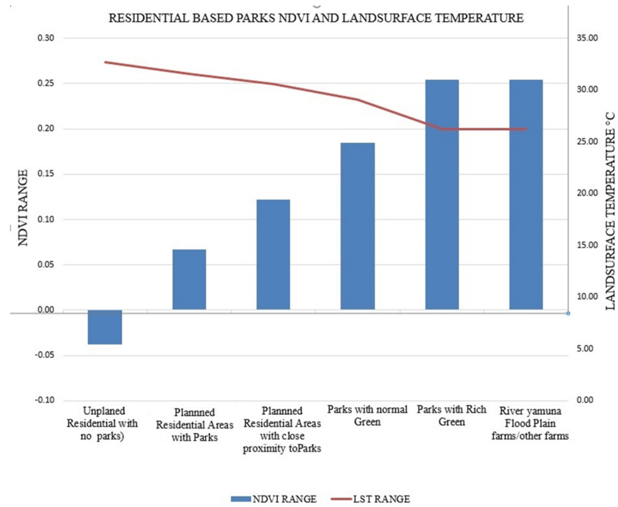

Figure 8: NDVI and LST under various residential conditions

2 decades. Similarly, the changes in NDVI the good quality vegetated area increased by around 5% and the are under no vegetation also increased by 5%.

Considering North-East Delhi area based on distribution of parks under various residential condition the NDVI and LST values shows a different story. As seen in Figure 8, unplanned residential with no parks located with high temperature in the particular region with negative NDVI shows is no vegetation. Planned residential areas with parks, though the NDVI values are not very high (0.07) only existence of shrubs and grasses, the parks vegetation quality is not good still it effects the temperature of the area because of the presence of parks in cohesion. Region where parks are at proximity to planned residential area and big, with high NDVI values depicting existence of no dense vegetation but a mixed area of few big trees and shrubs and grasses helps to reduces the temperature of surrounding. This shows drop of around 5°C temperature from rest of the area (maximum temp 35°C). Parks with normal to high NDVI values (0.25) includes the protect forest area near Sonia Vihar and other vegetated area and agricultural region in Yamuna flood plain has the lowest temperature of the region of 26°C (Table 4).

The relationship between the NDVI range of parks and land surface temperature of residential colonies under various residential types is seen in (Figure 9). This graph shows that the unplanned residential localities where there's no green space or parks are the most affected by the urban heat, also as the NDVI range increases from planned residential areas where there has provision for green parks to the lush green agricultural land towards Yamuna bed the intensity of urban heat is reduced, somehow it depicts the importance of existence of green parks in various residential type rather than existence of vegetation in the area.

It is evident that the area is densely populated with few patches of greens and of immense important to study the sustainably of cities through green area is of concern for today's urban health in cities, the parks and the open vegetation land are principal areas for recreation and cells for maintain the urban heat generating from concreted surfaces. The vegetation health of the parks is shown here to indicate towards the relationship between green cover and the surrounding heating combat mechanism of nature. In Figure 9 some individual large size parks are displayed with the analysis emphasizing that the quality of vegetation

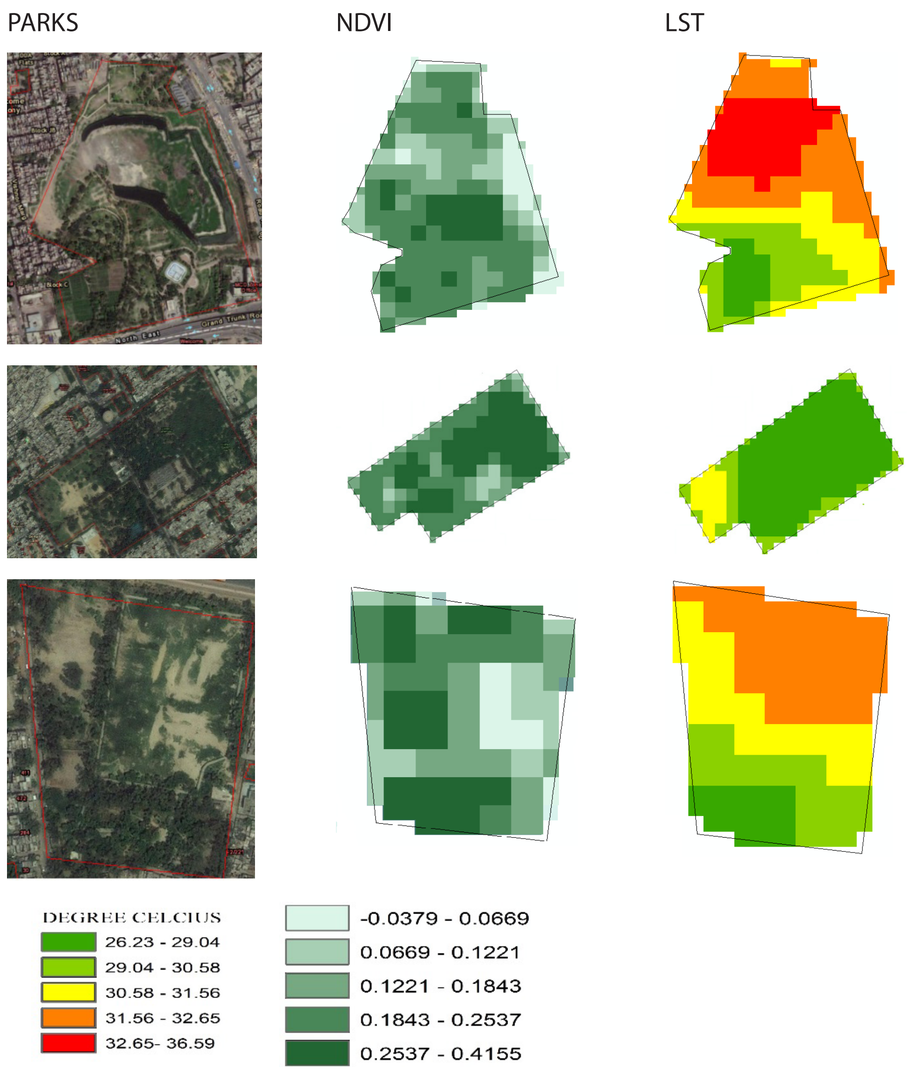

Figure 9: Comparison of some sampled park's vegetation quality using LST and NDVI

cover even within a park leads to differences in the land surface temperature.

Conclusion

Remote sensing-based analysis of two biophysical parameters for parks, LST and NDVI, which considered being important for the study of social wellbeing for the society as mitigating the heat island taking into account already increasing temperature in Delhi, people are reported to have cases of heat exhaustion and heat cramps, dehydration, typhoid, jaundice and diarrhoea with maximum temperature of 40 °C and minimum of 23 °C. The results observed that how the existence of big and small parks can change the microclimate of the region. The big spaces help the flow of wind to normalise the increasing temperature but parks with green cover the has the influence of reducing the temperature as the vegetation cover absorbed the emitting heat from urban areas and gives sooth environment. The intensity in reduction of surface temperature largely depends on the health of the vegetation of urban parks. It summarises that not only the presence of vegetation in an area, but the open space and the quality of the vegetation is important for sustainable social wellbeing in urban areas. The residential areas are categorised based on existence of parks in the area, like unplanned residential area, planned residential area with proximity to parks, planned residential areas with parks, the normal green parks, the rich green parks and Yamuna bed farms. All categories have different influence in maintaining the urban heat mitigation. The unplanned residential areas have the maximum land surface temperature as there is no space for parks, on their hand the regions with planned residential area and region fixed for parks have 1°C fall in temperature. The difference between the temperatures of no parks region to parks in planed region is about 4°C. this difference in temperature evident the parks as urban cooling island. These findings can deepen the understanding of parks as UCI formation and provide urban planners to accommodate parks and maximises their green component to save the urban area from intense heating or effect of urban heat island (UHI).

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