DESIGN FOR OUTDOOR THERMAL COMFORT

A
DISSERTATION
Submitted in partial fulfillment of the
Requirements for the award of the degree
Of
MASTER OF TECHNOLOGY
In
DISASTER MITIGATION AND MANAGEMENT

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled **"Design For Outdoor Thermal Comfort"** in partial fulfillment of the requirement for the award of degree of **Master of Technology** in **Disaster Mitigation And Management,** and submitted in the Centre of Excellence in Disaster Mitigation and Management of Indian Institute of Technology Roorkee, is a record of my own work carried out during a period from 2018 to 2019 under the supervision of **Prof. Mahua Mukherjee,** Professor in CENTRE OF EXCELLENCE DISASTER MITIGATION AND MANAGEMENT, Indian Institute of Technology Roorkee, Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

ABSTRACT

A standout amongst the most significant effects of urbanization in Indian urban areas is the change of green belts and agribusiness land into the developed zone in the fringe (Chadchan and Shankar, Int J Sustainable Built Environ 1:36–49, 2012; Pandey and Seto, J Environ Manag 148:53–66, 2015). In this way, significant issues are related with fast advancement, for example, extra framework, casual settlements, natural contamination, demolition of biological structure and poor air quality. With these physical changes there is decline in green spread and increment in developed, the land surface temperature (LST) will undoubtedly increase.

Gurugram is one such example of explosive urbanization, which is accommodating thousands of migrant beyond its stretch hence transforming the natural built environment. This study will focus on the relationship of urbanization and its consequences on land use and land cover and how is it affecting the local environment and human health in terms of air quality, it will also identify the relationship between LULC, LST and air quality using ERDAS IMAGINE ARCGIS 10.3.and RAYMAN software.

The present study aims to analyse the association between built-up, green cover and land surface temperature for which district-level analysis of the Normalised differential built-up index (NDBI), Normalised differential vegetation index (NDVI), and land surface temperature (LST) has been done over the urban area of Gurugram. In this and Landsat 8 (OLI/TIRS) for 2018 have been used together with Air quality Real time data. Indices like NDBI, NDVI, LULC and LST are calculated for 1998, 2010and 2018. The study showed that NDVI and LST are negatively correlated with each other as vegetation has a cooling effect on the land surface temperature whereas NDBI and LST are positively correlated with each other. The studies show a change in the distribution of vegetation cover and gradually increase in the built-up land which results in the increase in land surface temperature over last 10 years.

Further, green strategies are proposed to mitigate the effect of temperature and. These green infrastructures can be in the form of a patch or network of patch.

1.1 Contextual Background

The urbanization trend is more in developing country than developed; as per report developing countries contribute about 96% of all urbanization. In 1950 about 2/3 of the population used to live in rural areas as agricultural was the primary sector for the economy for most of the settlement, and 1/3 in urban settlements. By 2050, it is expected that the ratio will be reversed and more than 6 billion people will make their home in the crowded environment of urbanized areas. This global shift of population has various impacts over urban areas throughout the globe such as issues including water, food, energy consumption and the problems can easily identify in the developing countries. Out of all the challenges urban areas are facing, the increase in demand of water and energy is one of the common issues. Urbanization can be a positive, if manage with strategies and plan otherwise it will have adverse effect to our built environment and exacerbated the existing challenges. In the 20th century the process of urbanization is changing to complete new dimensions, currently about 5% of the entire landmass is cover with urban areas.(Zhang, 2016) This 5% of landmass is eating about 70% of energy of the total global reservoir and generating greenhouse gas. Cities grow with both the dimension in numbers and in size.

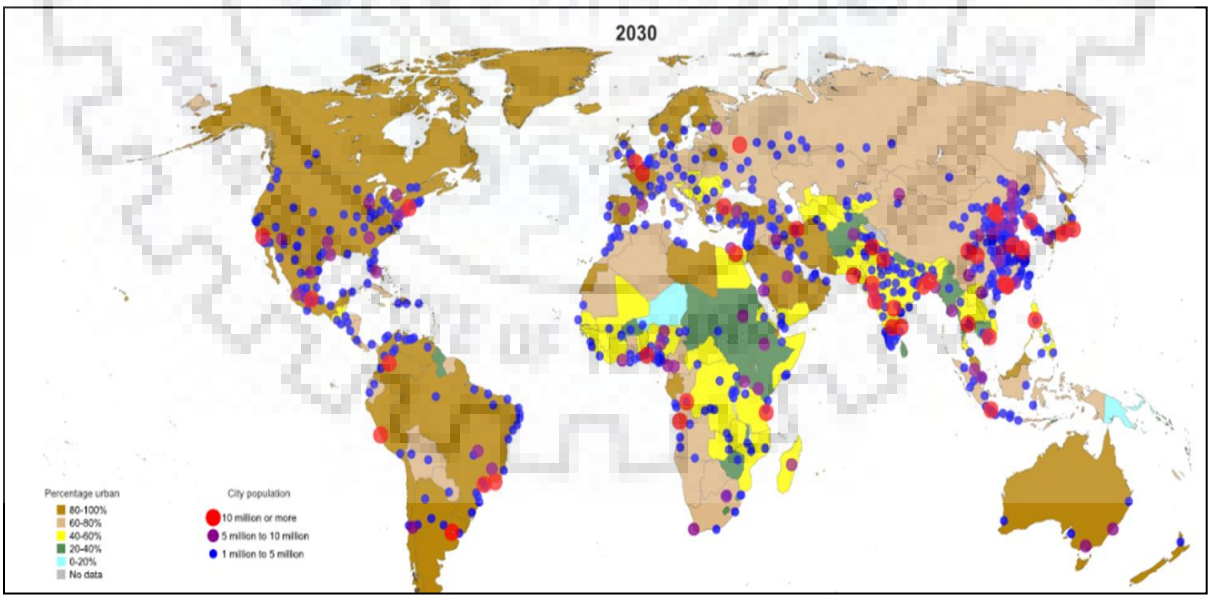


Figure 1: Global urbanization map showing the percentage of urbanization per country 2030. Source: United Nation Department of Economic and Social Affairs

Urbanization and Climate

Urbanization transforms the landscape to anthropogenic urban land and adjustments surface traits. Of those results, one of the most essential is floor temperature variation. Land surface temperature is very important to the look at of city climates (Voogt&Oke, 2003). It modifies the air temperature of the atmospheric boundary layer and is a key aspect inside the surface energy stability. Change in urban area and temperature can have huge effects on weather and climate (Kalnay&Cai, 2003; Landsberg, 1981). By covering the land with buildings, roads, parking masses, and different paved surfaces, city areas typically have higher sun radiation absorption and a greater thermal conductivity and potential for liberating warmth stored at some point of the day at night. This process generally results in a modified climate that is warmer than the surrounding rural areas and is called an urban warmness island (UHI) (Voogt &Oke, 2003). The higher temperatures in urban warmness islands growth air con needs, improve pollution stages, and can alter precipitation patterns.

Indian urbanization

Indian cities are growing at high rate with their population as it was only 5 cities with population more than one million in the year 1951, where as in year 2011 the number of such cities increase to 53 and it is estimated that till 2030 about 73 Indian cities will have population in millions count.

The 2018 Revision of World Urbanization Prospects produced by the Population Division of the UN Department of Economic and Social Affairs (UNDESA), India will account for 35% of the projected growth of the world's urban population between 2018 and 2050.

Since India is the fastest growing economy of the world and having high urbanization rate, India has entirely different urbanization trend comparing to other developing countries.

Census of India define urban area considering following basic features (Census of India, 2011):

1) Census Towns: defines urban area on the following criteria:-

- Population size 5000 or more
- About 25% population work for in industrial sector or non-agricultural work
- Population density should be at least 400 people per square km.

Major causes of Urbanization

The main causes of urbanization are as follows:
Industrial revolution: Industrial employment catches the attention of human beings from rural to city regions. In the city areas, people tend to work public or private sector occupations that help country with economic development. This represents that the vintage agricultural economics is converting to a brand new non-agricultural economic system. This is how we can build a new modern society (Cobbinah, Erdiaw-Kwasie and Amoateng, 2015).Emergence of large manufacturing centres.

Employment opportunities: There are number of job opportunities in metropolitan cities, due to which people from rural area tend to migrate to urban area for better employment opportunities.

Availability of transportation: Due to ease of transport, people prefer to relocate themselves in towns.

Migration: Migration is purposeful phenomenon which led to increase of population and growth of mega-cities. Migration has been going on over centuries and it's far on going phenomenon. When talking about urbanization rural-city and urban-rural and rural-rural migrations are very vital. Urban-city migration approach that people circulate from one metropolis to another. People may circulate to the city because they may be forced through poverty from rural community or they may be pulled by means of the magnetism of town lives. Combination of these push and pull factors can force humans to migrate to cities (Gugler 1997).

Infrastructure facilities in the urban areas: Infrastructure has vital position inside the process of urbanisation in the improvement of countries. As agriculture becomes greater fruitful, cities develop through soaking up working labours from rural regions. Industry and services growth generate higher cost-added jobs, and this caused in increasing economic growth.

1.2 Problems due to urbanization

Deterioration of environment

Due to urbanization, there may be environmental degradation mainly within the first-rate of water, air and noise. With the more numbers of people coming to the city, there are high-quality demands of centers such as housing. Some illegal factories or even homes which have a bad infrastructure, the waste from homes are at once channeled to the nearest river or water resources which directly pollute the water. (Chen et al., 2013; Kumar et al., 2013).The home waste, industrial effluents and different wastes that were dumped at once to the river, degrade the water high-quality.

Exploitation of Resources

Due to excessive population density and luxurious existence style, the intake of consumption of natural resources (e.G. Water, strength, fossil gasoline, woodland products and many others.) may be very excessive in urban regions. There is likewise misuse of these available whose immediately reimbursement becomes difficult.

Air Pollution and Noise Pollution

The populations residing in urban areas are polluting the air by anthropogenic activities, using private automobiles, industries etc. Due to anthropogenic activities pollutants like (CO)carbon monoxide, (CO2)carbon dioxide, (NO)oxides of nitrogen, oxides of sulphur, hydrocarbons, vapours of organic compounds, particulates, and toxic metals etc. have adverse impact on human health.The incoming noise produced from automobiles, certain functions, factories etc. causes noise pollution which causes psychological and physical diseases.(Donohoe, 2008)

Rise in Temperature

The haphazard development of houses in city areas absorbs sun radiation and during day time, which emit absorbed radiations and increase the growing climatic pressure. As a result year 2015 turned into the hottest year from remaining years. Cities frequently acquire extra

rain than the surrounding geographical region for the reason that dirt can initiate the condensation of water vapor into rain droplets.

Decline in living quality of urban dwellers:

Urbanization is foremost situation for management researchers because it decline in great of living for city inhabitants. As the town becomes more developing, the land cost may even increase with the development. The housing provision will cognizance greater to fulfill the wishes of the high earnings organization. As such, there can be a trouble in the provision of housing, specifically for the middle income group and lower income group of people. The supply of housing for the city remains inadequate because the value of those houses is very high due to which low and center income group cannot come up with the money for the basic amenities. (Chen et al., 2013; Kumar et al., 2013).

Urban Heat Island

The urban heat island (UHI) is a phenomenon where rapid and unplanned urbanization of cities and continuous decrease in vegetation resulting in raised temperature compared to rural areas. It can be identify in all spatial scale at building or plot scale the problem is termed as thermal load, the term UHI is coined when the problem is discussed at city level regardless of climatic regions and the UHI effect is exacerbated when the natural land features is modified with an artificial surfaces that also alter the city aerodynamic properties (geometry of the urban sector), radiate, thermal (albedo of the materials used), and moisture properties of the landmass compared to the natural surroundings.

The UHI include negative impacts on climate which is contributing to the increase in global warming. It also affects the ecosystem of the urban area as well as region surrounding the urban region. UHIs emerged as global issues and have been directly or indirectly related with global issues like global warming, greenhouse gas emission and all in one global climate change.

1.3 Problem Identification

Due to rapid increase in rate of urbanization it has been observed that the some specific area of the urban city changing in terms of land use category. More open and green spaces are getting depleted resulting in high rise buildings which include residential as well as commercial buildings. Though this results in unusual rise in temperature, poor air quality and increase in greenhouse gases. Sterling and Ducharne, (2008) pointed out that approximately 40% of the Earth's surface is covered by anthropogenic land-cover and that the natural vegetation-dominated landscapes have been replaced by impervious surfaces.

The role of green interventions can help us mitigate the problem identifies above. Green interventions will not only help us in improving the micro climate but also helps in absorbing certain pollutants which are present in the atmosphere due to anthropogenic activities.

1.4 Need of the Study

The world is undergoing the largest wave of urban growth in history. At present, more than half of the world's population is living in urban areas such as towns and cities, and it is expected that by 2030 this number will increase to about 5 billion (UNFPA). United Nations Population Fund (UNFPA) also predicted that much of this urbanization will take place in Africa and Asia, bringing huge social, economic and environmental transformations.

Gurugram cities recorded 44.15 % of increase in its population when compared to 1991. According to the study, the population of Gurugram is expected to be 5.834 million in 2031, due to combination of effects of urbanization, and industrialization.

Recently, monitoring teams appointed by the Central Pollution Control Board (CPCB) has identified 21 most polluted spots in the city. According to the report IMT Manesar, Sec9, Sec10, and stretches along NH-8 were the worst affected areas, due to massive flouting of green norms, open dumping of construction and demolition waste, open storage of construction material, broken roads and burning fuel of transport. The propose research study is motivated by approach to improve the air quality and temperature at micro level for urban area. Developing relations between planning and climate, which will be further useful for planners /architects to improve air quality and outdoor thermal in newly developing areas and existing areas of Gurugram.

1.5 Aim & Objectives

The aim of the study is to review the influence of green interventions and suggest landscape design strategies to improve outdoor thermal comfort and poor air quality index.

- To determine the trend of urbanization, locate the urbanized areas through LULC and prepare a map to represent increase in surface temperature through LST.
- To analyze and correlate between LULC and LST.
- To identify the relation between different indices LST with NDBI and LST with NDVI.
- Identify the different parameters of the Outdoor thermal comfort indices and simulating it with Rayman software and questionnaire.
- To investigate the factors of thermal comfort effects in order to propose a strategy based on green mitigation measures for improving the maximum temperature gradient and poor air quality.

Further this study will aim to identify the area within the city which is subjected to poor air quality and high outdoor temperature and proposing the mitigation approach designed to produce good outdoor thermal comfort in the identified critical zone.

Objective I	Identifying urbanization trend by exploring change in LULC for the Gurugram city.
Objective II	To investigate relationship between : (i)LULC & LST (ii)LULC & AQI
Objective III	To identify combined impact of LST and AQI on outdoor thermal stress.
Objective IV	To propose appropriate mitigation measures for outdoor thermal comfort.

Table 1: Aims & Objectives

1.6 Scope of the study

1.6.1 Scope

The scope for the study is summarized as below:

- Remote sensing data and GIS application helps a lot in analyzing the impact of urbanization.
- LULC change will help us to take up strategies for managing natural resources available and monitoring climatic or environmental changes.
- Remote Sensing and GIS both from the conventional sources has proved to be an effective tool in planning for Land management.
- Design landscape strategies for the outdoor thermal comfort area using green interventions.
- Calculation of PET index using Rayman software for summer.

1.6.2 Limitations:

Limitations of the study are summarized as below:

- Availability of advance geospatial information techniques (GIS).
- Availability of real time monitoring air quality data.
- Remote Sensing data includes reliability and cost effectiveness of data with area and location information.

1.7 Methodology

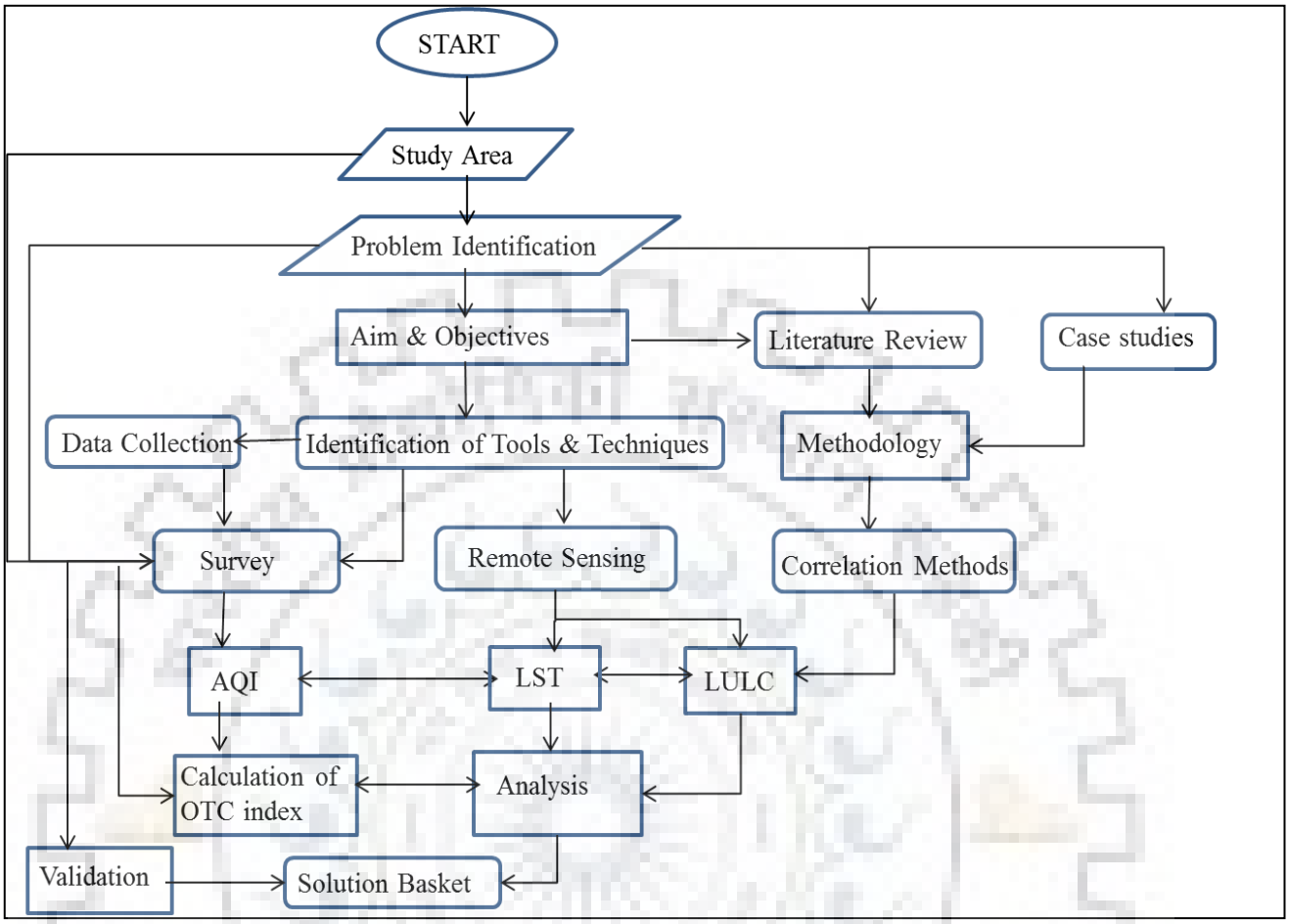


Figure 2: Methodology Chart

The methodology can be assumed to be broadly divided into 5 major steps. Firstly, classification of images for land cover information, secondly, land surface temperature derivation temperature effect, thirdly calculating NDVI and NDBI comparing it with LST and fourthly correlation analyses of the datasets and lastly calculating PET and relating it with temperature and proposing green mitigation measures .

1.8 Chapterization

- **Chapter 1**: Provides an overview about the urbanization trend. It also discuss about the current issues related with urbanization and their effect at micro-level.
- **Chapter 2**: Discuss about the different parameters of outdoor thermal comfort and landscape design
- **Chapter 3**: Provides the literature review of the different research carried out by various researchers and suitable tools and techniques which are used.
- **Chapter 4**: Discuss in brief about the study area and its characteristics. Gurugram and its impact on data used for further study.
- **Chapter 5**: The chapter discusses the detailed methodology and work flow, tools and techniques used for the processing. Analytical frame work for the study is discussed with the flow chart diagram.
- **Chapter 6**: Describes summary of the obtained results with recommendations for planning and mitigation for future study.
- **Chapter 7**: The chapter discuss about result obtained showed the role of vegetation in improving the outdoor thermal comfort and air quality.

2.1 Outdoor thermal comfort

"Thermal Comfort is a state of mind which tends to express satisfaction with the outdoor thermal environment which is assessed by subjective evaluation (ANSI/ASHRAE Standard 55, 2004)." In the past decade, (Mahanta, 2014) valuable researches were carried out for outdoor conditions (Hoppe, 2002; Givoni et al., 2003; Ahmed, 2003; Wu, & Zacharias, 2004; Cheng & Ng, 2006; Cheng, Ng,(Park, Tuller and Jo, 2014). The parameters of Outdoor Thermal Comfort are shown in fig. 4 below:-

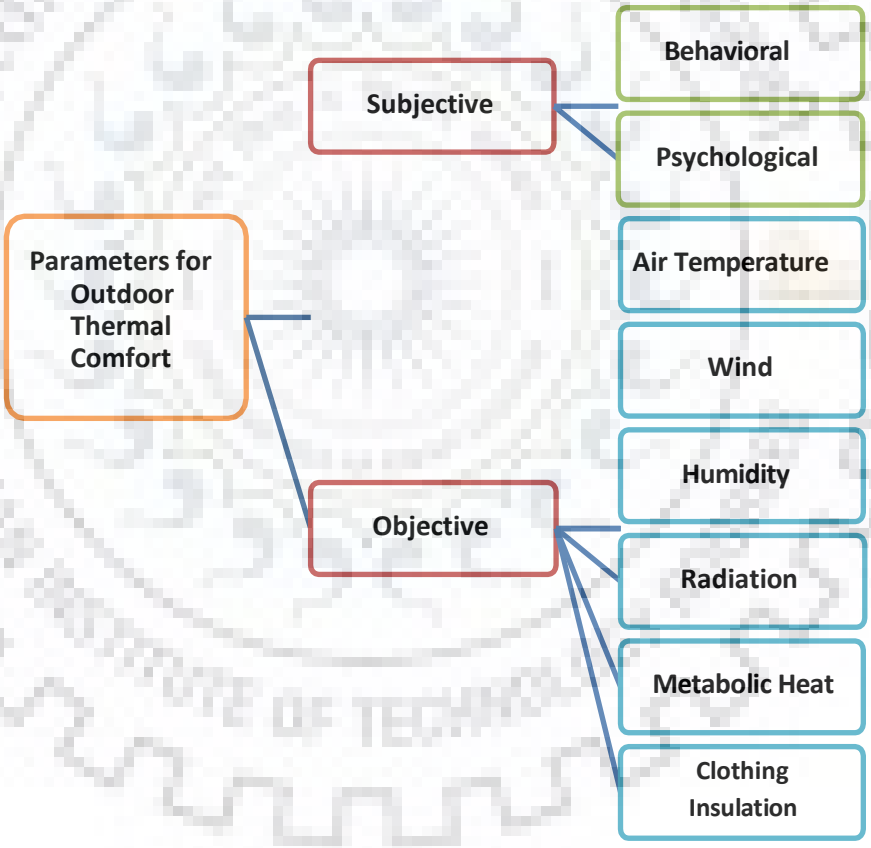


Figure 3: Parameters of outdoor thermal comfort

Outdoor thermal comfort assessment methods

The Outdoor Thermal Comfort Evaluation is carried out by two methods:

Micro-Meteorological Measurement: The four basic microclimatic parameters which influence the outdoor thermal comfort sensation are Air temperature, Relative humidity, Wind and Solar Radiation. In this survey, the microclimatic parameters are measured by the instruments using Heat Stress Meter which measured Air temperature and relative humidity Which was useful in calculating PET for this research study.

Guided User Questionnaire Survey: During the field survey, a questionnaire survey is carried out where the subjects' comfort condition (e.g. thermal sensation, humidity sensation, etc) are enquired and also record the subjects' personal factors (age, gender, height, weight, etc). The thermal comfort sensation can recorded lied in the given scale, table given below:

ASHRAE SCALE		BEDFORD SCALE		SEVEN POINT		NINE POINT	
Hot	3	Much Too Warm	3	Very Cold	1	Very Cold	1
Warm	2	Too Warm	2	Quite Cold	2	Cold	2
Slightly Warm	1	Comfortably Warm	1	Cold	3	Cool	3
Neutral	0	Comfortable	0	Comfort	4	Slightly Cool	4
Slightly Cool	-1	Comfortably Cool	-1	Hot	5	Neutral	5
Cool	-2	Too Cool	-2	Quite Hot	6	Slightly Warm	6
Cold	-3	Much Too Cool	-3	Very Hot	7	Warm	7
						Hot	8
						Very Hot	9

Table 2: Thermal Comfort Table, (Nasir 2012)

Also external parameters (e.g. Clo value, Metabolic Rate, etc.) are required for the measurement of outdoor thermal comfort conditions, calculation needs to be obtained from this questionnaire survey.

Activity level: According to nature of activity, the human body converts an amount of food taken into energy. Table given below presents metabolic rate for various activities:

Clothing: It is an intermediate required for the human body and the outdoor environment. Different clothing type has different efficiency level which can be expressed by Clothing value as shown in table 3 given below:

Activity	Metabolic rate (*MeUnits) 1 met = 58.2 W/m² (18.4Btu/h·ft²)
Sitting	1
Eating	3
Walking	2.6
Playing/exercise	4
Standing	1.2
Studying and sitting	1
Serving	1.6

Table 3: Metabolic Rate of Various Activities (Source: ASHRAE Handbook of Fundamentals, 1989)

Types	*Clo Values* of various clothes					
Under Garments & Inners	0.05	Briefs				
	0.15	Vest (light)	0.29	Vest (heavy)		
Clothing above waist	0.14	Shirt short sleeve	0.22	Shirt long sleeve		
	0.25	T-Shirt short sleeve	0.29	T-Shirt long sleeve		
Clothing below waist	0.15	Shorts/Half pant				
	0.2	Capris				
	0.3	Jeans				
	0.26	Trouser light material	0.32	Trouser heavy material		
Winter Wears	0.3	Inner above waist	0.3	Inner below waist		
	0.2	Sweater light	0.37	Sweater heavy		
	0.22	Jacket light	0.49	Jacket heavy		
	1.5	Overcoat				
Others	0.5	Hat/Cap				
	0.1	Scarf/shawl				
	0.05	Tie				
	0.1	Socks till knee	0.5	Socks till ankle		
	0.04	Shoes	0.02	Sandal / Slippers	0.08	Boots

Table 4: Clothing Value Chart for Male
(Based on ASHRAE Handbook of Fundamentals/ANSI ASHRAE Standard, 1989, pp. 55-201)

Types	*Clo Values* of various clothes			
Under Garments & Inners	0.05	Bras & panties		
	0.19	Slips/Spaghetti		
	0.04	Shape wear		
Clothing above waist	0.14	Shirt short sleeve	0.22	Shirt long sleeve
	0.25	Tshirt short sleeve	0.29	Tshirt Long sleeve
	0.25	Short Sleeve Top	0.29	Long sleeve Top
	0.25	Kurti Short sleeve	0.29	Kurti Long sleeve
Clothing below waist	0.10	Skirt light	0.22	Skirt heavy
	0.15	Shorts		
	0.2	Capris		
	0.3	Jeans		
	0.26	Trouser light	0.32	Trouser heavy
Indian wear/dress	0.7	Dress/Frock		
	0.22	Peticot		
	0.20	Blouse short sleeve	0.30	Blouse long sleeeve
	0.5	Sari		
	0.2	Kameez/Long Kurta		
	0.2	Salwar/Churidar/Leggings		
	0.15	Dupatta		
Winter Wears	0.3	Inner above waist	0.3	Inner below waist
	0.2	Sweater light	0.37	Sweater heavy
	0.22	Jacket light	0.49	Jacket heavy
	1.5	Overcoat		
Others	0.5	Hat/Cap		
	0.1	Scarf/shawl		
	0.05	Tie		
	0.1	Slacks		
	0.04	Stockings		
	0.1	Socks till knee	0.5	Socks till ankle
	0.04	Shoes/Pumps	0.02	Sandal 0.08 Boots
Any other worn then please specify				

Table 5: Clo Value Chart for Female

(Based on ASHRAE Handbook of Fundamentals/ANSI ASHRAE Standard, 1989, pp. 55-210)

2.2 Different Outdoor thermal comfort indices

There are several indices through which we can analyses outdoor thermal comfort. These indices can be classified in number of ways.[1](Honjo, 2009)
According to capability for evaluating hot and cold conditions, they are classified as:-

Thermal Stress Model: - Heat stress indices such as Discomfort Index (DI), heat index (HI), Tropical Summer Index (TSI), Humidex, and Wet Bulb Globe Temperature (WBGT) are used for hot conditions. Cold stress indices like Wind Chill Equivalent Temperature (WCET) and Wind chill Index (WCI) are used for cold conditions.

Heat Budget Model: - These indices are capable of evaluating both cold and hot conditions like Temperature Humidity Index (THI), Perceived Temperature (PT) and Physiological Equivalent Temperature (PET), Universal Thermal Climate Index (UTCI) which is bon heat budget model of human body.
The **Energy Balance Equation of the human body** according (ANSI/ASHRAE Standard 55, 2004) :

$$M + W + R + C + ED + ERe + ESw + S = 0 \qquad \text{(Eq. 1)}$$

Where, ***M*** is metabolic rate (W/m2),
W is mechanical power (W/m2),
C is convective heat loss from skin (W/m2), R is radiation heat loss from skin (W/m2),
E is evaporative heat loss from skin (W/m2),
E res is evaporative heat loss from respiration (W/m2),

[1] (Mukherjee and Mahanta, 2014)(Mukherjee and Mahanta, 2014)(Mukherjee and Mahanta, 2014)(Mukherjee and Mahanta, 2014)(Mukherjee and Mahanta, 2014)(Mukherjee and Mahanta, 2014)(Mukherjee and Mahanta, 2014)(Mukherjee and Mahanta, 2014)(Mukherjee and Mahanta, 2014)(Mukherjee and Mahanta, 2014)⁴(Mukherjee and Mahanta 2014)[4](Mukherjee and Mahanta)⁴(Mukherjee and Mahanta)Mahua Mukherjee and Shatabdi Mahanta, 'Outdoor Thermal Comfort', ARCHITECTURE - Time Space & People April, April 2014, 2014, 16–22 <https://doi.org/10.2741/245>.

C res is convective heat loss from respiration (W/m2) and S is the rate of body heat storage (W/m2). (Based on ASHRAE Handbook of Fundamentals/ANSI ASHRAE Standard, 1989)

These terms in this equation have positive signs if they gain energy for the body (M is always positive, W, ED and ESw are always negative). These individual terms are mainly influenced by the meteorological parameters.

C and ERe are affected by air temperature, ED, ERe, ESw are affected by humidity, C and ESw are affected by wind velocity and R is calculated as the exchange between environment and human body by short wave and long wave radiation. (HONJO, 2009)

Important Outdoor Thermal Comfort Indices

2.2.1 Physiological Equivalent Temperature (PET):-

PET was developed by Hoppe, 1993, is an Outdoor thermal index which regulates all the basic thermoregulatory processes. It is based upon the Munich energy balance model for individuals (MEMI) (Hoppe, 1987). According to Hoppe (1987) and Hoppe (1999), "PET is defined as the equivalent air temperature at which, in a standard indoor condition heat balance of the human body exists (working metabolism 80 W of light activity, and clo value of (0.9) ." The following assumptions are made for the indoor reference climate:

Radiant temperature equals air temperature (Tmrt =Ta).

Air velocity is set to 0.1 m/s. Water vapour pressure is set to 12hPa (approximately equivalent to a relative humidity of 50% at Ta=20°C)."(Mukherjee and Mahanta, 2014)

A big advantage of using PET is that we can calculate the temperature in degree Celsius. PET and PT (Perceived Temperature) are correlated. PET is applicable to outdoor conditions also. PET has been one of the recommended indices in the new "German guidelines for urban and regional planners" (VDI, 1998). PET can easily be calculated by using the RayMan Software developed by (Matzarakis, 2007)

2.2.2 Predicted mean vote (PMV):-

PMV (Predicted Mean Vote) has been developed by Fanger (1972) for indoor climates. Jendritzky and Nubler (1981) added other indices which is complex outdoor radiation for applying the PMV index to outdoor conditions as well. This model is also known as Klima-Michel Model (KMM).

2.2.3 Outdoor standard effective temperature (OUTSET):-

The new effective temperature (ET) is based on two-node model and human energy balance (Gagge, 1971). With effective temperature the thermal situations may be in comparison to the situations in a standardized room with a median radiant temperature equals to air temperature and a consistent relative humidity of 50%. Gagge et al. (1986) proposed the new preferred ET (SET) with the aid of enhancing Effective temperature. SET is used very regularly in interior and outside. Ishii et al. (1988) had as compared various thermal indices concluding that for comparing outdoor thermal comfort SET has been used widely. Pickup and pricey (1999) advanced OUT-SET indices by using improving the SET.(Coccolo *et al.*, 2016)

2.2.4 Universal thermal climate index (UTCI):-

The Universal Thermal Climate Index UTCI is developed by Hoppe in 2002. It gives an evaluation of the outdoor thermal comfort environment in the meteorological applications. The main purpose of UTCI is to give the information to the public about how the weather acts with driving factors such as wind, solar radiation and relative humidity. UTCI is also calculated in degree Celsius scale so that it becomes easy for the general public to use. It can also be calculated online.(Walls, Parker and Walliss, 2015)

2.3 Role of landscape design

Landscaping plays a significant role in modifying the outdoor temperature. Vegetation contributes in improving the urban climate by evapo-transpiration, and channeling wind. Landscaping can control various elements of the outdoor microclimate like air temperature, solar radiation, relative humidity, wind speed and wind direction and also glare.

- **Control of solar radiation**

The sun emits solar radiation that warms the elements of a landscape design. The sun rises in the east, moving to the highest position in the southern sky and then finally sets in the west direction. While in winter, it rises in the southeast and sets in the southwest and in summer; it rises in the northeast and sets in the northwest. The sun is usually at the midpoint of the south along its arc, and the southern sun is at its highest point in the sky during summer and at its lowest point in the sky during winter. When the solar's rays are without delay perpendicular to the floor of any object, it receives the highest quantity of radiation. If the color of the surface is darker, it will absorb greater sun radiation.

- **Control of humidity**

Generally plants increase the humidity of any site. During hot and dry seasons, they can increase the thermal comfort even though the plants need water regularly. But during this process, the relative humidity increases but it reduces the air temperature. Ponds and pools also behave in a similar manner.

- **Control of reflectance (albedo) and surface absorptivity**

For controlling the rate in which surfaces absorb and also reflect solar radiation, landscaping elements can be used. For controlling the ratio of solar radiation that is absorbed to that which is reflected, the plants, lawns, color and proper selection of pavement materials can be helpful.

- **Control of air temperature**

The landscape cannot change Air Temperature and Relative Humidity very much, except in certain circumstances. However, the air near the pervious surface in parks will be much more cooler than surrounding hard surfaces (concrete and asphalt) in urban areas. Shading by tree canopies is a significant measure in controlling and reducing the air temperature. It is due to evapo-transpiration, a process in which plants collect water from the ground and gives out the water through the leaves by the process of evaporation as shown in fig 6 given below. This causes cooling and it is similar to the cooling caused by sweating in humans.

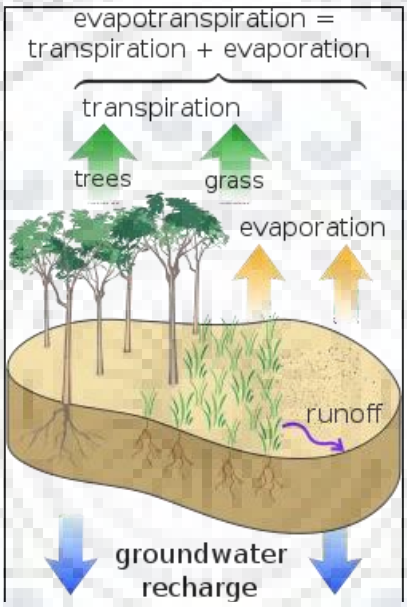


Figure 6: Evapotranspiration of Trees : (Tsuni, June,2003)

- **Control of wind speed & Wind Direction**

In a landscape, the only mechanism for cooling objects is the wind. It will take away heat from items until they are the equal temperature as the wind. Through proper placement of elements the wind can be slowed down in a landscape. Vegetation can be used to increase the velocity of slow moving and stagnant air and also to reduce wind speed. A very successful way of filtering dust and reducing wind speed is to create windbreakers in a pattern with rows of trees. Trees and shrubs help to channel the wind's direction towards the site or deflect away from the site. Walls, fences, trees and hedges when combined together can be some obstruction which can divert the direction of the wind. On plots which are larger, rows of trees can be used for channeling the wind into a desired direction.

2.4 Influence of shape of trees on microlimate

Rounded forms of tress are most common in plants. They allow for easy eye movement and create a pleasant undulation that leads itself to plant groupings.

Horizontal and spreading forms of trees emphasize the lateral extent and breathe of space. They allow for the natural direction of eye movement.

Vase-shaped trees define a comfortable “people space” beneath the canopy.

Weeping trees forms lead the eye back to the ground.

Pyramidal form trees-grouping pyramidal trees will soften the upward influence. They will look more natural in the surroundings with foliage to the ground.

Figure 4: Different sizes and shapes of the vegetation

Scale – The outdoor design should balance the size of the buildings it surrounds, while maintaining a comfortable environment for the individuals who will use the area.

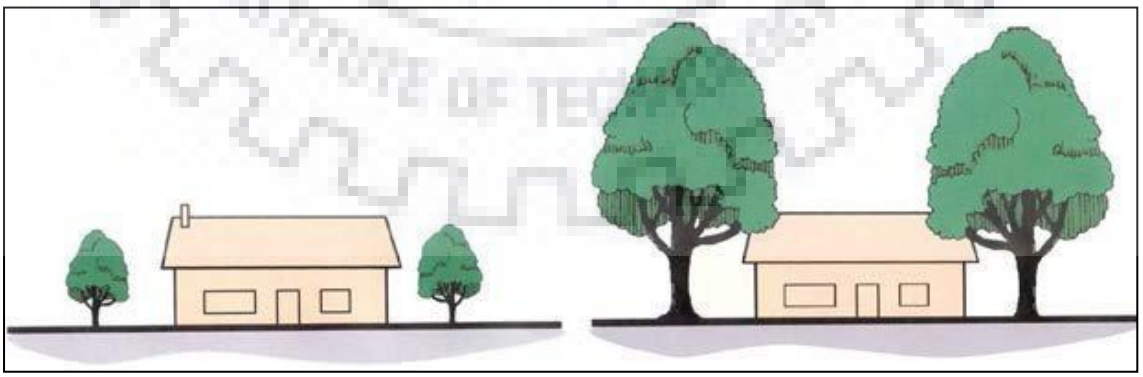


Figure 5: : Buildings and Trees in different Scale Source: (Jong, Nov,2012)

Literature Review

. In this study supervised classification was performed using Non Parametric Rule. The major LULC classified were agriculture (65.0%), water body (4.0%), and built up areas (18.3%), mixed forest (5.2%), shrubs (7.0%), and Barren/bare land (0.5%). The study had an overall classification accuracy of 81.7% and kappa coefficient (K) of 0.722.

The work with the aid of Katzschner (2006) in Kassel, Germany, is every other noteworthy example of the impact of outdoor thermal comfort on outdoor activities. The study aimed to offer measurement strategies and evaluation strategies which can be smooth to apply in urban planning. The temperature index of PET turned into used to assess outdoor thermal comfort, and a PET variety of 18–21 °C was located to be impartial. easy microclimatic size routines were designed to measure and calculate solar radiation and PET. the usage of open areas close to a small bistro become determined and as compared to the calculated PET. The finding changed into usually in accordance with the observe by Thorsson et al. (2004); this is, the conduct of human beings is dependent on outside thermal situations however is also influenced by using character expectancies.

Thorsson et al. (2007) studied the subjective out of doors thermal comfort and human pastime in an city environment. They carried out case studies in a park and in a staleiite park of Tokyo,Japan. The PET index become also used for quantifying human beings's objective thermal circumstance, and a PET value of approximately 20 °C turned into considered to be relaxed. In parallel, a 9-factor scale was used to evaluate the subjective thermal sensations of 1192 human beings through the use of questionnaires. The sets of information have been as compared, and just like Nikolopoulou et al. (2001) and Thorsson et al. (2004), the PET curve became also skewed closer to the nice and cozy area. An critical locating is that human beings tended to stay longer (19–21 min on common) whilst their notion of thermal conditions changed into within the applicable comfort sector than whilst their belief became outdoor of the region (11 min on average). Human activities in phrases of attendance and behavior when it comes to sunlit and shaded styles have been discovered unobtrusively; a complete of 7304 humans had been recorded. In contrast with previous studies, the end result showed that the impact of the thermal environment on the use of previous studies, became typically insignificant.

A have a look at through Eliasson, Knez, Westerberg, Thorsson, and Lindberg (2007), four city public spaces in a Nordic city (Gothenburg) (i.E., square, park, courtyard, and waterfront plaza) have been tested. A overall of 1379 humans had been interviewed. Human point of view of the urban environment changed into categorized into functional and psychological opinions, which have been measured via total attendance and emotional satisfaction, respectively. Thermal comfort was surveyed primarily based on a nine-factor scale starting from very cold to particularly warm when it comes to the emotional states of the individuals. Multiple regression analyses showed that clearness index, air temperature, and wind velocity accounted for greater than 50% of variance in area-associated attendance, suggesting that the 3 climatic factors had a large have an impact on the behavioral assessment of human beings. Although the observe revealed wonderful aesthetical critiques of the waterfront plaza and the rectangular in phrases of emotions of splendor and pleasantness, social capabilities had been now not taken into consideration, at least explicitly, when it comes to behavior assessment and usage variation. Nevertheless, the significance of weather-touchy making plans in urban layout and making plans initiatives turned into substantially confirmed by means of the study.

From an ecological/environmental point of view, green spaces assist sustainable urban development through recycling carbon, soaking up pollutants, offering smooth air, soil and water and comforting the city temperatures and humidity. They additionally offer habitats for natural world and might keep or maybe improve biodiversity. (Gilbert, 1991; Hough, 1995; Niemela, 1999; Woolley, 2003; Baycan-Levent and Nijkamp, 2004; Kaye et al., 2005; Krisdianto et al., 2012).

Air pollution, being a vast human health problem, can purpose headache, respiration issues, throat and eye inflammation, heart disorder and cancer (Nowak, 2002).Researcher additionally determined that urban inexperienced spaces are the most effective manner of removing atmospheric pollution in huge cities. This study was taken under 5 cities of United States of America, it was found that environmental pollution really worth more than seven lakh metric tonnes in step with 12 months (valuing US $ three.8 billion) became eliminated through the plant life. plant life of Guangzhou town, China along with 7,360 ha of urban forests removed 312 metric tonnes of atmospheric pollutants annually (well worth US $ 11,000), out of which particulate count number accounted for 234 metric heaps (Jim and

AUTHORS	TOOLS, TECHNIQUES and DATA	RESULT
Tianyu Li Qingmin Meng 2018	Data on land surface temperatures (LANDSAT 8),Band 10 and Band 11, Single Channel Algorithm, Mono Window, Split Window	(i) LSTs from four different approaches (MonoWindow-MAoE, MW_NDVITHM, Single Window-MAoE and SC_NDVITHM) exhibit qualitatively close distributions and similar spatial patterns and (ii) Single Window algorithm using two thermal bands presents relatively larger LST estimates than Monowindow and Single Channel algorithms using only one TIR channel.
(K M Kafi, 2010)	Landsat 7 ETM+ and Landsat 8	(i) All LULC classes except farmland were increased with built up increased to 138% from 2003-2010 , farmland showed drastic decrease of 178%. However, classification overall accuracy was 98% and kappa coefficient 0.843 for the year 2013.
(Pandit, March,2016)	Landsat 8 OLI/TIS.	The Accuracy assessment was performed using error matrix. The research study had an overall classification accuracy of 81.7% and kappa coefficient of 0.722.
(AmnaButt, December,2015)	Landsat TM/ETM+ data	Land use land cover map is prepared and it is identify that built-up land is increased by 219.50% and consequently these drastic change leads to UHI effect in city.

Table 7: Literature Review

2.5 Tools & Techniques

In this study LANDSAT (lANDST-5 AND LANDSAT-8) is used for the LULC mapping and LST retrieval. Cloud Free LANDSAT satellite data geo coded with UTM projection and WGS 1984) of 30m spatial resolution of three different years (1998, 2010&2018) which has been downloaded USGS Earth Explorer website.

Band 6 and Band 5 of Landsat 8 had been processed for extracting the built-up index NDBI, at the same time as Band 4 & Band 5 processed for NDVI analysis. Thermal band TIRS (Band 10) was used to analyze for surface temperature retrieval (LST).The entire extraction process is extracted y using ArcGIS and ERDAS software. Table 9 given below shows software which has been used in this study.

Satellite	Sensor	Path	Row	Acquisition Date	Time (GMT)	Cloud Cover	Resolution (m)
Landsat 5	TM	20	37	30-Nov-2010	15:53:09	0.00	30/120
		32	39		17:23:43	0.00	
Landsat 8	OLI/TIRS	146	40	5-Nov-2018	5:17:54	0.00	30/100
		147	40	18-Mar-2019	5:24:37	0.42	

Table 7: Specification of Landsat TM and OLI/TIRS Data

Instrument	Band	Centre Wavelength (m)	Bandwidth (m)	Spatial Resolution (m)
TIRS	10	10.9	0.6	100
TM	6	11.4	2.0	120

Table 8: Salient Characteristics for Different Landsat sensors

- **NDBI stands for Normalized Difference Built-up Index(NDBI)**

In comparison to the other land use / land cover surfaces, built-up lands have higher reflectance in wavelength range (1.55~ 1.75μm) than in NIR wavelength range (0.76~ 0.90μm). NDBI is very useful for mapping the urban built-up areas,using the equation expressed as follows;

$$(\mathrm{NDBI}) = \frac{\mathrm{MIR(band6)} - \mathrm{NIR(band5)}}{\mathrm{MIR(band6)} + \mathrm{NIR(band5)}} \qquad (\mathrm{Eq.2})$$

Where, MIR is middle infrared reflectance, which is band 6 of Landsat-8. NIR is near infrared reflectance such as band 5 of Landsat-8; NDBI values range from -1 to 1. The greater the NDBI is, the higher the proportion of built-up area is.

- **Normalized Difference Vegetation Index (NDVI)**

NDVI the vegetation proportion by measuring the difference in the near-infrared portion of electromagnetic spectrum which is strongly reflected by green vegetation and red portion of the spectrum which is absorbed by vegetation. NDVI were calculated by using Where, NIR represents (Band 5) and R represents the red band (Band 4) of the Landsat-8 data given by equation below and calculated using ArcGis software. The calculation of the NDVI is important because, the proportion of the vegetation (p_v) will be calculated and they are highly related with the NDVI and emissivity (ɛ) is calculated, which is related to the (p_v),

$$(\mathrm{NDVI}) = \frac{\mathrm{NIR(band5)} - \mathrm{R(band4)}}{\mathrm{NIR(band5)} + \mathrm{R(band4)}} \qquad (Eq.3)$$

- **Rayman**

For the assessment of Outdoor thermal comfort different software can be used, one such software is RAYMAN which can be used to calculate the indices as well as carry out simulation in outdoor spaces (Rafaj *et al.*, 2018). This software is available online . Rayman software has been very successful and accurate and is discussed below:

Rayman Model: Rayman stands for "radiation on the human body".It were developed in 2007 by Matzarakis et. al., can be used for PET calculation. Three different outdoor thermal comfort indices can be calculated using RAYMAN software i.e., PET, PMV and SET.

2.6 Summary

From the literature review, various correlations have been developed to study for outdoor thermal comfort. Urbanization impact has been mapped by preparing LULC map using ERDAS Imagine software, which is image processing software that allows users to process both image and geospatial as vector data. Due to the effect of urbanization Land surface temperature has been increased which has been calculated by ArcGIS software.

These structural development and anthropogenic activities, changes the environment quality and further affecting the human health causing respiratory issues, headaches eye inflammation etc.

Different studies have already been done where China has successfully be able to remove 1261 of metric tons of pollution through landscaping.

Outdoor thermal comfort is an important factor when we talk about the quality of life of in urban areas. Due to anthropogenic activities and urbanization microclimate of the urban area start rising unusually. OTC can be calculated different software. For evaluating outdoor thermal comfort PET is the best suitable indices when compared to PMV and SET.UTCI is also another index which is similar to PET but its further application and suitability is required for Indian Tropical Climate. PET is calculated online using Rayman software.

Role of Vegetation has been discussed briefly; Landscape design is an important driving factor to design area for outdoor thermal comfort. It helps in modifying the microclimate by using trees which have large canopies, increasing green network patches, maintaining open spaces with vegetation, avoiding hardscape landscape design.

3.1 General

Many case studies have been studied out of which only three has been in briefly. These case studies helped in understanding the Outdoor Thermal Comfort parameters and how study has been carried out at different locations. It also helped in understanding how the simulation is carried out for Outdoor Thermal Comfort by using different software, field survey and questionnaire.

3.2 Case Study: " A Strategy to improve outdoor thermal comfort in open public space of a desert city, Ouargla, Algeria".

Objective of the Research Study:-

- Study and analyze the effect of vegetation in urban areas.
- How the shading effects the microclimate
- Calculating the indices before and after the insertion of two types of vegetation, thermal comfort in outdoor city area of Ouargla, Algeria. (BENZAOUI, 2018)

Location:-

Study area is situated in the city of Ouargla, located in the Saharan Desert of Southern Algeria shown in figure 8. City is located at an altitude of 135m and the city is characterized by hot weather and massif dunes.

Figure 6: Geographical location of Orguala

The climate of the city is expressed in high temperature, low precipitation and evaporation.

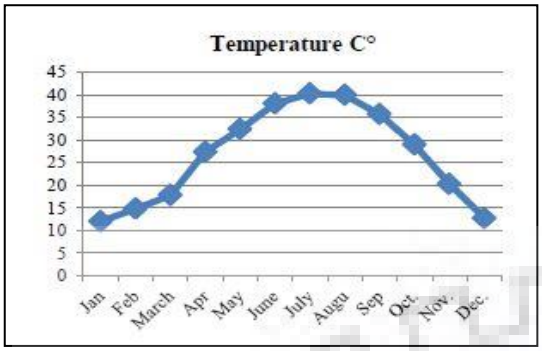


Table 9: Temperature of City Ouargla

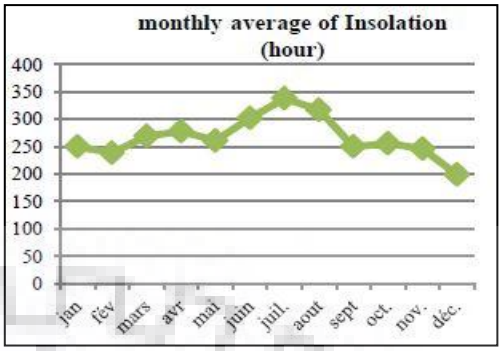


Table 8: Precipitation Chart of Ouargla

Methodology: - The study is conducted in an open plaza which has poor vegetation and the plaza is crowded almost whole year. In order to evaluate the effect of the vegetation Rayman software is used to calculate PET which is an outdoor thermal comfort index. Input data required for calculating PET in Rayman software are Air temperature, wind speed, Humidity and type of sky. The measurement was performed during summer season of July.

Observation:-

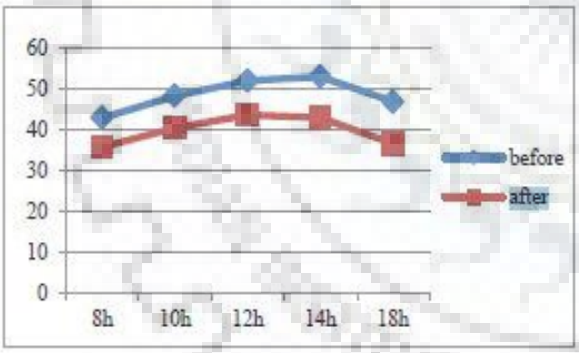


Figure 7: Tmrt before and after intervention

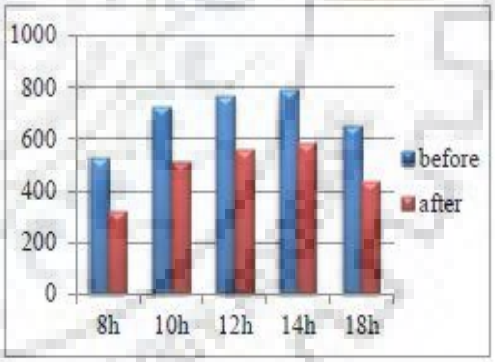


Figure 8: Global radiation before and after the interventions

Vegetation can affect the micro climate in many ways, reduces temperatures, and provides shades, decrease solar radiation. The study was based on two conceptions, firstly, not to plant trees all over the surface of the plaza, rather planting them only around sitting area. Second was introducing a deciduous tree (*Acacia Raddiana*) and a coniferous tree (*Ficus Retusa*)

Two different types of trees were introduced for the intervention. Results showed that the temperature shifted from 52.9°C to 42.9°C and the global radiation was passed from 789w/m2 to 589w/m2. In addition trees improved the environment and visual quality of the environment.

3.3 Case Study: "An Urban outdoor thermal comfort prediction for Public Square in moderate and dry climate."

Objective of the research study: The objective of the study is to examine the acceptable range of the human body in the outdoor area in dry climate zone. (Shahab Kariminia, 2011)

Location: - The study area is a large open square, located in city od Esfahan central Iran. The city is located at51°41'E longitude and 32°37'N latitude. It is situated above 1590m altitude of sea level. The city recorded 43° Celsius in july and -19.4°C in December

Figure 7: Park square, fieldwork experiment

Methodology: - Two field work experiment were done in an open park square. The field work was performed in the coolest month of December and hottest month of July. Finally, PET values and thermal acceptable range was derived through modeling.
Questionnaire survey- In total 402 people were surveyed during this study

Observations: - The thermal acceptable range which was derived from model showed the range between 12.3 and 30.9°C PET. Relation has been showed before and after intervention in fig 16.given below.

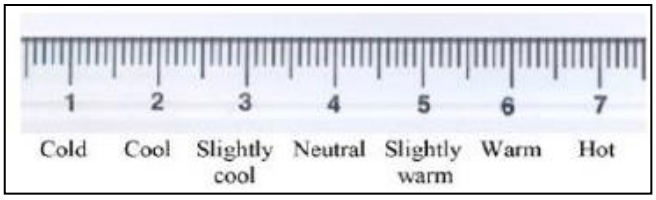


Figure 8: ASHRAE-7 point thermal scale

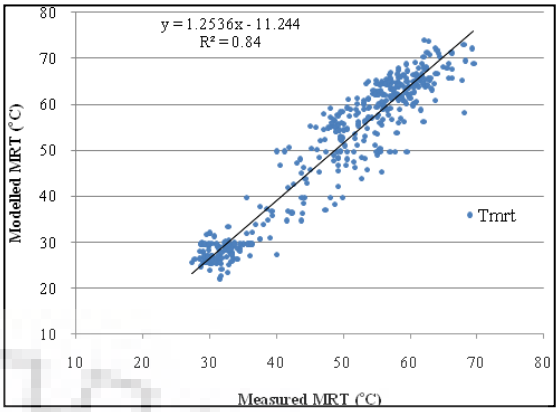


Figure 9: Correlation of mrt before and after intervention

3.4 Case Study: "A field study on sensitive analysis of landscaping elements on outdoor thermal environment in a residential community in Guangzhou, China"

Objective of the research study - The goal of the research became on how to the landscaping factors affect the outside environment characteristics. Field studies and Envi-Met evaluation have been done. Finally, some guidelines and conclusions in landscape layout have been proposed.

Methods Used: - Data was collected from 19thof July to 24th of July in Guangzhou, China**.** Observation and data collection was performed from morning 10:00 am to evening 5:00 pm. Parameters like temperature, wind speed, relative humidity and globe temperature was measured at different spots. Envi-Met simulation was done to review the behavior of landscaping elements.

Observations: -

Surface types: 5 exceptional styles of surface have been simulated. It was observed that the unique surfaces which include various substances have different surface temperatures but air temperature is same if the regions are located nearby. The asphalt showed the highest surface temperature.

Water intensity: 5 types of lakes with diverse depths from 0m to 1.75m had been simulated. It was observed that the intensity of water has minimal results on the air temperature.

Vegetation types: Three distinct types of vegetation were simulated. The grass has little or no effect at the air temperature although it has high effect in reducing the floor temperature. The trees can reduce air temperature to a great volume.

3.5 Summary

The case studies discussed above gave a brief detail about outdoor thermal comfort and how landscaping can influence the microclimate, in reducing the air temperature. Simulation was carried out using Rayman software. Soft landscaping like trees and grass can help us to achieve the outdoor thermal comfort in outdoor spaces.

From the case research it is found at that Tmrt (mean Radiant Temperature) it is the most driving factor in determining the conditions. With the help of these data we can calculate PET for outdoor comfort.

These case studies will further help in carrying out the research work and carry out different assessment method.

4.1 Gurugram city

Gurugram was quoted amongst a few cities referred to as the 'Detroit of India' in the Hindustan Times Business14 section. It is also addressed as 'the Corporate Hub of India' and 'Cyber City' by the residents. These adjectives used for defining the city indicate towards the range and number of work options offered by the city.

Thus rampant urbanization and industrial growth have resulted in high increase in population in last 10 years.

Gurugram's population in last 10 years (2001-2011).

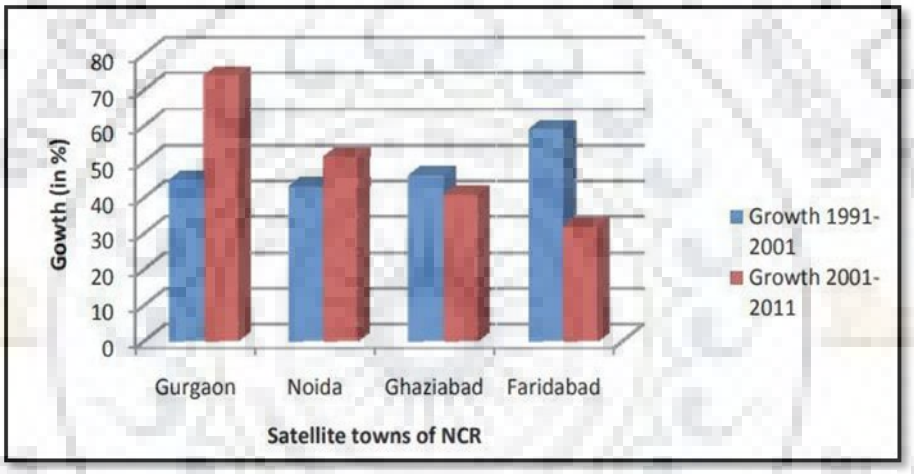


Figure 10: Gurugram Population in last 10 years(2001-2011)

4.2 Location

The district lies in latitudes between 27º39´N and 1748 R. K. Jain, Dr. Kamal Jain and Dr. S. Rehan Ali 28º32´N and in longitudes 76º39´ and 77º20´ E. Gurugram district is adjacent to the Delhi State surrounded by way of Jhajjar, Rewari, Mewat, Palwal and Faridabad districts. It has each oval and elongated form. It lies between 27° 39' 00" North and 28° 32' 25" North latitudes and between 76° 39' 30" East and seventy seven° 20' forty five" East longitudes.

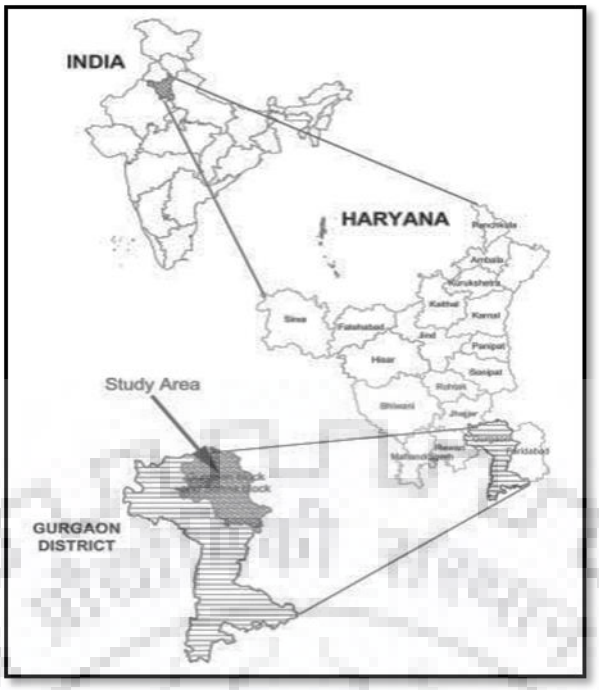


Figure 11: Location Map of Gurugram City

4.3 Topography

Gurugram district has a rolling undeniable extensions through Aravallis. Aravalli levels offshoot alongside the western part of the district and similarly upto the countrywide Capital, Delhi inside the north-east. The region is sub divided into two elements Gurugram :- Sohna Undulating plain with Aravalli Offshoots. Gurugram plain spreads over northern and north-western components of Gurugram tahsil and entire of Pataudi tahsil.The area is quite homogeneous to Sahibi plain of Rewari district. The whole region is blanketed with rocky surfaces of Aravalli .These landforms make a sequence of flat topped ridges. There may be little cultivation owing to rocky areas, terrible soil cover and roughness of surface. (Gurugram Fact sheets, 2018)

4.4 Drainage

No perennial river can be located in the district. There are very few seasonal streams, smaller in size and are inland. Drainage of semi arid and arid is normal due to the topographic range , the streams flow in unidirection. The Sahibi Nadi, which rises within the Sewar hills of Jaipur (Rajasthan), additionally makes its presence in Gurugram tahsil earlier than losing itself in the topographic melancholy of Jhajjar tahsil (Jhajjar district) after flowing in northern course via Rajasthan kingdom and Rewari district. (Gurugram Fact sheets, 2018)

4.5 Climate

Gurugram reports dry climate with hot summer time and cold winter except in the course of the monsoon. The town reports 4 awesome seasons - spring (February - March), summer (April - August), fall/autumn (September - October) and winter (November - January. Summers, from early April to mid-October, are usually hot and humid, with a median day by day June excessive temperature of 40 °C (104 °F). The season reports warmness indices easily breaking 43 °C (109 °F). Winters are bloodless and foggy with few sunny days, and with a December daylight average of 3 °C (37 °F) The average annual rainfall is about 714 millimetres (28.1 in). which is received from July to Septmber.Temperature begins growing in March. (Statistical abstract, Haryana, 2001-2002). (Gurugram Fact sheets, 2018)

4.6 Demographic

Gurugram is the 4th largest populated district of the nation containing 1,514,432 individuals and bills for 6% of the overall population in 2011 Census.. The growth is astonishingly higher inside the district throughout 2001-2011 at 73.1 percent in contrast to increase fee of populace for the state as a whole, which is 9.9%. The relative higher growth population can be attributed to in migration, due to near proximity to the national Capital. IT hub, industrial development of the district is chargeable for attracting in migration. The density of population in the district has significantly long past as much as 1204 people per square kilometer in 2011 as against 717 men and women in 2001. The literacy rate is 84.7% for the district as a whole that is better than that of the country common of 75.6 percent. Above 68.8% of the entire population of the district lives in urban region which money owed for eleven.8 percentage of the total city population of the state.

4.7 Summary

Due to urbanization Gurugram is facing serious problems in terms of outdoor thermal comfort and poor air quality. Upcoming problems in Gurugram are all due to migration. Gurugram has become an IT hub in recent past which is driving maximum population to the city in terms of employment and social factors. These problems can be mitigated through introducing soft landscaping, which includes certain types of deciduous and coniferous trees.

5. ANALYTICAL FRAMEWORK

5.1 General

The research study is assumed to be broadly divided into 4 major steps. Firstly, classification of land Use Land Cover Map, secondly, retrieval of land surface temperature derivation effect, thirdly co relating Land Surface Temperature with different indices like NDBI and NDVI. Acquiring AQI data from the HSPSCB website and simulating the result in ArcGIS software identifying the hotspot area with the help of Land Surface Temperature Map, doing a questionnaire survey in the identified area and calculating PET for outdoor thermal comfort. Finally, proposing design based solution according to the identified problem which includes green interventions. Detailed flow chart of the methodology used in the research study is given below in Table 21.

5.2 Analytical Framework

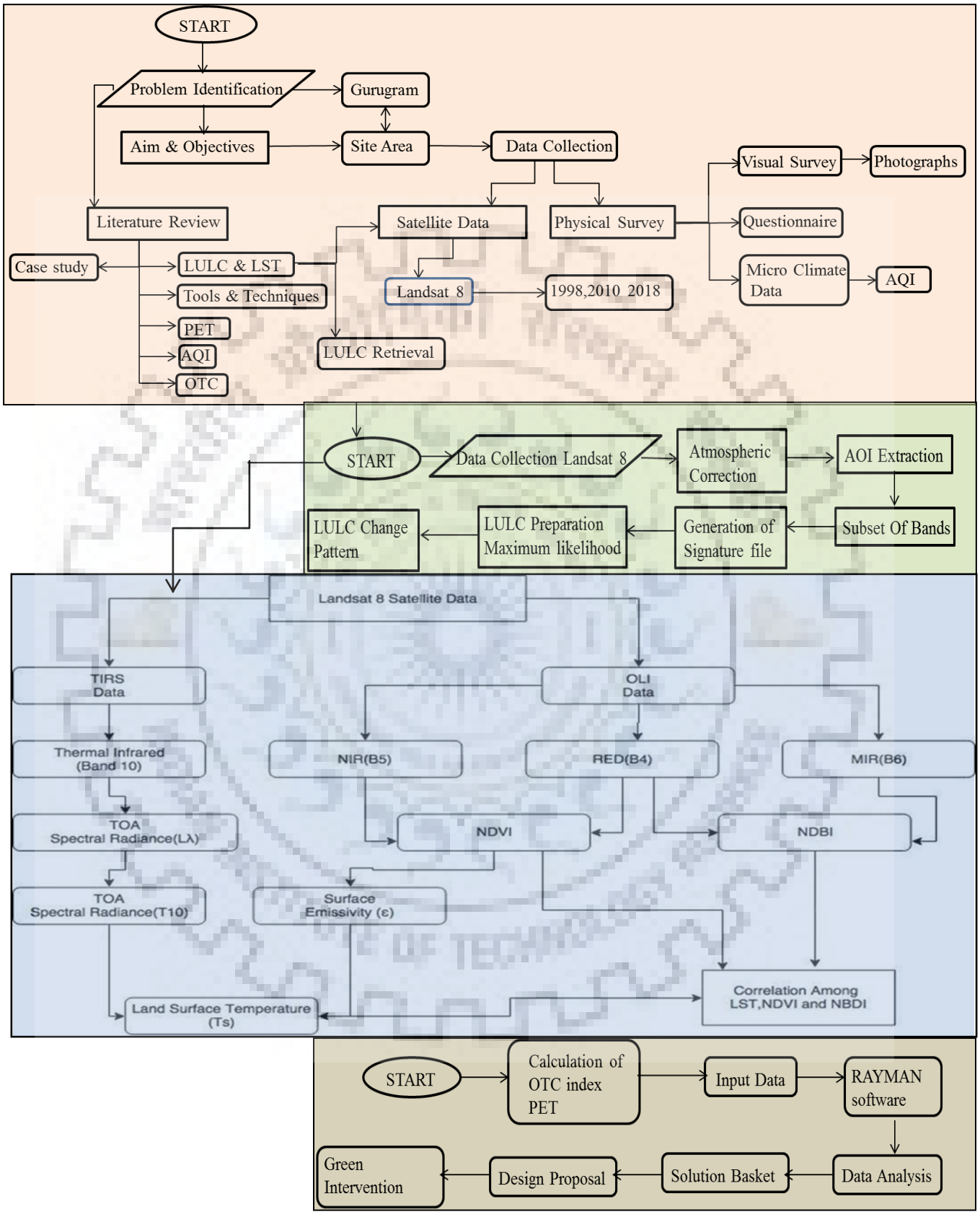


Table 11: Analytical Framework Chart

5.3 Retrieval of Land Use Land Cover Change pattern

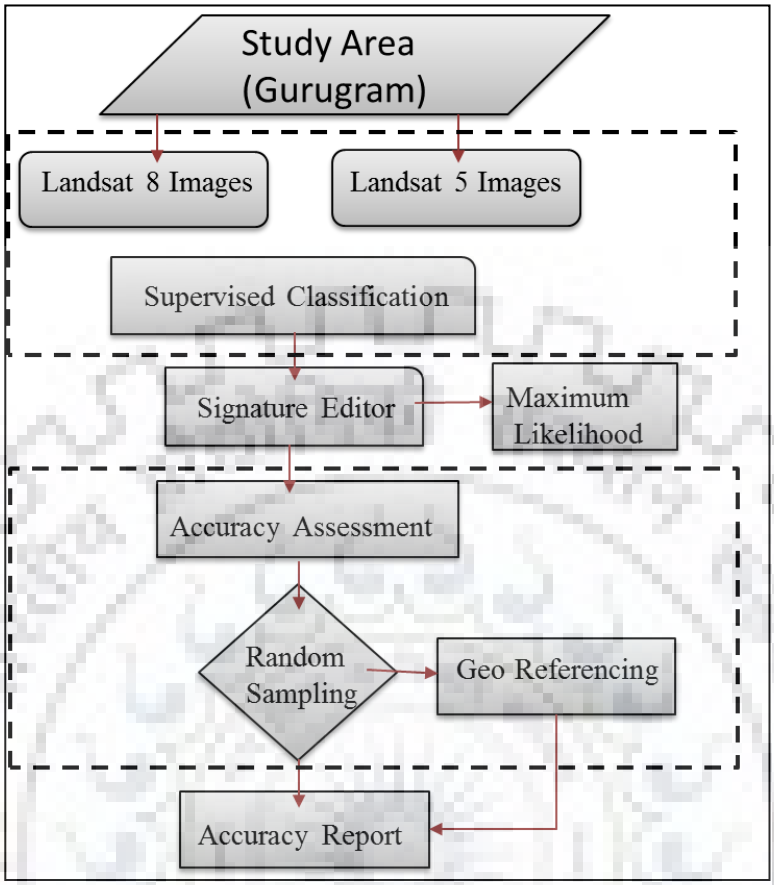


Figure 12: Flow Chart for Retrieval of LULC change pattern

- For the year 1998 the data of **Landsat -5** is used where as for the year 2008 and 2018 **Landsat-8** data is used.
- Landsat 5 band 1,2,3,4,5,7 are used for band combination, later SFCC (standard false colour composite) is prepared by change the band value for red blue and green as band 4, band 3 and band 2. For Landsat 8 band 2,3,4,5,6,7 are used and for SFCC band 4,5,3 is used.
- LULC map is prepared using supervised classification in **Erdas imagine** using parametric of maximum likelihood, considering four classes built up area , agricultural land, vegetation (dense and sparse), bare soil.
- **Accuracy assessment report** is being prepared by generating 70 random points for each year and geo referencing it with ground truth points.

In line with the maximum probability set of rules, a supervised signature extraction was used to change the TM image into 4 training classes: urban built-up land, agricultural land,

vegetation and bare soil. 70 random point were generated for the assessment of the category accuracy, and the Kappa values were all greater than 0.7.

Satellite	Sensor	Path	Row	Acquisition Date	Time (GMT)	Cloud Cover	Resolution (m)
Landsat 5	TM	20	37	30-Nov-2010	15:53:09	0.00	30/120
		32	39		17:23:43	0.00	
Landsat 8	OLI/TIRS	146	40	5-Nov-2018	5:17:54	0.00	30/100
		147	40	18-Mar-2019	5:24:37	0.42	

Table 12: Specification of Landsat TM and OLI/TIRS Data

Instrument	Band	Centre Wavelength (m)	Bandwidth (m)	Spatial Resolution (m)
TIRS	10	10.9	0.6	100
TM	6	11.4	2.0	120

Table 13: Salient Characteristics for Different Landsat sensors

- **Process of Classification**

The process of image classification involves in assigning the pixels of a raster image to predefined land cover classes. The fundamental way of image classification is by means of visual interpretation where in tone, texture, length, form and association are considered (Serra et al. 2008; Qasim et al. 2011, Lillisand and Keifer 2004).

The Land use/Land cover interpretation key the usage of satellite for imagery as according to the manual of national Land use/ Land cowl Mapping the use of satellite Imagery published by (national far flung Sensing business enterprise (NRSA) is given within the table under:

LAND USE / LAND COVER CATEGORY	TONE/COLOR	SIZE	SHAPE	TEXTURE	PATTERN
Built up land	Dark bluish green in the core and bluish in periphery	Small to big	Irregular and discontinuous	Coarse and mottled	Clustered and scattered & non contiguous
Crop land	Bright red to red	Varying in size	Regular to Irregular	Medium to smooth	Contiguous to non-contiguous
Fallow land	Yellow to greenish blue	Small to large	Regular to Irregular	Medium to smooth	Contiguous to non-contiguous
Plantations	Dark red to red	Small to medium	Regular with sharp edges	Coarse to medium	Dispersed contiguous
Evergreen forest	Bright red to dark red	Varying in size	Irregular discontinuous	Smooth to medium	Contiguous to non-contiguous
Deciduous forest	Dark red to red	Varying in size	Irregular discontinuous	Smooth to medium	Contiguous to non-contiguous
River/ Stream	Light blue to dark blue	Long narrow to wide	Irregular sinuous	Smooth to medium	Contiguous , nonlinear to dendritic

Table 14: Land Use Land Cover Interpretation Key

For the present study, supervised classification the usage of Maximum likelihood Classifier (MLC) is carried in ERDAS Imagine software. The maximum likelihood classification algorithm selected because it can

incorporate the statistics of the Training samples earlier than assigning the land covers to each pixel. The MLC is a parametric classifier which assumes that the information for person training are distributed generally. It requires enough spectral education sample statistics for each class to correctly estimate the statistics through the type set of rules. In this study 4 tarining samples of every Land use classes have been taken. The basic sequence followed on supervised classification :

- **Defining of Training Sites:**

Step one is assignment a supervised class is to define the regions on the way to be used as training websites for each land cover classes. That is typically executed by means of the use of the on-display screen digitized features. The created functions are known as place of interest (AOI).The selection of the training sites was primarily based identified in all sources of images.

- **Extraction of Signatures:**

After the training set (AOI) is digitized, the next step is to create statistical characterizations of every information. These are known as Signatures editors in ERDAS imagine 2015. In this step, the intention is to create a signal (SIG) file for every class defined. The SIG files include a selection of information about the land cover training described. After the entire signature had been created, then the SIG record saved as dialog.

- **Classification of the Image (Supervised classification):**

The supervised classification has been implemented after defining training classes. One or a couple of training vicinity turned into used to represent a selected class. At some stage in the supervised classification technique, the complete Signature editor was selected so that it can be used on the classification procedure. Then the classify photograph become selected from the Editor Menu bar, classify/supervised. Non Parametric Rule is used on this type.

Accuracy Assessment of Image Classification

Accuracy assessment is beneficial due to the fact that mapping errors are inevitable. It is vital to estimate the accuracy level of a map with the aid of calculating the wide variety of ground truth that had been categorized correctly. The accuracy of a category is generally assessed by comparing the thematic maps produced with the validation dataset that is believed to as it should be reflecting the genuine LULC. According to Anderson et al., the minimum stage of interpretation accuracy of LULC categories from remote sensing data ought to be at the least 85%. The procedure is a very effective manner to represent accuracy, accuracies of each class are evidently described along with error of inclusion (commission errors) and errors of exclusion (omission errors) given inside the classification.

Overall accuracy, producer's accuracy, user's accuracy and Kappa records are usually mentioned. In this study, accuracy evaluation was achieved for the MLC categorized maps of all 3 time steps: 1998, 2010, and 2018. Stratified random sampling design was adopted for the accuracy assessment. most effective 4 categories, urban built up area, Agricultural land, Vegetation and bare soil had been taken into consideration for accuracy assessment with the minimal of 70 pattern factors for every taken into consideration category, as recommended through Anderson et al., shown in fig. 20.

The assessment of reference facts and type results turned into executed statistically the use of errors matrices. In addition, a non-parametric Kappa test was also done to degree the quantity of category accuracy (Rosenfield and Fitzpatirck-Lins, 1986). Kappa is a degree of settlement among predefined producer ratings and consumer assigned ratings.

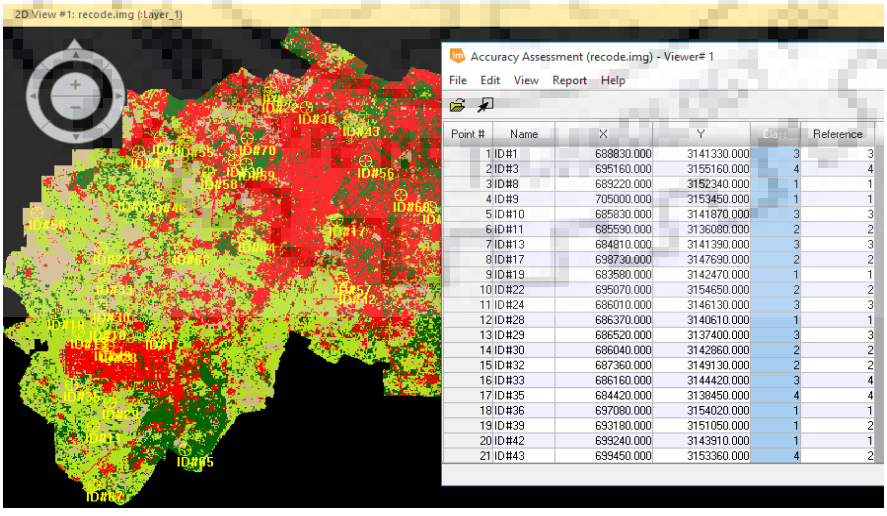


Figure 13: Accuracy Assessment, generation of random points

5.4 Retreival of Land Surface Temperature

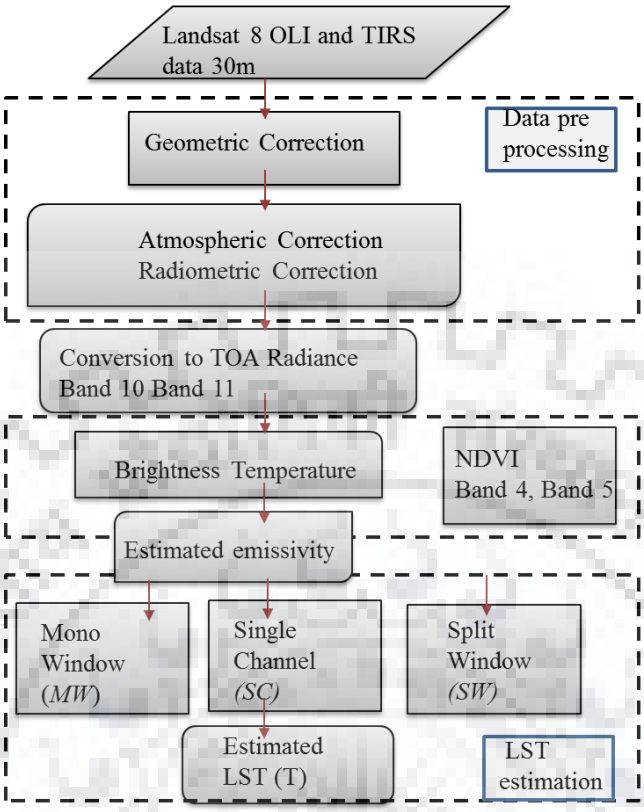


Figure 14: Flow Chart for Retrieval of LST

While calculating Land Surface Temperature from the Landsat-8 satellite, different mathematical algorithms have been used and processed in ArcGIS software. Assessment of LST, from LANDSAT-8 in ArcGIS raster processing concerns the following steps:

1) Conversion of Digital Number to Radiance
2) Converting Radiance to Brightness Temperature
3) Calculating Emissivity

1. **Conversion of satellite digital number into radiance by:**

$$L\lambda = ML * Qcal + AL - Oi \qquad (Eq.4)$$

Where, ML represents the band-specific multiplicative rescaling factor, $Qcal$ is the Band 10 image, AL is the band- specific additive rescaling factor, and Oi is the correction for Band 10.

2. **Conversion of Radiance At-Sensor Temperature by:**

$$BT = K2 // ln\,[(K2/L\lambda) + 1\,] - 273.15 \qquad (Eq.5)$$

Where BT is brightness temperature presented in Kelvin(K), $L\lambda$ is the spectral radiance in $Wm^{-2}sr^{-1}mm^{-1}$; $K2$ and $K1$ are calibration constants. For Landsat 8 OLI/TRS, $K1$ is 774.89 and $K2$ is 1321.08(which is given already in MTL file)

3. **Conversion of Satellite Brightness Temperature to LST by;**

$$T_s = BT/\{1 + \lambda\,(BT/\mathrm{p})\,ln\,\epsilon\lambda]\} \qquad (Eq.6)$$

Where T_s is the LST expressed in Celsius ($_0$C), BT is at-sensor BT ($_0$C), λ is the wavelength of emitted radiance (λ= 11.5 μm) $\epsilon\lambda$ is the emissivity. λ is effective length (10.9 mm), where p is Boltzmann constant (1.38x 10^{-23} J/K) , and ϵ is the emissivity.

When converting satellite brightness temperature into land surface temperature(LST) we require emissivity(ϵ), which can be calculated from NDVI in ArcGIS using the formula given below

$$e = 0.004Pv + 0.986 \qquad (Eq.7)$$

Where ϵ is the emissivity calculated from the proportion of vegetation (Pv) by using following formula:

$$Pv = \frac{[NDVI]-[NDVIs]}{[NDVIv]+[NDVIs]} \qquad (Eq.8)$$

Where, the $NDVI_s$ and $NDVI_v$ are the thresholds of soil and vegetation pixel.

- **Normalized density vegetation index**

The Normalized distinction plants Index (NDVI) is a numerical indicator that uses the visible and close to-infrared bands of the electromagnetic spectrum, and is followed to analyze investigate whether the target being observed carries live inexperienced vegetation or not (Chandra, 2011)The NDVI set of rules subtracts the red reflectance values from the close to-infrared and divides it by the sum of near-infrared and red bands.

$$(NDVI) = \left(\frac{\text{NIR(band5)} - \text{R(band4)}}{\text{NIR(band5)} + \text{R(band4)}}\right) \qquad (Eq.9)$$

- **Normalized built-up density index**

NDBI stands for Normalized difference built-up Index, In contrast to the other land use / land cover surfaces, built-up lands have better reflectance in MIR wavelength range (1.55~ 1.75μm) than in NIR wavelength range (0.76~ 0.90μm). NDBI is very useful for mapping the city built-up regions and has been computed the usage of the equation given below:

$$(NDBI) = \frac{MIR(band6) - NIR(band5)}{MIR(band6) + NIR(band5)} \qquad (Eq.10)$$

5.5 Simulation Software for Outdoor Thermal Comfort (RAYMAN)

For the outdoor thermal comfort assessment, different software can be used for the calculation of the indices as well to carry out simulation in the outdoor spaces. Amongst them, Rayman which RayMan Model - RayMan stands for "radiation on the human body". Developed in 2007 by Matzarakis et al., it can be used for the PET calculation. The three thermal indices PET, SET* and PMV can be calculate in the RayMan model. It is also easily available online.

Hence for carrying out the outdoor thermal comfort evaluation and also to review the influence of landscape in the outdoor spaces, the tools and techniques were developed. They are as follows:

- Site Analysis
- Microclimatic Data Collection Survey
- Questionnaire Data Survey
- Calculation of PET index by RayMan model

RayMan model

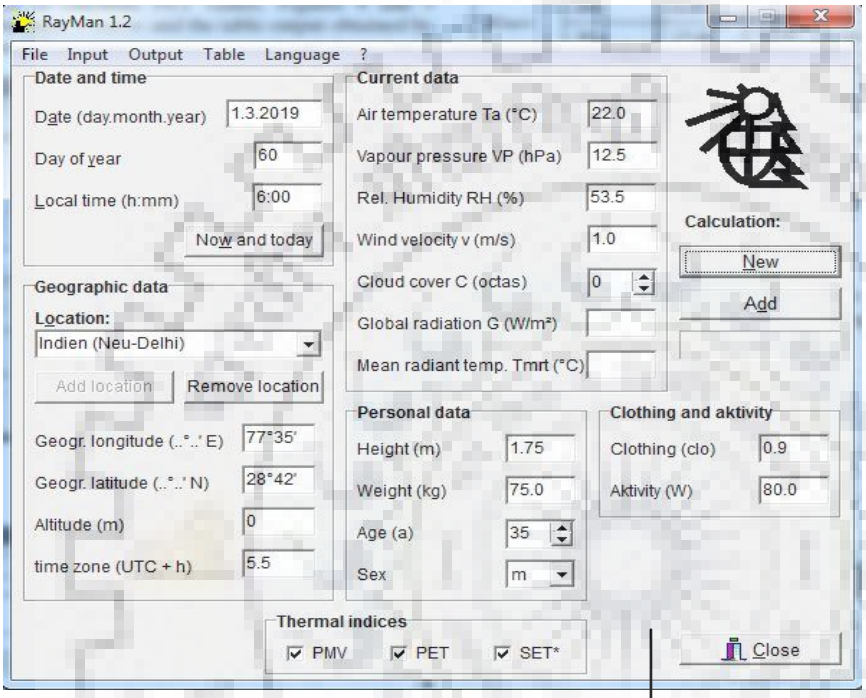


Figure 15: Rayman Model Window

Input Data

Thermal Comfort Index, PET

Air Temperature Relative Humidity Wind Speed

Questionnaire Survey Data

Height Weight Age Gender Clo Value

Metabolic Activity Rate

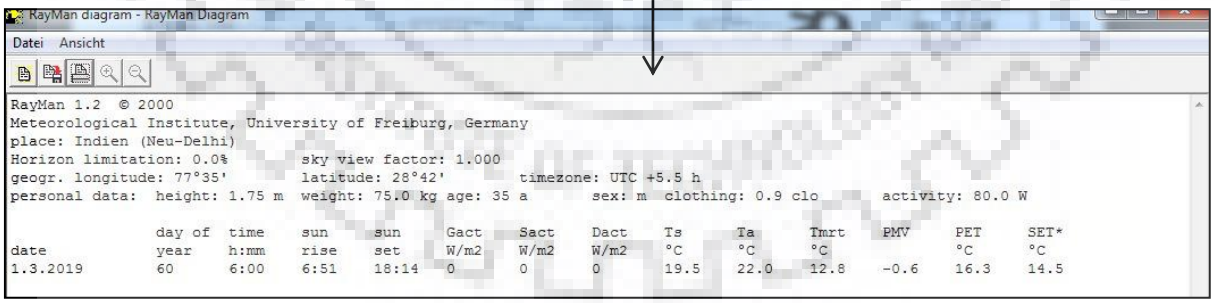


Figure 16: Output of Rayman Model

5.6 Field Survey & Data Used

Equipment used for the collection of Data:

Air temperature, globe temperature and relative humidity were measured using Heat Stress Meters. The device measure temperature and Relative Humidity based on capacitive sensing. The inbuilt black globe in the device measures the globe temperature which has diameter of 50mm .

S.NO.	PARAMETER	MONITORING TYPE	EQUIPMENT
1.	Air Temperature	Continuous	Heat Stress Meter
2.	Globe Temperature	Continuous	Heat Stress Meter
3.	Relative Humidity	continuous	Heat Stress Meter
4.	Land Surface Temperature	Discrete	Remote Sensing
5.	Air Quality Index	Continuous	Monitoring station of AQI, Haryana

Table 15: Equipment used for Data Collection

Figure 17: Heat Stress Meter

6.1 Land Use Land Cover Change Over Time

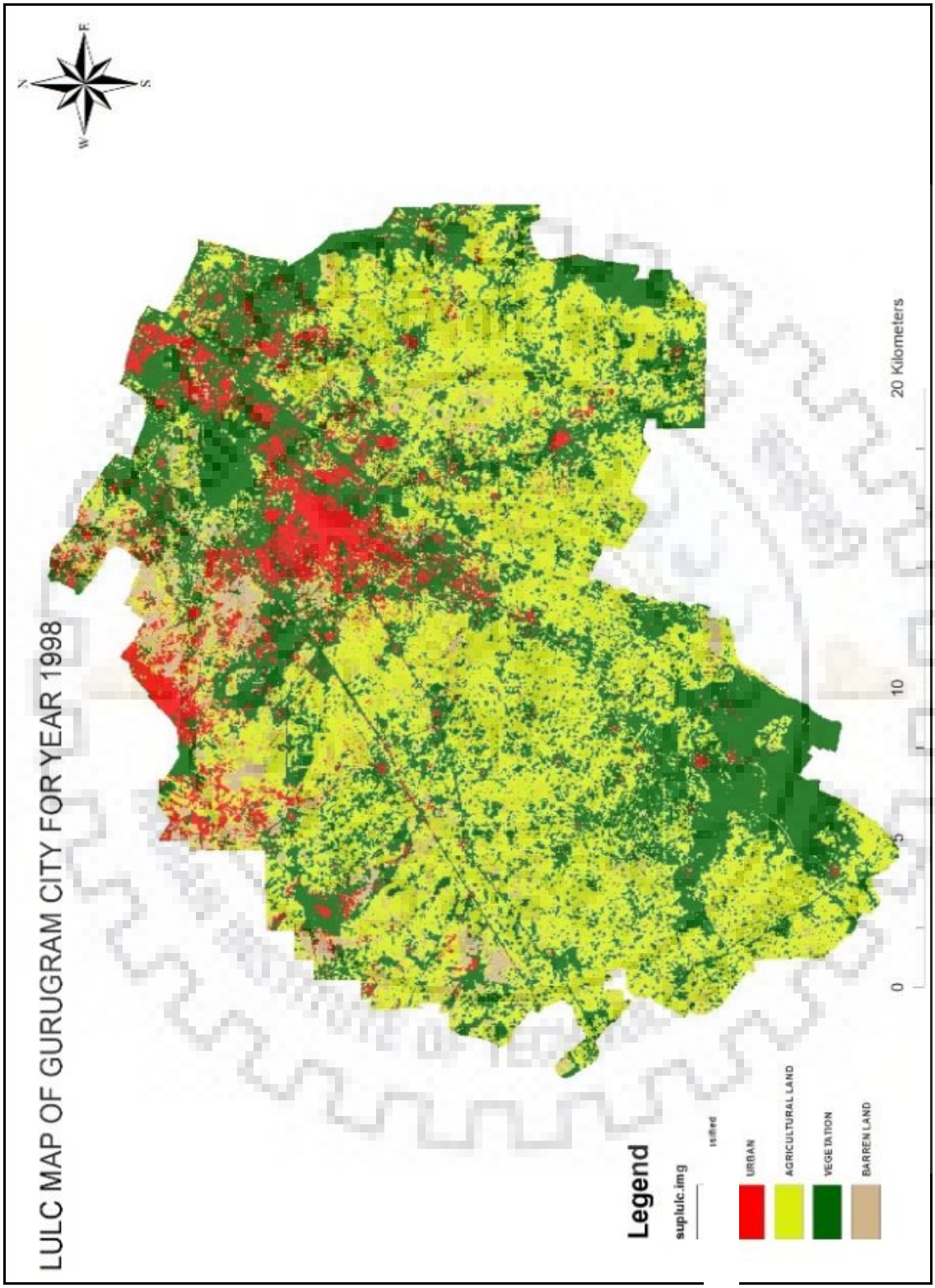
For this examine, a complete of 4 classes of land area were decided on for the LULC evaluation, namely rather built-up, vegetation, agricultural land, and bare soil. The excessive built-up area is cited the place which constructed-up with residential, commercial and commercial sports.
Figures 27-28 illustrate the map after classification of various LULC changes for the Gurugram metropolitan city from the year 1998 to 2018.

The entire accuracy and Kappa coefficients for LULC maps for have been as compared with each of the class strategies of maximum likelihood. The general accuracy and Kappa coefficient, is illustrated in Table 11, Overall accuracy of 1998, 2010, and 2018 is above 80% and 0.8 is the kappa coefficient which indicates the first-rate agreement of the classified images. Accuracy assessment report is being prepared by generating 70 random points for each year and geo referencing it with ground truth points.

The utilization of remote Sensing and GIS tools were helpful in detecting the significance of LULC change that has taken in Gurugram over the span of 10 years.There was a significant increase in the built up area and decrease in vegetation cover. However the overall accuracy was 85%, 81.48% and 83.78% respectively.Fig. 26. Shows the land use land cover of year 1998 and fig.27. And fig.28. Shows LULC classification map of Gurugram city over.

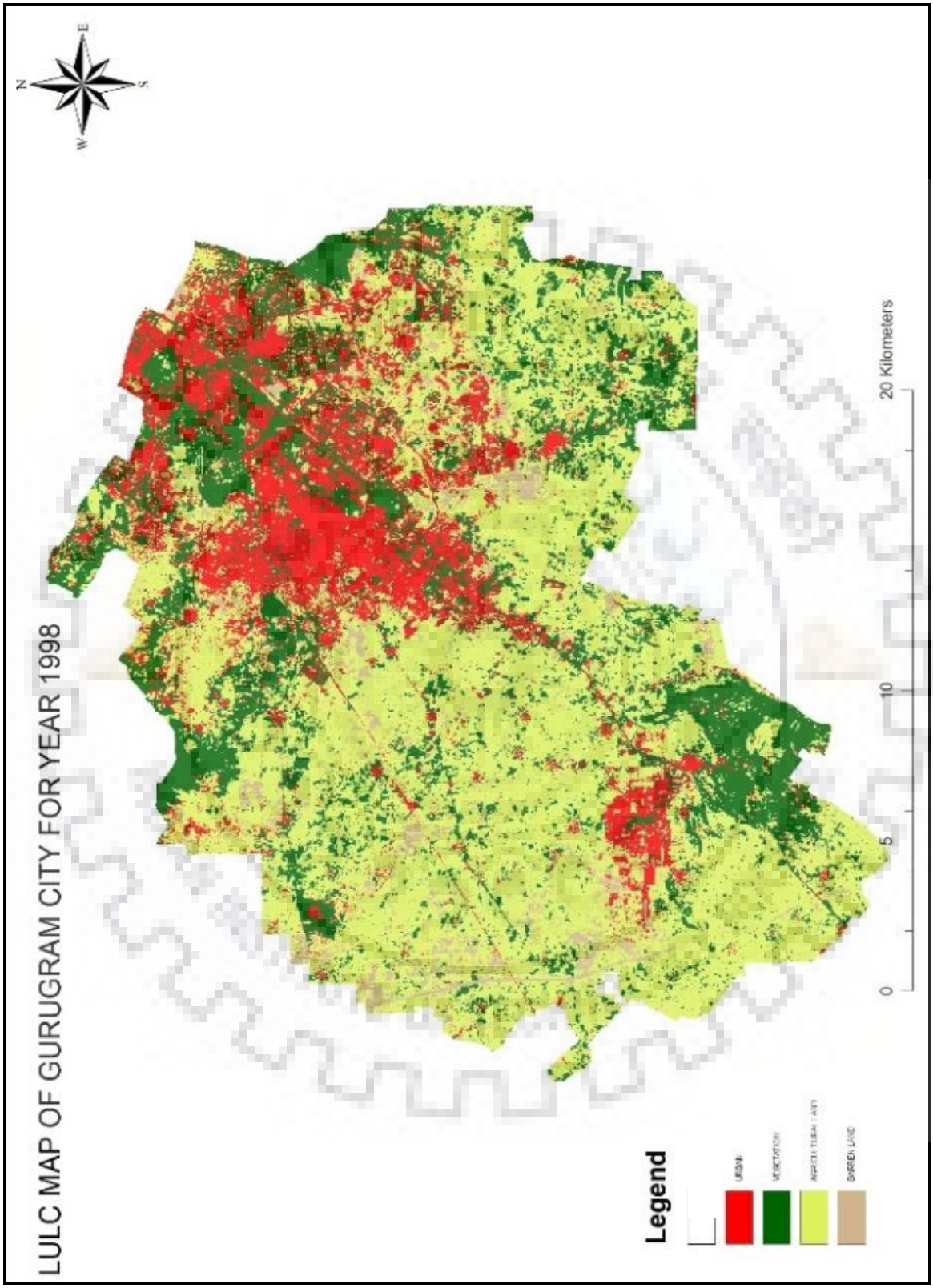
LULC map of the area depict drastic change in urban patch from the year 1998 to 2018. In the year 1998 and 2010 the area allocated for the urban or built up was 95 square km and 250 square km respectively where as for the year 2018 it increased drastically to 243 square km. During the 10 year of period Gurugram experienced about 160% increase in urban built up area. Vegetative land kept on constant trend in urban region or for the study area.

LAND USE LAND COVER MAP OF 1998



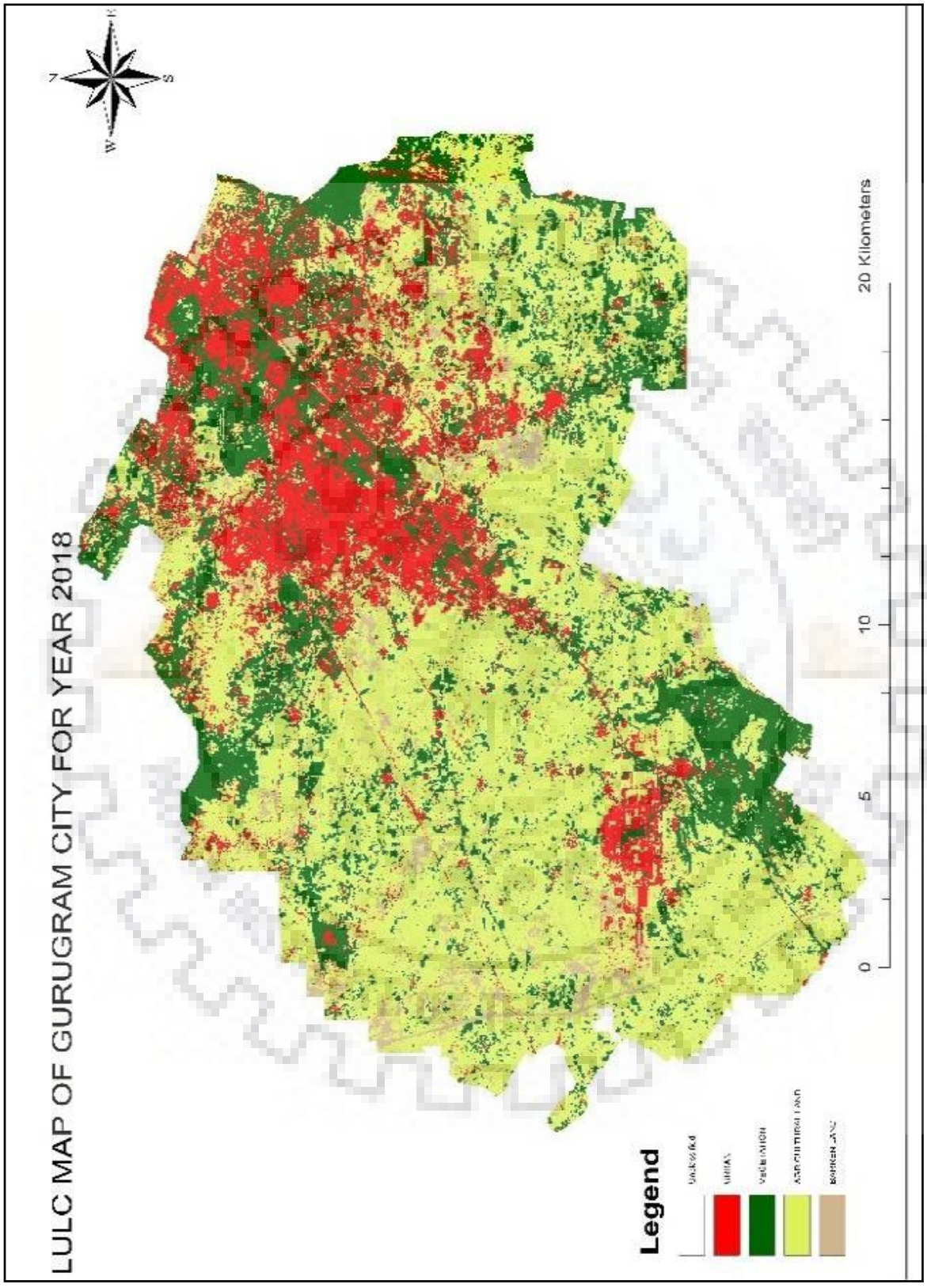
Map 1: Land Use Land cover map of 1998

LAND USE LAND COVER MAP OF 2010



Map 2: Land Use Land Cover Map of 2010

LAND USE LAND COVER MAP OF 2018



Map 3: Land Use Land Cover Map of 2018

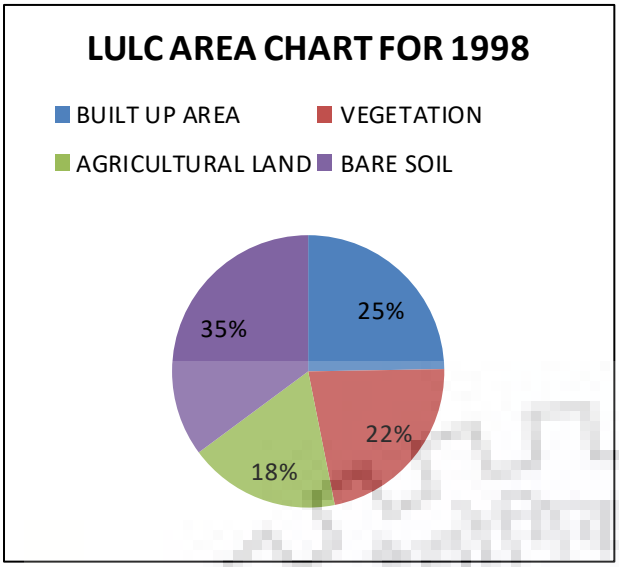


Figure 19: LULC area for year 1998

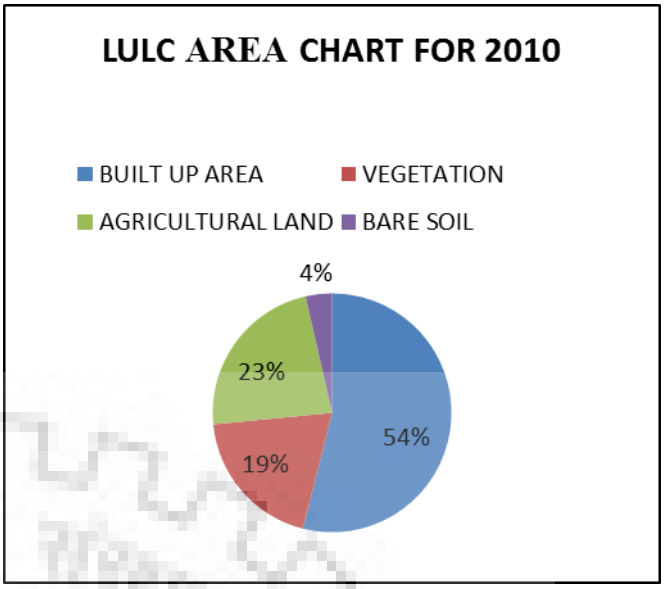


Figure 18: LULC area for year 2010

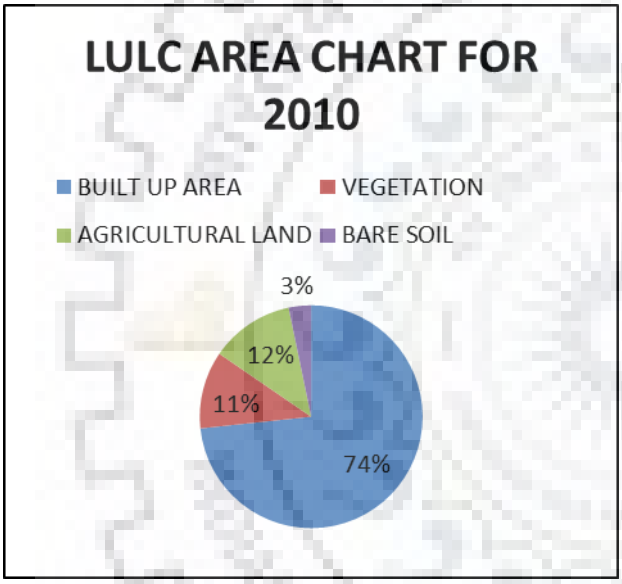


Figure 20: LULC area for year 2010

CLASSIFICATION	AREA	CLASSIFICATION	AREA	CLASSIFICATION	AREA
BUILT UP AREA	95	BUILT UP AREA	120	BUILT UP AREA	243
VEGETATION	85.05	VEGETATION	43.48	VEGETATION	37.27
AGRICULTURAL LAND	69.12	AGRICULTURAL LAND	51.12	AGRICULTURAL LAND	40.35
BARE SOIL	13.5	BARE SOIL	7.93	BARE SOIL	10.79

Table 16: LULC Classification Area Calculation

YEAR	OVERALL ACCURACY	KAPPA STATISTICS
1998	88.78%	0.7568
2010	81.48%	0.7128
2018	85%	0.7924

Table 17: Accuracy assessment result of the classified field

A Kappa coefficient equal to 1 means perfect agreement where as a value close to zero means that the agreement is no better than would be expected by chance. As per categorization of Kappa statistic is widely referenced which reproduced in Table is given below:

S.No.	Kappa statistics	Strength of agreement
1	<0.00	Poor
2	0.00 - 0.20	Slight
3	0.21 - 0.40	Fair
4	0.41 - 0.60	Moderate
5	0.61 - 0.80	Substantial
6	0.81 - 1.00	Almost perfect

Table 18: Rating criteria for kappa statistics

Results and Discussion on Accuracy Assessments

The results of the accuracy assessment showed an overall accuracy obtained from the random sampling process for the image of 1998 is 88.78%, for year 2010 it is 81.48% and for the year 2018 it is 85% described in the table no. 25 above. User's accuracy ranged from 73.3% to 100% and producer's accuracy ranged from 75% to 100%, shown in table.27 below

The large range of accuracy suggests a severe confusion of Barren/bareland with other land cover classes. Moreover, the measure of producer's accuracy (Sensitivity) displays the accuracy of prediction of the unique category. The user's accuracy displays the reliability of the type to the user.

Category Wise Accuracy Assessment Table

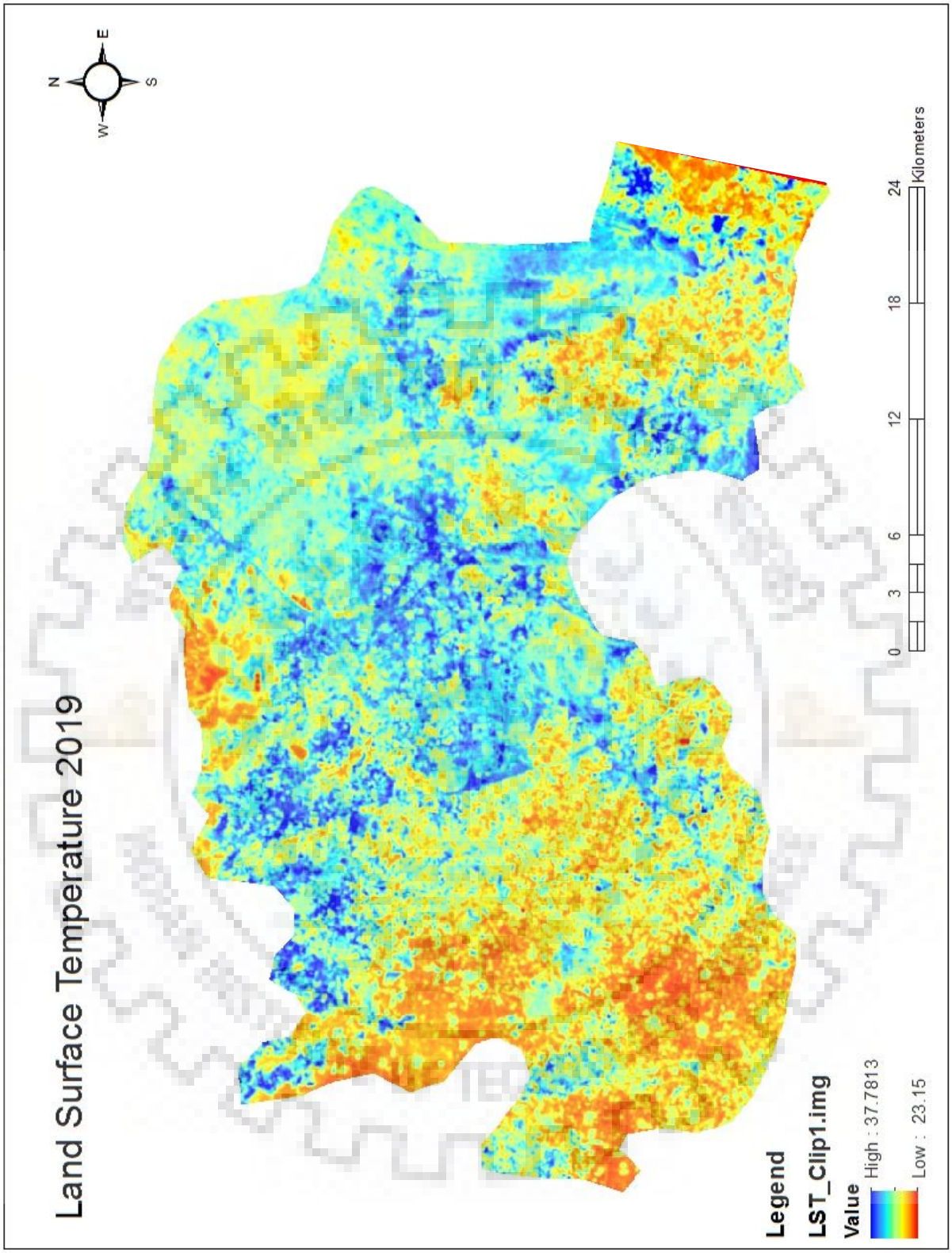
YEAR 2018	Classified Data	Producers Accuracy	Users Accuracy	Kappa
	Built Up area	100.00%	73.33%	0.6322
	Vegetation	83.33%	100.00%	1
	Agricultural Land	76.92%	90.91%	0.8653
	Bare Soil	75.00%	75.00%	0.7222
YEAR 2008	**Classified Data**	**Producers Accuracy**	**Users Accuracy**	**Kappa**
	Built up Area	100.00%	100.00%	1
	Agricultural Land	80.00%	66.67%	0.5909
	Vegetation	100.00%	81.25%	0.6384
	Bare Soil	33.33%	100.00%	1
YEAR 1998	**Classified Data**	**Producers Accuracy**	**Users Accuracy**	**Kappa**
	Built Up Area	60.00%	75.00%	0.7109
	Agricultural Land	87.50%	87.50%	0.7798
	Vegetation	91.67%	78.57%	0.6829
	Bare Soil	75.00%	100.00%	1

Table 19 : Category wise accuracy assessment

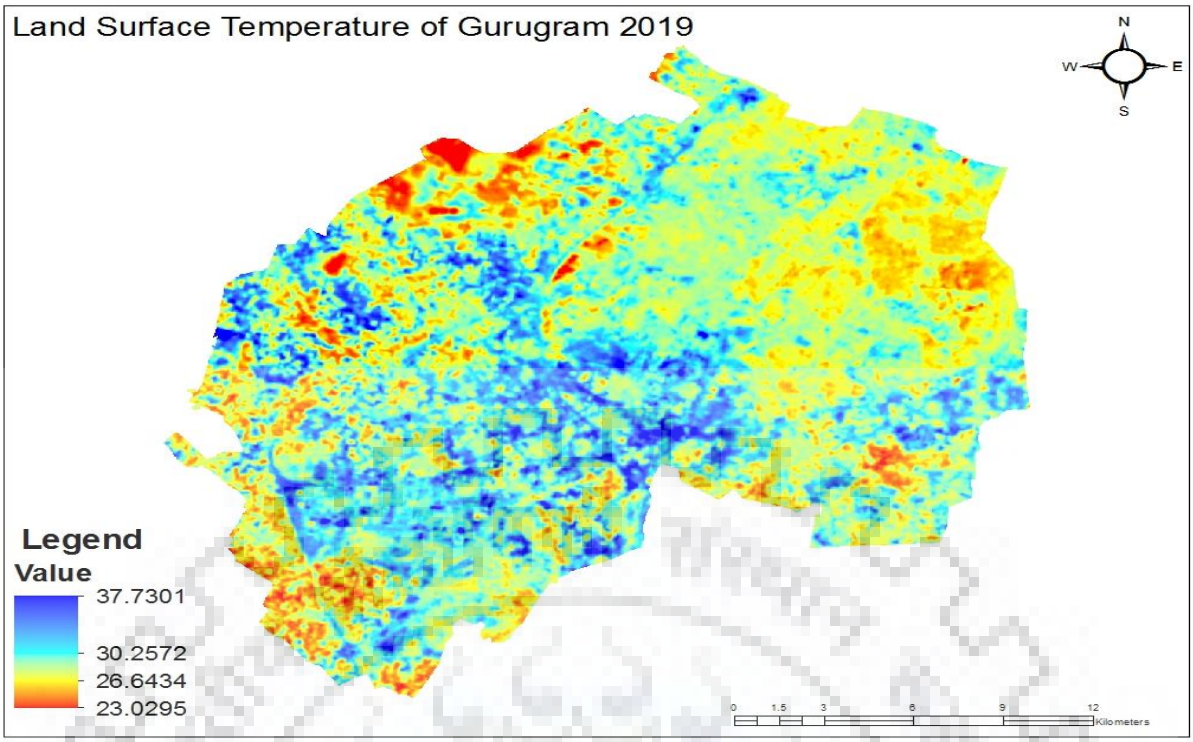
6.2 Land Surface Temperature of year 2019

Simultaneously, the average LST of 2019 detected that urban (high built-up area) areas lied from 37.73℃ to 23.02℃ .The main reason for the retrieved higher LST values than the actual values is the effect of the surface roughness which is not taken into consideration when retrieving the LST value (Pal & Ziaul, 2017 Pal, S., & Ziaul, S. (2017). Detection of land use and land cover change and land surface temperature in English Bazar urban centre. . In other words, LST is influenced by the land surface structure, water content and chemical composition . (Suresh, V and Mani, 2016)

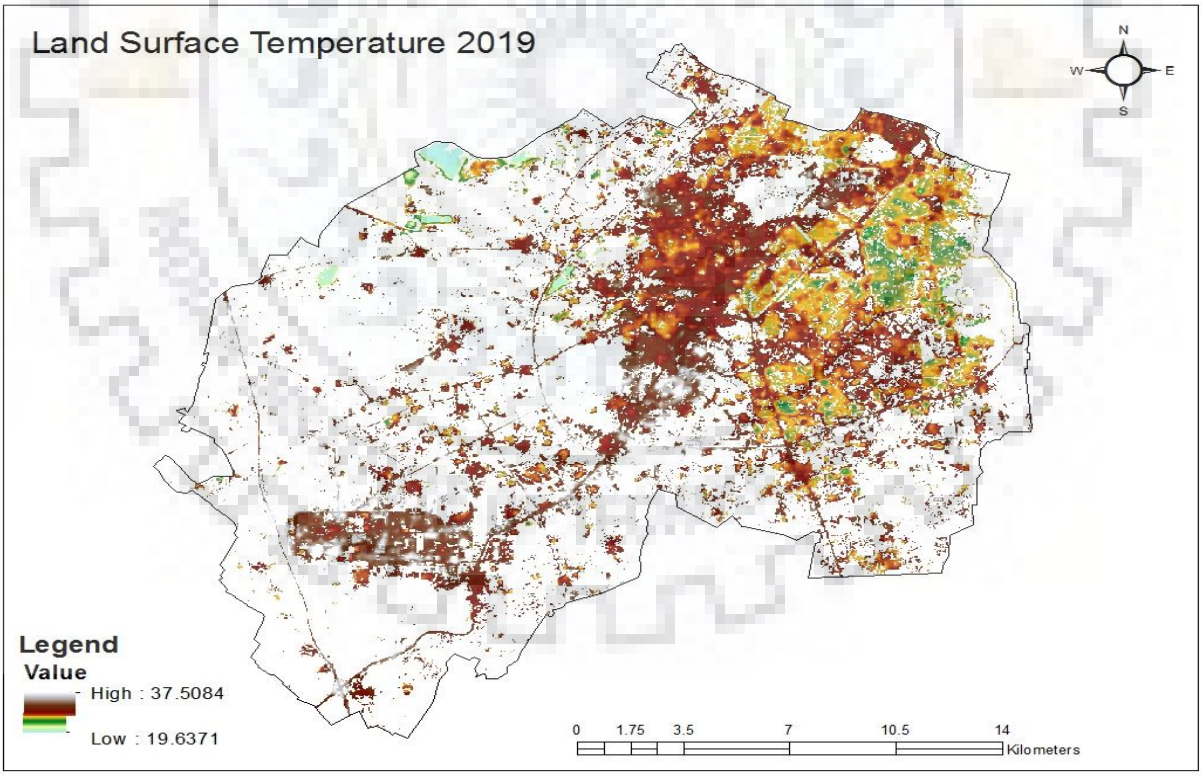
According to Bokaie et al. (2016 Bokaie, M., Zarkesh, M.K., Arasteh, P.D., & Hosseini, A. (2016). Assessment of urban heat island based on the relationship between land surface temperature and land use/land cover in Tehran, who stated that, in order to improve the result of LST, the temperature of every part of the vegetation-ground system must be taken into account. Additionally, the different canopy structures may also react as a factor in affecting the surface temperature.



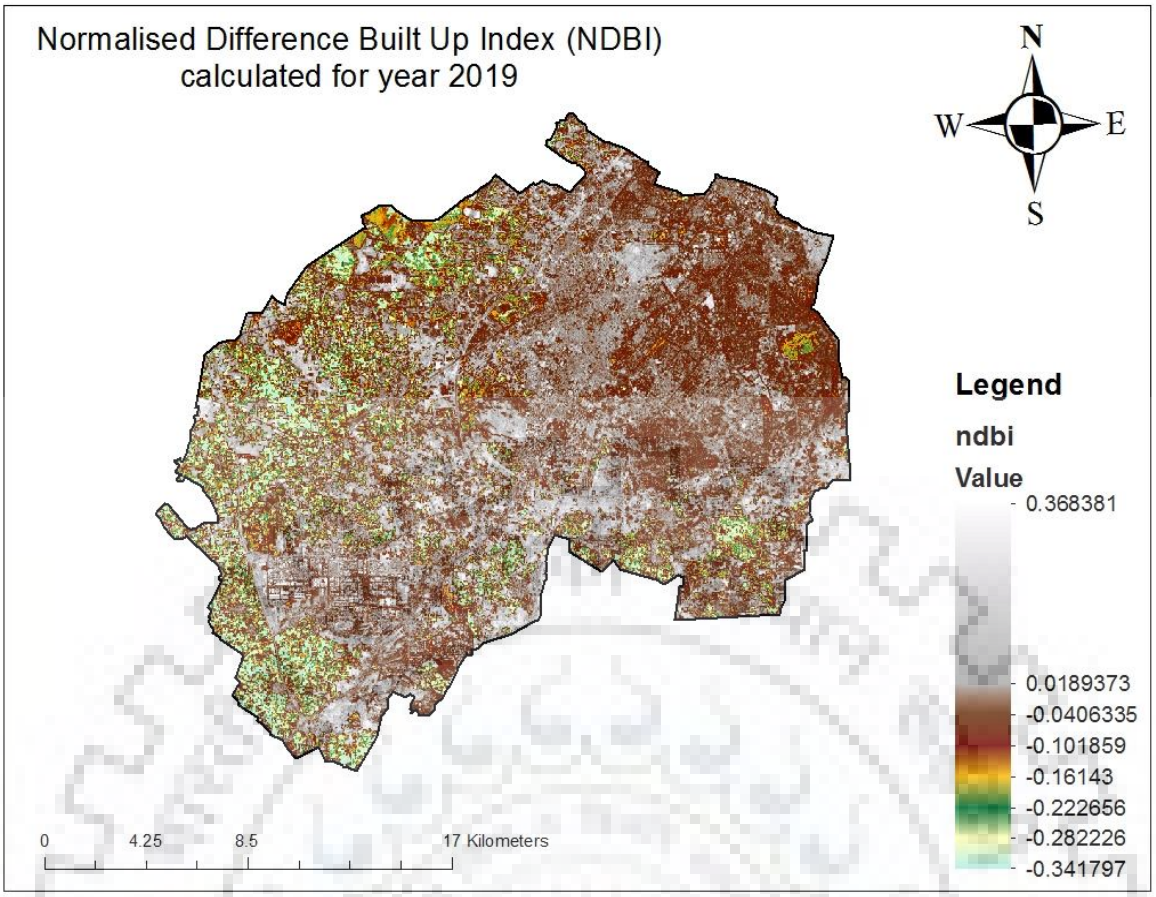
Map 4: LST Map of Gurugram , March 2019



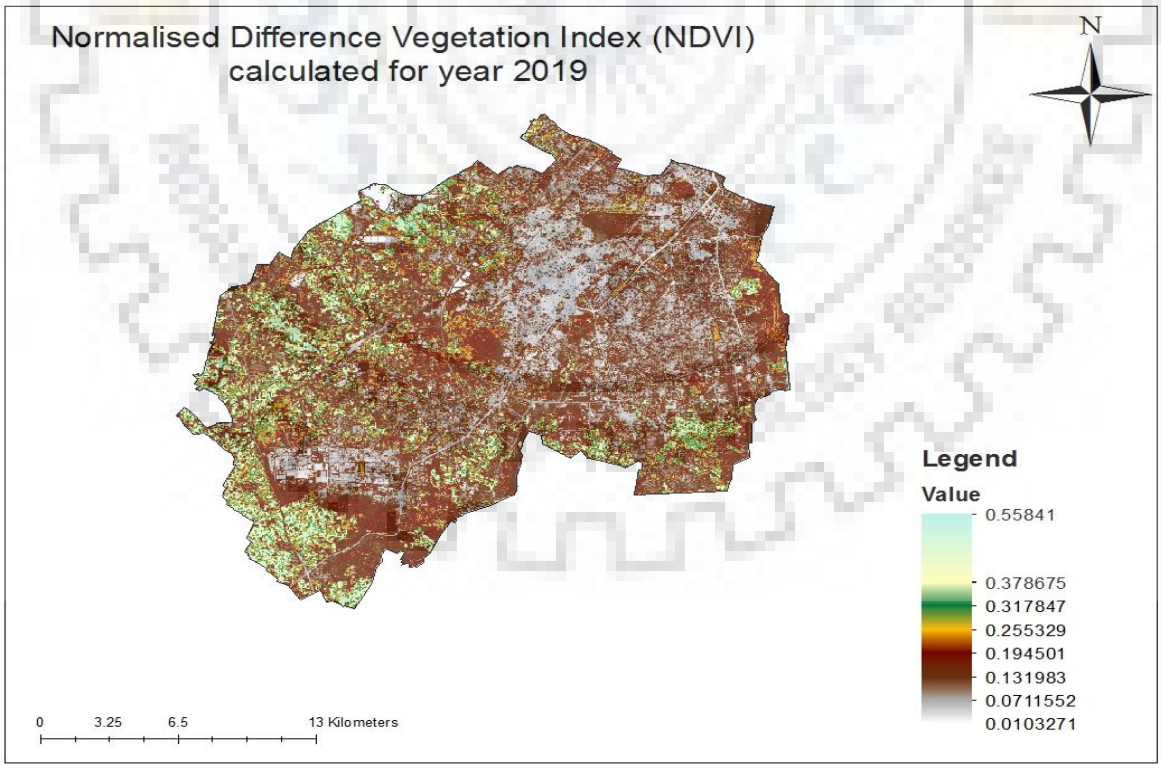
Map 5: LST map of Gurugram with Municipal Boundary, March 2019



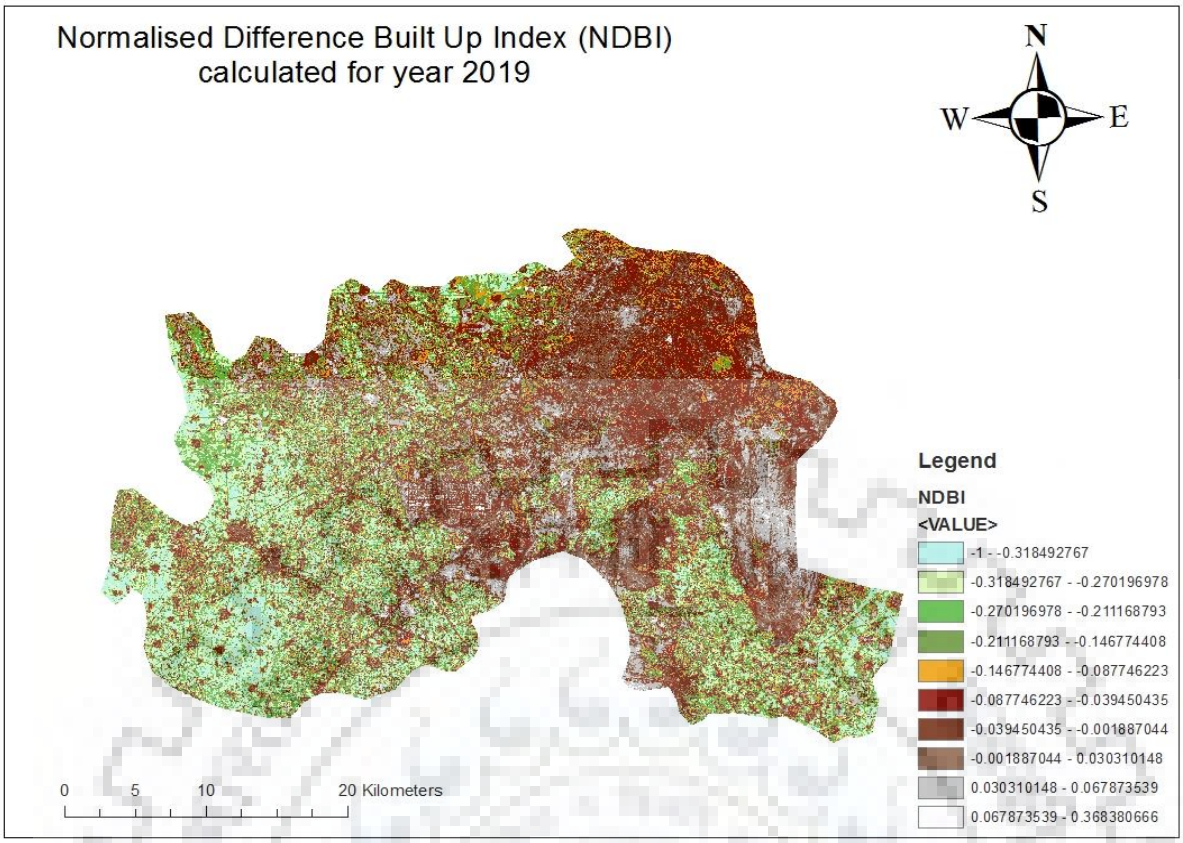
Map 6: LST Map with Built Up Area, 2019



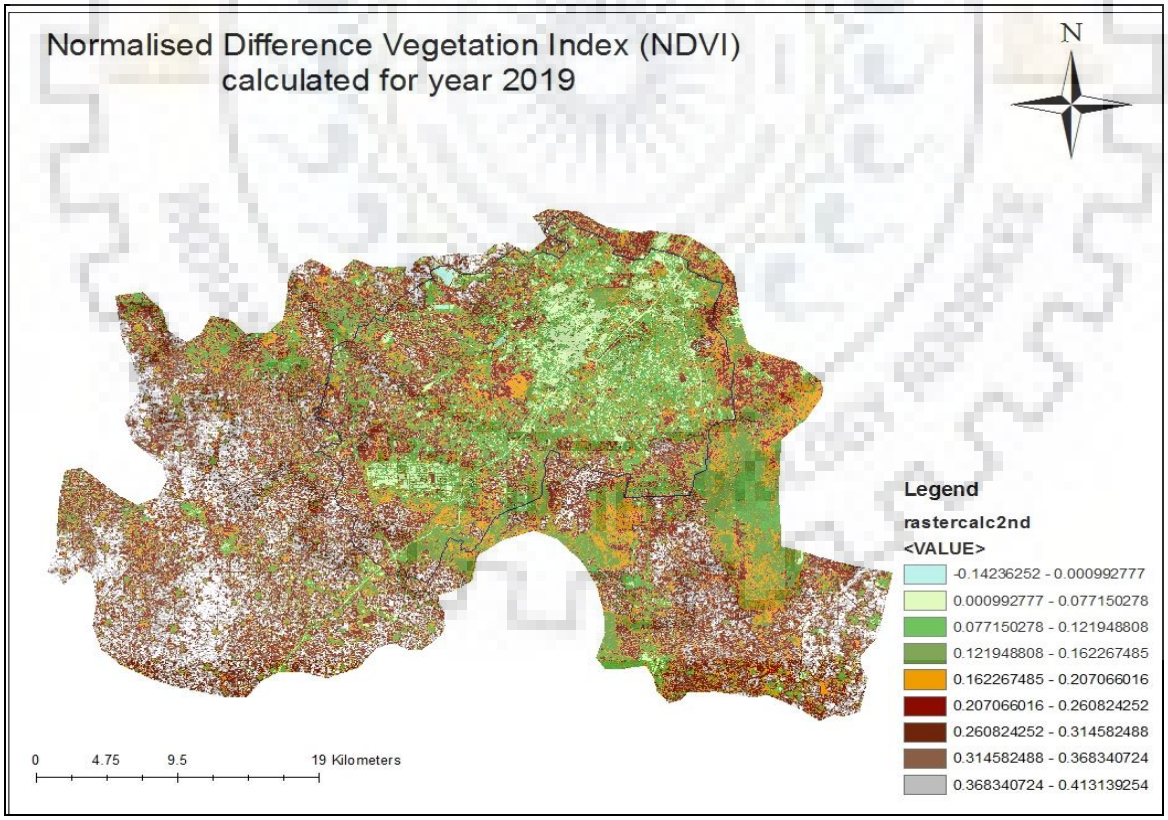
Map 7: NDBI calculated for year 2019



Map 8: NDVI map of Gurugram with Municipal Boundary, 2019



Map 9: NDBI map of Gurugram with Municipal Boundary, 2019



Map 10: NDVI calculated for year 2019

6.3 Relationship between Land surface temperature (LST) and normalized difference build- up index (NDBI)

Land surface Temperature (LST) and Normalized Difference Build- Up Index (NDBI) Linear Regression on LST and NDBI statistics of the year 2019. From the observation, it's miles obvious that the correlation between LST and NDBI have been extensively positive with R 2 0.9697. Built -Up/ Roads shows positives value even as others feature indicates negatives values. From the observation, LST could increase with the density of urban built-up, naked land and cultivated land (no flora) in which the R2 is 0.9697.

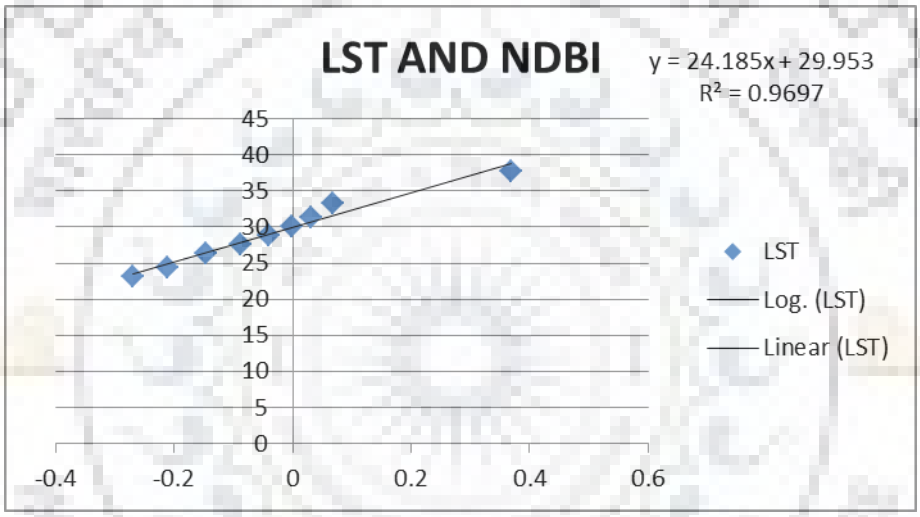


Figure 21: Relation between LST and NDBI

NDBI	LST	NDVI
-0.270196978	23.05273028	0.413139254
-0.211168793	24.33347742	0.368340724
-0.146774408	26.25459815	0.314582488
-0.087746223	27.53534529	0.260824252
-0.039450435	28.81609244	0.207066016
-0.001887044	30.09683959	0.162267485
0.030310148	31.37758674	0.121948808
0.067873539	33.29870746	0.077150278
0.368380666	37.78132248	0.000992777
LST VS NDBI	y = 24.185x + 29.953 R² = 0.9697	

Table 20: LST, NDBI AND NDVI values

6.4 Relationship between Land surface temperature (LST) and normalized difference build- up index (NDVI)

Land floor Temperature (LST) and Normalized distinction vegetation Index (NDVI) indicates a summary of the linear regression between Land surface Temperature 2019 with Normalized distinction flora Index (NDVI). (Complex and Parameters, 1996)

9 random samplings have been carried out that allows you to see the relationship. From the observation, it become apparent that the coefficients value between LST vs NDVI was suitable in vegetation area with R2 0.42 but, the coefficient value for water, built-up / roads, grassland, cultivated land, were small due to presence of water at the which cause the negative values. The correlation between LST and NDVI of the year 2019 become R2 = 0.972

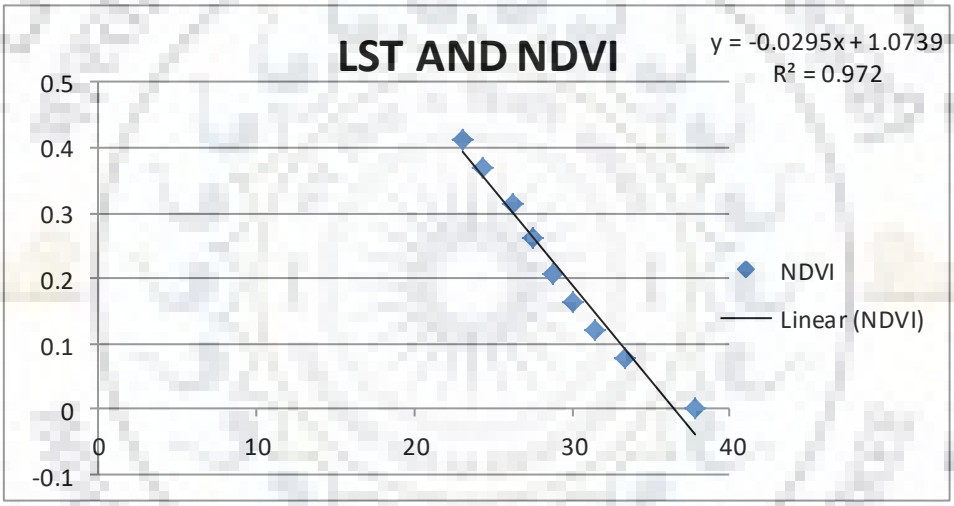
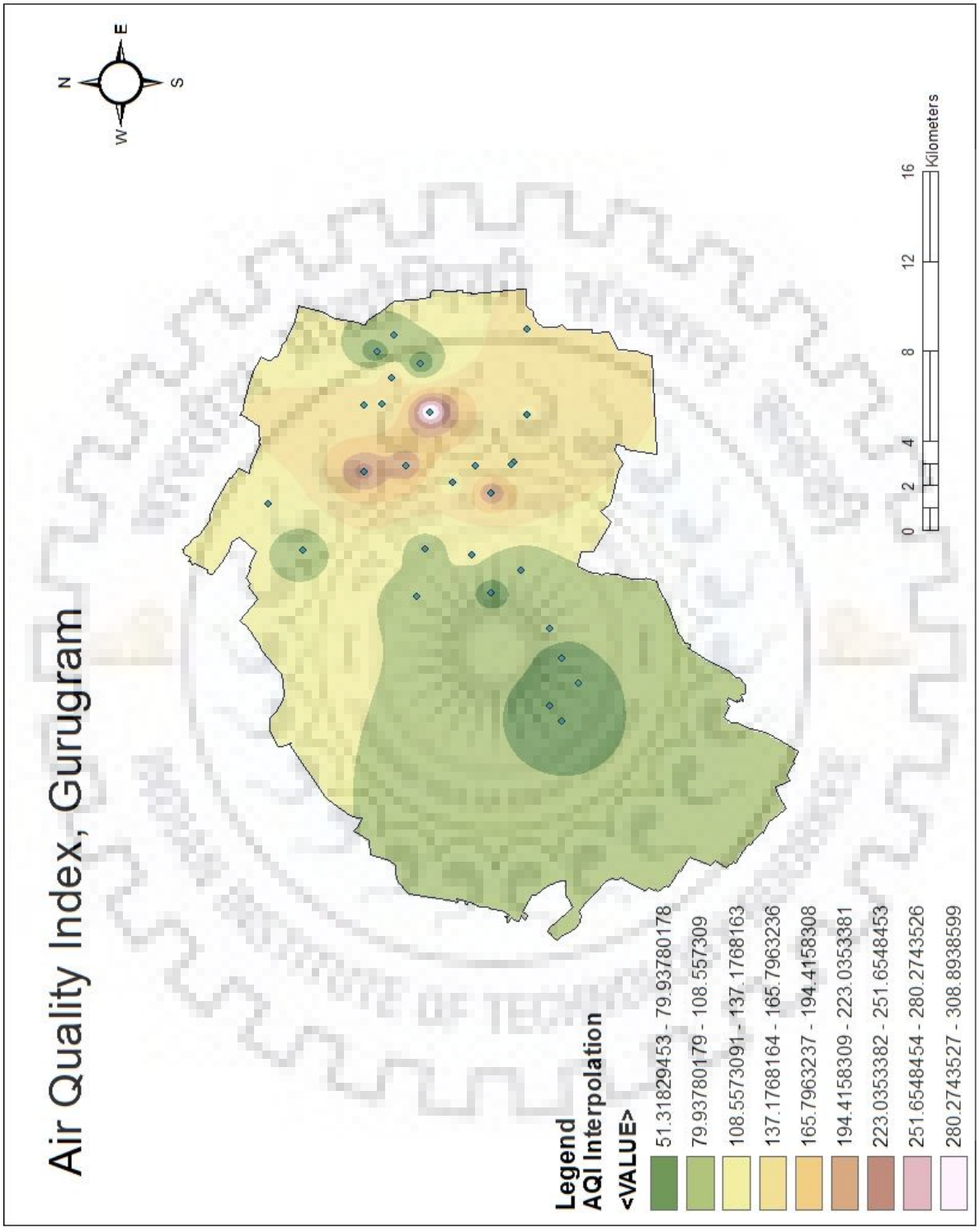


Figure 22: Relation between LST and NDVI

NDBI	LST	NDVI
-0.270196978	23.05273028	0.413139254
-0.211168793	24.33347742	0.368340724
-0.146774408	26.25459815	0.314582488
-0.087746223	27.53534529	0.260824252
-0.039450435	28.81609244	0.207066016
-0.001887044	30.09683959	0.162267485
0.030310148	31.37758674	0.121948808
0.067873539	33.29870746	0.077150278
0.368380666	37.78132248	0.000992777
	LST VS NDVI	Y= -0.0295x + 1.0739 R² = 0.972

Table 21: LST, NDBI AND NDVI values

6.5 Gurugram Map showing areas with poor air quality index



Map 11: AQI Interpolation Map for March, 2019

6.6 Simulation Results for Rayman Model

A questionnaire survey was conducted simultaneously on the site with weather measurements. In total 200 people responded to the survey. The survey consisted of three sub sections where firstly they were enquired about demographic information like clothing, age/ sex, and activity level. Second part of the survey consisted of their thermal sensation their preferences and comfort ability issues and microclimate data like wind, relative humidity and sun referring to thermal ASHRAE scale given in fig.3. Lastly the third section enquires about people visiting to park. The survey was done according to the people who were visiting the park which was from afternoon till late evening .i.e., from 3:00 pm – 8:00 pm.

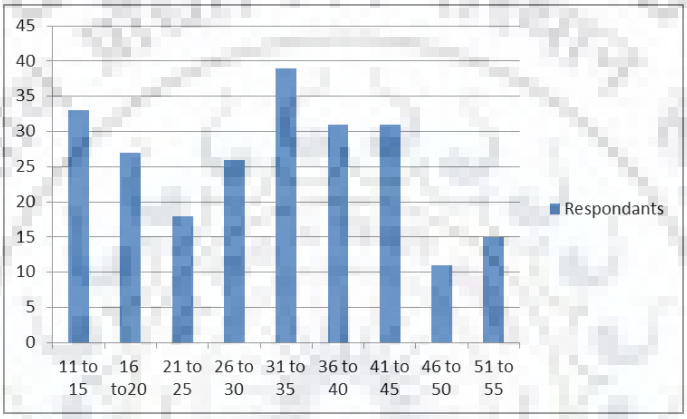


Figure 23: The percentage of respondents by age group

For Sector 15 Gurugram, Haryana

During the survey thermal sensation was enquired from the visitors who were visiting the park. The result of TSV is show is shown in the fig.22.below. Around 60 numbers of respondents felt hot and larger group of people responded towards warm and only 10 people felt comfortable with the temperature.

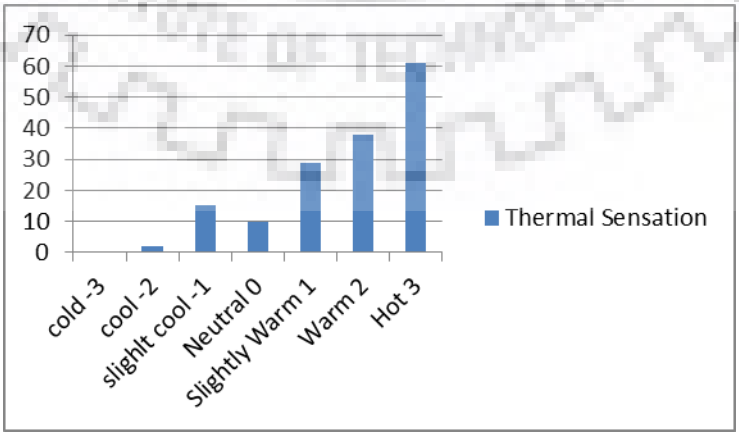


Figure 24: Distribution of number of thermal sensation votes (TSV)

For Sector 12 Gurugram, Haryana

Simultaneously, the TSV survey was performed for sector 12 of Gurugram, Haryana. The result is shown below in fig. 23. More than 35 respondents reported that they felt warm and around 33 respondents stated that they just felt slightly warm. .Responding to the question, if they are feeling comfortable around 16 felt the environment neutral.

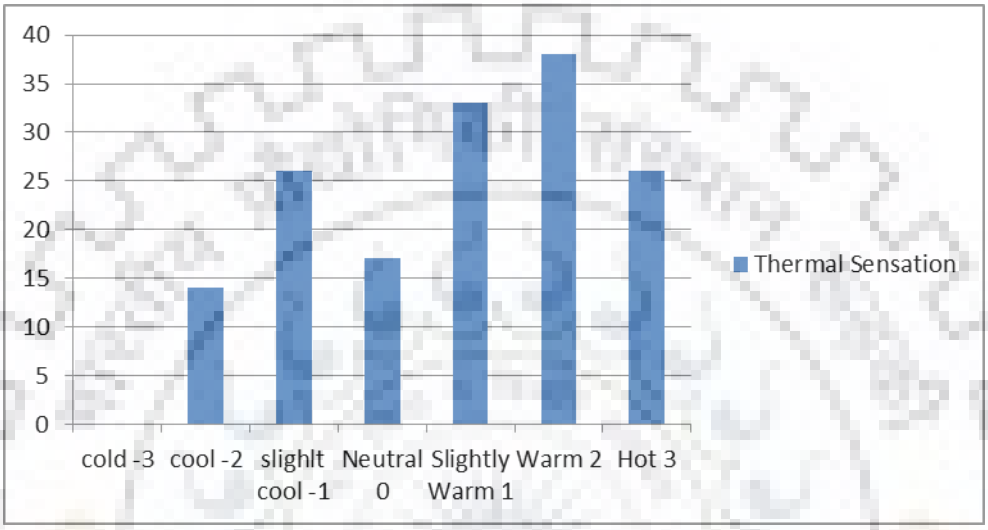


Figure 25: Distribution of number of thermal sensation votes for sector 12

For Sector 6 Gurugram,Haryana

The TSV result for sector Gurugram, Haryana is shown in the fig.24 36 number of visitors reponded that they felt hot. There was a closeness in the result of neutral and slighlty warm, as two largest groups of votes were feeling slightly warm and neutral.

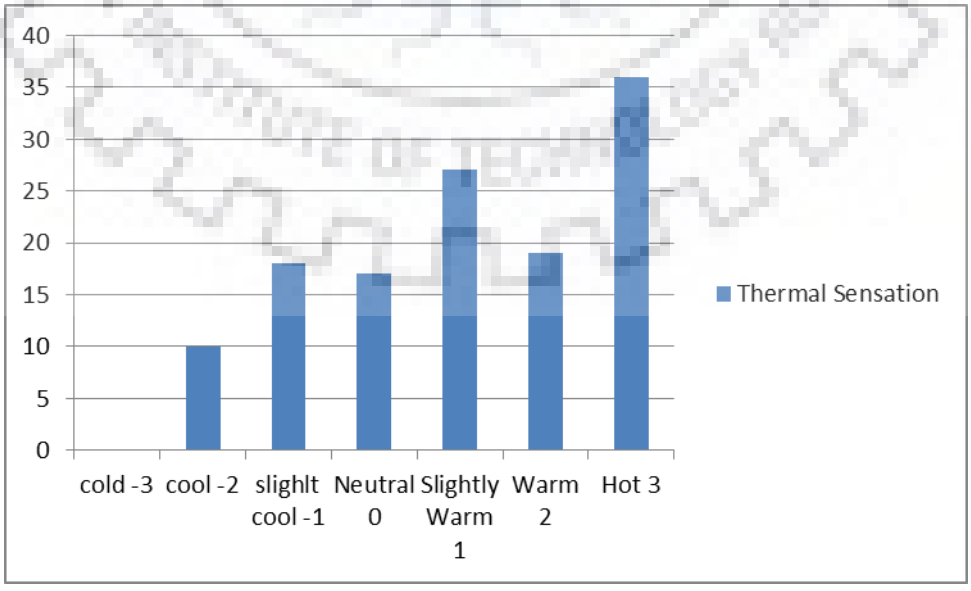


Figure 26: Distribution of number of thermal sensation votes for sector 6

PET Result for Sector 15 Gurugram, Haryana

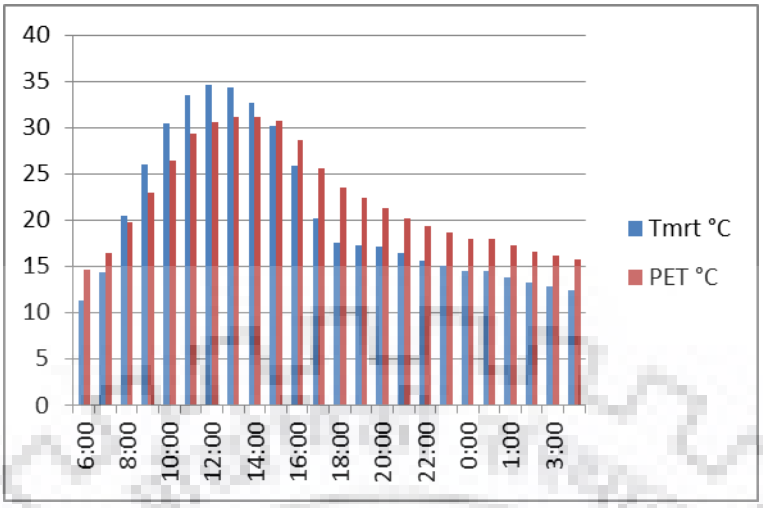


Figure 27: PET result for sector 15, Gurugram

PET Result for Sector 6 Gururam, Haryana

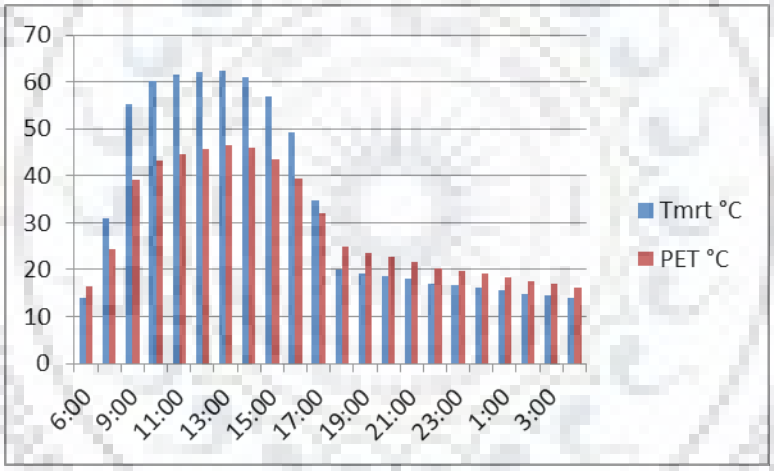


Figure 28: PET result for sector 6, Gurugram

PET Result for Sector 12Gurugram, Haryana

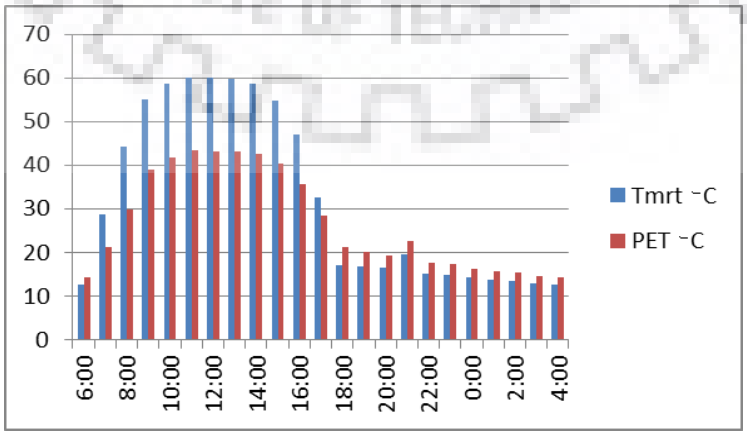


Figure 29: PET result for sector 12, Gurugram

6.7 Summary

The impact of land use/cover modifications (Kiyoshi Sasaki, 29 June - 3 July 2009)

The unique classified images of Gurugram depicting four kind LULC for the years 1998, 2010 and 2019 are shown in Fig. 7-eleven. In the span of approximately 10 years, massive adjustments in LULC pattern can be determined. The metropolis has increased in phrases of constructed-up area. A radially outward growth from the earliest urban establishment may be referred to over the years.

The impact of land use/cover changes on LST

The digital remote sensing method provided a measure of the magnitude of surface temperatures of the entire metropolitan area. In this study, we selected three Landsat images, i.e., the Landsat 8 OLI/TIRS images on Mar. 18, 2019 (the early summer).

It was found that average surface temperature (Mean ± S.D.) was about 37.73 ± 23.02 ˚C of Gurugram in 2019. Observed result showed the maximum temperature in the core of city where maximum built-up area/urbanization has taken place with 37.16 ± 19.6371˚C when compared with the municipal boundary of Gurugram city.

Figs.16-18 shows the increasing extent of LST over the study period. In 2019, the areas with higher surface radiant temperature were mainly located in the central urban area.

Relation between LST NDBI and NDVI

NDVI has been used widely as an indicator of vegetation abundance to estimate LST of Gurugram 2019. However, for other LULC classes, it is not effective index to correlate with LST. By employing positive relationship were found on NDBI and LST.

In addition, this process indicated that, land surface temperature increases in correlation to significant increase of impervious surface on the area. In conclusion, the correlations between land surface temperature with NDVI, NDBI and LST can be used as an indicator in monitoring urban thermal environment.

Simulation Result of PET and AQI

It was observed that people were not feeling comfortable during the summers in the park. Less than 40% of people felt neutral when asked to respond for outdoor thermal comfort. AQI data extracted from HSPCB website for 1 month showed that sector 15, 12 and sector 6

have poor AQI. The analysis of thermal comfort through Physiologically Equivalent Temperature (PET) across the three study outdoor locations reveals that green environments like urban parks are uncomfortable. The mean of the PET inside the sector 15 park during the survey was 38.8 °C, which is close to "hot" thermal perception. For sector 6 park, it was 43 °C, which is also equivalent to be perceived as "hot". In sector 12 park , the mean of PET was 41.6 °C, which also comes under the category of "hot" thermal perception of the environment (Potchter *et al.*, 2018).

In the present study of urban parks in tropical climate, the Tmrt and PET appeared to be significantly related to the tree canopy cover ($p < 0.001$). 10% tree canopy cover in a park lowers Tmrt by about 0.7 °C and lowers PET by about 0.8 °C. Further, it is estimated that high percentage canopy cover (say, 70%) reduced Tmrt by 2.2 °C and PET by 2.6 °C. This estimate is comparable to the surface temperature reduction of 2.8 °C by dense tree cover in tropical city(Ali, Patnaik and Madguni, 2017). This indicated the importance of vegetation shade in providing thermal comfort.

7.1 General

The monitored effects verify the presence of increase in air temperature and poor air quality in different pockets of the metropolis.

This is because of numerous motives which include:

1. Low Green cover: Low evapotranspiration and reduced shading results in low Relative Humidity, and excessive Air Temperature.
2. Increased impervious surfaces: Greater warmth absorption ensuing in higher temperatures.
3. High density and excessive H/W ratios, with high-emissivity finishes: multiplied night time temperatures because of warmth trapped in street canyons.
4. Anthropogenic heat rejected from air conditioned buildings and site visitors on roads.

Presently most of the prevailing byelaws and urban making plans techniques do not consist of mitigating components. therefore, based on this observe, the following urban making plans interventions are recommended for future city growth of Gurugram city with a purpose to assist prevent in increasing the temperature gradient and assist in improving air quality via inexperienced interventions.

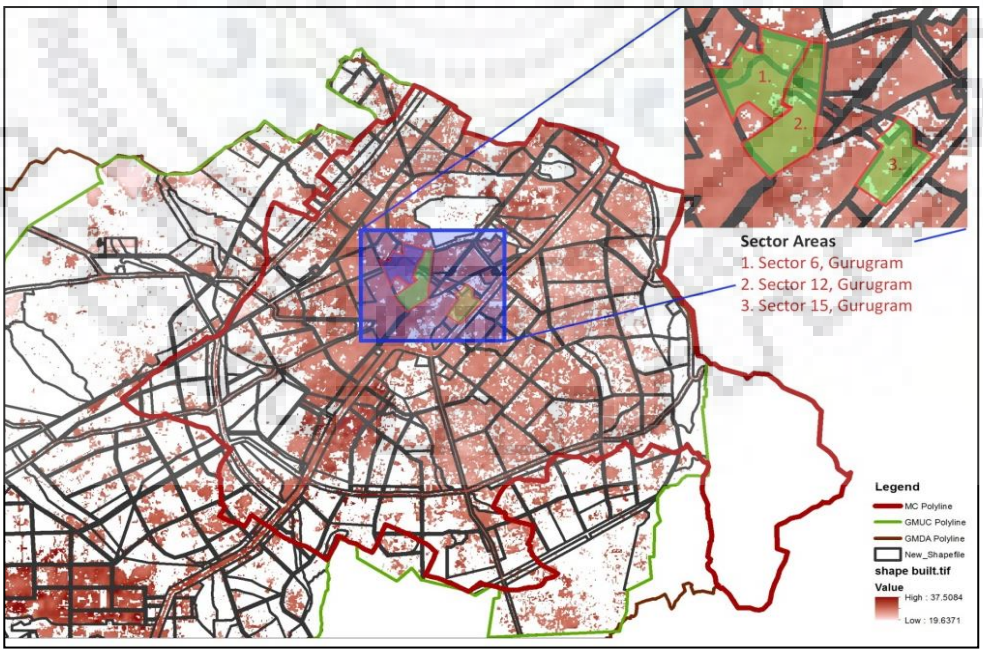


Figure 30: Location Map for Identified Parks in Gurugram, Haryana

7.2 Selection Criteria

	Sector 6	**Sector 12**	**Sector 15**
Size	~38,700m^2	~31,500m^2	~95,700m^2
Shape			
Location	Gurugram Village Park	West Rajiv Nagar Park	Citizen Park
Coordinate	28.470986^{o}N, 77.027183^{o}E	28.470718^{o}N, 77.029771^{o}E	28.456474^{o}N, 77.045269^{o}E
Identified Trees	Ficus Religosa Neem Ashoka Tree Keekar	Arjuna Tree Ashoka Tree Bahunia Racemos Tectona Grandis	Ficus Religosa Cassia Fistula Propis Ceneria Butea Monosperma Bahunia Racemos Delonix Regia Babool
Paved	0%	20%	30%
Impervious Surface	80%	60%	50%
Grasses	Partially Green	Green	Dense Green
Identified Factor	Low Green Cover High Density and Excessive H/W Ratio	Anthropogenic Heat Impervious Surface	Anthropogenic Heat Impervious Surface

Table 22: Selection Criteria for Parks

7.3 **Design Proposal for sector 12 Gurugram, Haryana**

Figure 32: Landscape Design for sector park 12 Gurugram

Figure 31: Landscape Design Proposal for sector 12 Gurugram

7.4 **Design Proposal for sector 6 Gurugram, Haryana**

Figure 33: Landscape Design Proposal for sector 6 Gurugram

7.5 **Recommendations**

Significance of H/W Ratio and its application:

The H/W ratio can be of high importance for making plans of residential locations in context of mitigating maximum temperature gradient. Currently, for the principle residential sector, for the street width of less than 9m, the most building height has been restricted to eleven.5 meters (or nonetheless+ ground storey + 2 floors, whichever is much less). From this the most H/W ratio for a 9m wide avenue with an 11.5 meter tall constructing can be calculated as 1.2 meters. But, this look at suggested that areas with low H/W ratios (<=1) prove to be effective in combating most temperature gradient and enhancing out of doors thermal consolation.

Therefore, it is recommended that in intensely dense layouts, with a purpose to preserve the H/W ratio as 1 or under, the maximum height restrictions can be revised.

1. Places in which H/W ratio is better than 1, it is very vital to combine green cover and water bodies inside the making plans of the layouts.
2. Whilst designing new layouts, urban planners must make sure that roads are fully shaded by the cover of deliberate plants.(Walls, Parker and Walliss, 2015)

In commercial structures which are normally air conditioned, the begin-up load within the morning has high strength consumption, observed via peak load which happens at some point of the sunlight hours. As a result it's far critical to lessen outside temperatures in business regions for the duration of the daylight hours and additionally in early morning.

Promoting green cover and vegetation.

Planting trees and vegetation lowers surface and air temperature by providing shade and cooling through evapotranspiration. Trees and vegetation provide shade there by reducing the direct solar radiation that gets absorbed by urban surfaces. Green cover thus, helps in providing comfort conditions inside out, thereby also reducing energy bills.

Cool Pavements/ Shaded pavements: Light coloured and permeable pavements help in maintaining comfortable temperature as well as reduce storm water run-off.

If light coloured paved areas are not possible, it is important to shade all the paved areas planned in city, to avoid trapping of heat. This should be done by planting trees/vegetation.

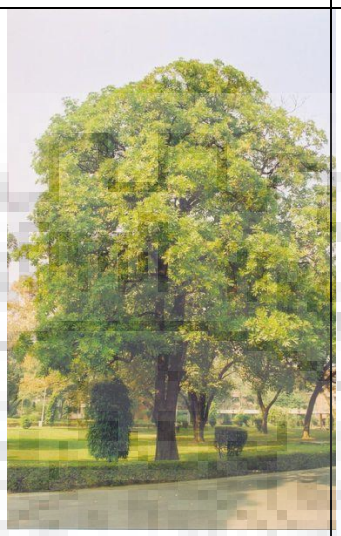
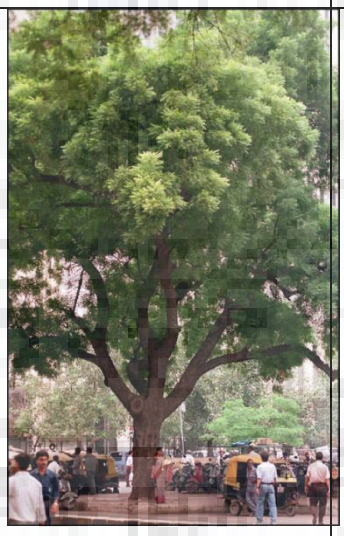
Shaded streets and Parking lots: It is important to ensure that streets carrying heavy vehicle movements and parking lots remain well shaded.

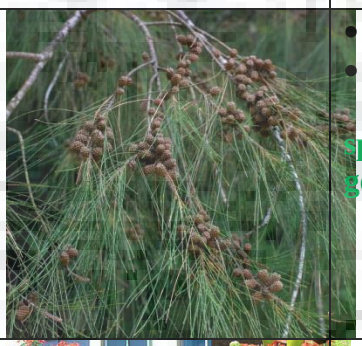
Vehicles moving or parked under unshaded streets get overheated inside, which leads to increased and prolonged use of air conditioning inside the vehicle. This would lead to increased fuel consumption as well exhaust emissions.

Thus shading of streets and parking lots can be effective in controlling anthropogenic heat also.

The dense canopy tree species that were encountered during the survey are Ficus religiosa, Ficus benghalensis, Artocarpus heterophyllus, Peltophorum pterocarpum, Azadirachta indica, Schleichera oleosa, Terminalia arjuna, Neolamarckia cadamba, Magnifera indica. Among these are other tree species like Spathodea campanulata, Mimusops elengi, Pongamia piñata, Delonix regia, which are flower seasonally, and have been adopted for urban park landscaping , other recommended trees are given below in table 41(Enviromental Management and Policy Research Institute (EMPRI), 2017)

Table 23: List of Recommended Trees

BOTANICAL NAME	COMMON NAME	IMAGE	FEATURES
Alstonia Scholaris	Devil's Tree (Saptaparni)		• Medium sized evergreen tree with white funnel-shaped flowers and milky sap. (strongly scented) • grows up to 30 m tall. • Spacing 6.0m c/c • used solely for medicinal purposes • Noise reduction **specs(ht) -3 mtr** **good foilage-3 - 4 year**
Azadirachta Indica	Neem		• Middle sized semi-evergreen tree • grows up to 30 m tall. • Spacing 6.0m c/c • used for medicinal purposes/ • provides a natural alternative to synthetic pesticides. • Noise reduction • Insect repellent **specs(ht) -2.8 mtr** **good foilage-3 - 4 yrs**
Butea Monosperma	Dhak		• Middle Sized deciduous tree • Grows upto 9-10m tall • This plant kills mosquitos. • Used as dye **specs(ht.) – 4 mtr** **good foliage-3-4 yrs**

Bombax Ceiba	Cotton Tree		• Large Deciduous tree • Grows upto 20m tall **specs(ht.)-3 mtr** **good foilage-4-5 yrs**
Cassia Fistula	Amaltas		• Middle sized deciduous tree • Fragrant flowers • grows up to10-15m tall. • Spread 4-5-6.0m • Ornamental tree **specs(ht)-2.8 mtr** **good foliage-5-6 yrs**
Casuarina Equisetifolia	Whistling Pine		• Large-evergreen tree • grows up to 16m tall. **specs(ht)- 3 mtr** **good foliage-2-3 yrs**
Delonix Regia	Gulmohar		• Middle sized deciduous tree • grows up to 10 m tall. • Spacing 3.0-m c/c • Ornamental tree **specs(ht)- 4 mtr** **good foliage-3-4 yrs**
Jacaranda Mimosifolia			• Moderate sized deciduous tree • grows up to 10-12 m tall. **specs(ht)- 3 mtr** **good foliage-4-5 yrs**

Millingtonia Hortensis	Akash Neem		• Middle sized deciduous tree • grows up to 10-12 m tall. **specs(ht)-3 mtr** **good foliage-4 yrs**
Grevillea Robusta	Silver Oak		• Tall semi-evergreen tree • grows up to 16-20 m tall. • used as shade tree, for wind breaks. Birds, bats and insects visit its nectar laden flower **specs(ht)-3 mtr** **good foliage-4-5 yrs**
Poplar			• Deciduous tree • Grows upto 12-15m tall **good foliage-4 yrs**
PacificRose Wood Tree	Portia		• Good for absorbing gases emitted by vehicles **good foliage-4 yrs**
Spathodea campanulata	African Tulip or Nandi Tree		• Good for absorbing gases emitted by vehicles • Reduces noise pollution

Peltophorum pterocarpum	Yellow Flame Tree		• Good for absorbing gases emitted by vehicles
Terminalia catappa	Bengal Almond Tree		• Good for absorbing gases emitted by vehicles
Ocimum Sanctum	Tulsi Tree		• Purifies Air • Absorb Carbon Dioxide **Foliage Feet – 5 ft – 6ft**
Indian Mohagany Tree	Mahu Tree		• Absorbs Carbon Dioxide
Pavazhamalli tree	Jasmine Tree		• Absorb Dust for smaller spaces
Mandarai Tree (For a breath of fresh air, April 10, 2015)			• Absorbs dust **Foliage Feet – 5 ft**

Grevillea robusta	Silver Oak		• Absorbs Carbon Dust
Juniperus Virgiania	Red Cedar		• Absorbs Black Carbon Dust

8.1 Conclusion

The negative implications of urbanization cannot be ousted entirely yet it can be minimized with significant efforts. One such effort is to multiplicate the available green spaces in the city.

Green spaces have an important legacy since time immemorial providing opportunities for individuals to ameliorate their health, for communities to develop, and to fortify the environment.

With additional support from literature review, the study also confirmed the vitality of green spaces' advancement towards physical health benefits of the users in all the study sites.

Different age-groups have different motives to visit green spaces and also variant activities they engage in. The management, therefore, should take into consideration different recreational requirements of all target groups.

My study supports a shared association of green spaces, health and environmental values by visitors' strong approval of green spaces' contribution to the mentioned significant values.

8.2 Scope of Future Work

There is a good scope for further carrying out further study in this area of research. The evaluation of outdoor thermal comfort is itself a very complicated task. In outdoors, the microclimatic parameters like the Air Temperature, Relative Humidity, Wind Speed, etc. are constantly changing and each of them depends upon each other for the evaluation of the comfort conditions. In indoor conditions, a stable microclimate can be achieved by controlling these physical parameters. But this is not possible in case of outdoors. Hence, there is a need to constantly observe the behavior of the microclimate of an outdoor space. For that to happen, it may require field studies which will continue for years.

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Annexure 1: AQI Data

NAME	LATITUDE	LONGITUDE	AQI	3/25/2019	3/26/2019	3/27/2019	3/28/2019	3/29/2019	3/30/2019	3/31/2019	4/1/2019	4/2/2019	4/3/2019	4/4/2019	4/5/2019	4/6/2019	4/7/2019	4/8/2019
SECTOR 6	28.4202	77.0356	224	313	379	251	251	270	226	181	284	113	264	279	149	102	302	105
SUSHANT LOL PHASE 1	28.4634	77.0768	134	281	336	200	244	209	199	149	130	257	252	244	206	100	274	71
SECTOR 65	28.4056	77.0708	135	229	299	185	213	278	142	110	240	219	266	273	123	301	90	144
SECTOR 59	28.4051	77.1097	146	224	292	175	156	199	163	116	101	121	193	220	201	85	259	66
SECTOR 57	28.4112	77.049	152	147	210	128	193	219	112	115	274	169	217	293	109	212	89	89
SECTOR 49	28.4121	77.048	156	268	348	192	212	283	246	182	132	248	237	263	280	125	300	78
SECTOR 46	28.4264	77.0478	158	263	330	175	221	213	174	146	266	233	217	117	254	76	83	212
SECTOR 42	28.458	77.1082	107	107	239	288	155	181	194	193	116	104	210	208	230	193	79	251
SECTOR 31	28.4542	77.0484	217	122	250	318	186	209	206	197	142	111	271	229	212	214	94	235
SECTOR 15	28.4707	77.0463	234	158	294	349	201	265	272	256	191	144	280	238	238	268	132	283
RICHMOND PARK	28.4591	77.0885	150	272	329	178	234	249	160	144	269	241	268	239	105	295	82	96
THE LABURNUM CONDOMINIUM	28.4703	77.0764	150	294	342	189	245	225	166	142	276	244	251	208	108	283	76	95
SECTOR 12	28.444	77.0728	309	118	251	319	193	244	231	70	139	119	272	255	267	214	103	275
DLF PHASE-5	28.4477	77.0948	51	61	75	61	58	64	77	60	40	48	61	60	80	71	91	100
DLF PHASE-1	28.465	77.1007	52	59	60	82	64	63	68	87	58	39	46	62	59	93	78	94
SECTOR 34	28.4283	77.0075	111	78	138	186	103	107	107	99	81	73	150	123	109	108	59	111
SECTOR 10A	28.4469	77.0106	91	174	236	111	132	136	132	99	86	165	130	121	140	81	133	60
SECTOR 37C	28.4508	76.9888	94	148	241	104	112	141	120	97	82	136	121	141	144	74	147	60
SECTOR 74A	28.4089	77.0003	81	122	179	104	114	141	141	83	72	130	116	147	146	73	149	65
SECTOR 38	28.4358	77.0406	120	174	270	130	133	134	112	99	153	73	139	139	85	144	70	75
SECTOR 2	28.5095	77.032	113	77	154	208	96	117	122	119	87	72	141	110	107	124	67	119
SEECTOR 84	28.3979	76.9736	93	129	175	103	95	116	95	81	75	122	112	127	113	64	133	62
SECTOR 105	28.496	77.0109	89	160	215	106	122	129	90	90	86	156	135	153	122	65	146	60
SECETOR 36	28.4209	76.9902	64	123	167	89	95	97	90	70	60	132	108	97	97	49	101	41
SECTOR 81	28.3867	76.9485	72	138	185	89	106	116	77	71	132	114	131	108	54	129	47	54
SECTOR 86	28.3986	76.9384	67	145	196	96	110	100	92	73	67	121	111	95	53	114	42	50
SECTOR 87	28.3936	76.9312	58	111	143	75	85	99	97	63	57	98	95	105	93	44	106	39
SECTOR 82	28.3935	76.96	67	108	158	88	99	125	38	71	58	112	98	127	128	59	130	51

4/10/2019	4/11/2019	4/12/2019	4/13/2019	4/14/2019	4/15/2019	4/16/2019	4/17/2019	4/18/2019	4/19/2019	4/20/2019	4/21/2019	4/22/2019	4/23/2019
246	117	100	124	191	85	69	60	114	226	177	255	257	182
222	97	73	82	118	62	60	41	65	270	141	186	231	194
107	78	98	133	63	60	59	92	92	156	201	232	219	214
183	86	66	76	100	54	62	49	64	292	157	127	197	180
110	124	144	86	73	107	61	54	89	178	196	263	182	124
240	115	86	112	159	76	62	60	87	190	168	243	241	165
81	90	120	61	79	80	80	80	80	173	131	255	206	122
84	206	102	65	92	88	58	81	39	66	237	121	135	191
79	201	91	75	92	112	62	53	35	57	281	141	159	253
90	241	113	89	114	82	66	44	76	304	186	228	272	269
118	84	96	129	73	72	57	85	85	163	215	232	221	159
106	78	93	133	70	64	172	194	289	241	241	106	108	241
87	224	103	71	88	109	64	51	52	226	111	231	251	238
84	60	53	51	36	41	36	41	72	68	67	56	53	78
73	93	64	57	51	33	43	40	25	40	68	59	55	55
59	101	62	57	59	71	45	39	24	40	152	81	85	134
125	75	66	69	87	55	30	51	100	185	100	116	152	129
121	74	64	70	91	47	51	47	29	100	91	140	129	89
114	72	61	65	79	48	49	45	61	86	102	131	112	107
74	69	74	110	57	52	44	44	72	114	93	149	129	93
53	112	62	50	58	74	46	38	26	44	157	85	103	134
103	68	61	61	72	48	60	39	50	195	95	83	122	106
129	73	62	66	77	54	57	42	56	93	108	133	117	87
90	51	44	50	59	37	31	21	34	131	70	76	118	89
62	48	54	64	43	41	41	34	47	77	95	114	100	77
53	43	46	60	38	34	25	39	128	69	84	114	88	66
92	56	39	50	50	35	30	23	38	104	63	68	91	89
100	59	46	54	66	38	35	35	51	76	90	111	96	95

Annexure 2: Outdoor thermal questionnaire survey

OUTDOOR THERMAL COMFORT QUESTIONNAIRE

This is questionnaire is entirely voluntary. If you do not wish to complete it, or any part of it, you are not under obligation to do so.

DATE: …. /……. /……. **TIME**: …….: ……. **LOCATION**: ……

Gender: 1) Male /2) Female **Age**: ……. **Weight**: …….kg

Height: ……m **Time spent outdoors**: ……hrs/mins

What is the reason for being in this place?

☐On my way to home/work/school/etc. ☐ See other people/relax/get fresh air ☐ other

How often do you pass by this place?

☐Daily ☐A few times/week ☐A few times/month ☐Rarely ☐First time

Where do you prefer to spend your outdoor time?

☐Indoors ☐Outdoor ☐Both

Your current activity is:

☐ Sitting ☐Standing ☐Walking ☐ Doing sports ☐other (specify)……..

What are you wearing right now? (*Please tick one*)

1. **T-shirt:** short sleeve/ long sleeve
2. **Sweater**: half sleeve- thick/thin/none full sleeve -thick/thin/none
3. **Hoodie**: thick/thin/none
4. **Jacket**: half sleeve- insulated/ thick/thin/none full sleeve- insulated/puffed/thick/thin/none
5. **Socks**: ankle length/calf length/ knee length/none
6. **Shoes**: boots/basic/slipper
7. **Hat/Cap**: Thick/thin/none
8. **Others**:

Color of your jacket ……

Color of your trouser ……

How do you feel at this precise moment?

Cold	Cool	Slightly Cool	Neutral	Slightly Warm	Warm	Hot
-3	-2	-1	0	+3	+2	+1

Annexure3: Outdoor Thermal Comfort Field Survey Questionnaire

Name: ..... Date: .....

Gender: ☐ Male ☐ Female Time: ..... (A.M/P.M)

Height :.....(feet) Weight :.....(kg)

Age: Please tick (✓) below

- ☐ 11 – 15 years
- ☐ 16-20 years
- ☐ 21-25 years
- ☐ 26-30 years
- ☐ 31-40 years
- ☐ 41-50 years
- ☐ 51-60 years
- ☐ Above 60 years

Physical Activity at present: .....
Example: Sitting, Standing, Playing, Eating, Walking, etc

Duration of the activity: ..... (time in minutes)

If duration is less than 5 minutes in the above activity then

The immediate physical activity you did before coming here?

.....
Example: Walking, Playing, Eating, Cycling, Driving, etc

Tick (✓) the Clothing you are wearing now in the dark empty boxes from the list below accordingly:

MALE

Types	Tick here	Name of the clothes			No. of layers (If more than 1)
Under Garments & Inners		Briefs			
		Vest (light)		Vest (heavy)	
Clothing above waist		Shirt short sleeve		Shirt long sleeve	
		T-Shirt short sleeve		T-Shirt long sleeve	
Clothing below waist		Shorts/Half pant			
		Capris			
		Jeans			
		Trouser light material		Trouser heavy material	
Winter Wears		Inner above waist		Inner below waist	
		Sweater light		Sweater heavy	
		Jacket light		Jacket heavy	
		Overcoat			
Others		Hat/Cap			
		Scarf/shawl			
		Tie			
		Socks till knee		Socks till ankle	
		Shoes ☐	Sandal / Slippers ☐	Boots	
Any other worn then please specify					

FEMALE

Types	Tick here	Name of the clothes			No. Of layers (If more than 1)
Under Garments & Inners		Bras & panties			
		Slips/Spaghetti			
		Shape wear			
Clothing above waist		Shirt short sleeve		Shirt long sleeve	
		Tshirt short sleeve		Tshirt Long sleeve	
		Short Sleeve Top		Long sleeve Top	
		Kurti Short sleeve		Kurti Long sleeve	
Clothing below waist		Skirt light		Skirt heavy	
		Shorts			
		Capris			
		Jeans			
		Trouser light		Trouser heavy	
Indian wear/dress		Dress/Frock			
		Peticot			
		Blouse short sleeve		Blouse long sleeeve	
		Sari			
		Kameez/Long Kurta			
		Salwar/Churidar/Leggings			
		Dupatta			
Winter Wears		Inner above waist		Inner below waist	
		Sweater light		Sweater heavy	
		Jacket light		Jacket heavy	
		Overcoat			
Others		Hat/Cap			
		Scarf/shawl			
		Tie			
		Slacks			
		Stockings			
		Socks till knee		Socks till ankle	
		Shoes/Pumps	Sandal / Slippers	Boots	
Any other worn then please specify					